

THE ROMAN AQUEDUCT AT LINCOLN

By F. H. THOMPSON¹

I. INTRODUCTION : GENERAL AND TOPOGRAPHICAL

It is a commonplace that early human settlement depended very largely on the presence of a good supply of fresh water; and it is unnecessary to labour the point that the Romans, with their engineering skill, were assiduous in bringing water, sometimes from a great distance, to their civil and military establishments to supplement the supplies already at hand. The towering aqueducts striding across the Campagna to Rome, the Pont du Gard in France, or the aqueducts at Mérida and Tarragona in Spain, are among both the earliest and most enduring monuments of the Empire. On the documentary side there is the treatise² on the water supply of Rome compiled by Frontinus, the *curator aquarum* under Nerva; or the careful archaeological studies of the very aqueducts enumerated by Frontinus made in recent times by such scholars as the late Thomas Ashby.³

In Roman Britain, however, there is no suggestion that the population resorted on any large scale to the building of long aqueducts in brick or stone, whether above or below ground, in order to add to the supply of water gained from sources already at hand. It is a legitimate assumption that the climate corresponded broadly to that borne by us to-day and the presence of wide tracts of dense forest may have induced an even greater precipitation of rainfall. Certainly, wherever a settlement was not already closely associated with a river, stream, or spring (from which, it is true, the water may have been brought along a short channel), it was usually only necessary to sink wells to a short distance in order to tap the water-table. Such aqueducts as are known are mainly military works and are largely confined to the northern frontier zone, as at *Aesica* (Great Chesters),⁴ *Hunnum* (Halton),⁵ *Cilurnum* (Chesters),⁶ *Condercum* (Benwell),⁷ *Vindolanda* (Chesterholm),⁸ *Bremennium* (High

¹ In the normal course of events, the composition of this report would have been undertaken jointly by Mr. F. T. Baker and the writer, but the former's heavy commitments in other directions precluded the adoption of this plan. However, with characteristic generosity, he gave the writer access to all the material he had collected on the subject and communicated the results of previous excavation to him. It can then be said, with rather more justification than usual, that without Mr. Baker's help and encouragement this report could never have been produced; and, in composing it, the writer feels that it may serve as a personal tribute to one who by his energy and zeal has contributed so much to our knowledge of Roman Lincoln. A further debt of thanks is owed to Professor I. A. Richmond, adviser to Lincoln Archaeological

Research Committee, for his kindness in reading the report in type-script and suggesting a number of amendments which can only have had a beneficial effect upon the text.

² *De Aquis*, i and ii. Cf. Clemens Herschel, *The Two Books on the Water Supply of the City of Rome of Sextus Julius Frontinus*, Boston, 1899, which has much additional information on Roman hydraulics in general.

³ In his *Aqueducts of Ancient Rome*, Oxford, 1935 (edited by I. A. Richmond).

⁴ *J.R.S.*, xxxv, 80, 81; Bruce, *Roman Wall*, edn. 2, p. 225.

⁵ Bruce, *op. cit.*, edn. 3, p. 134.

⁶ *Ibid.*, edn. 10, pp. 83, 84.

⁷ *Ibid.*, p. 136.

⁸ *Arch. Ael.*, Ser. 4, xix, 13-17.

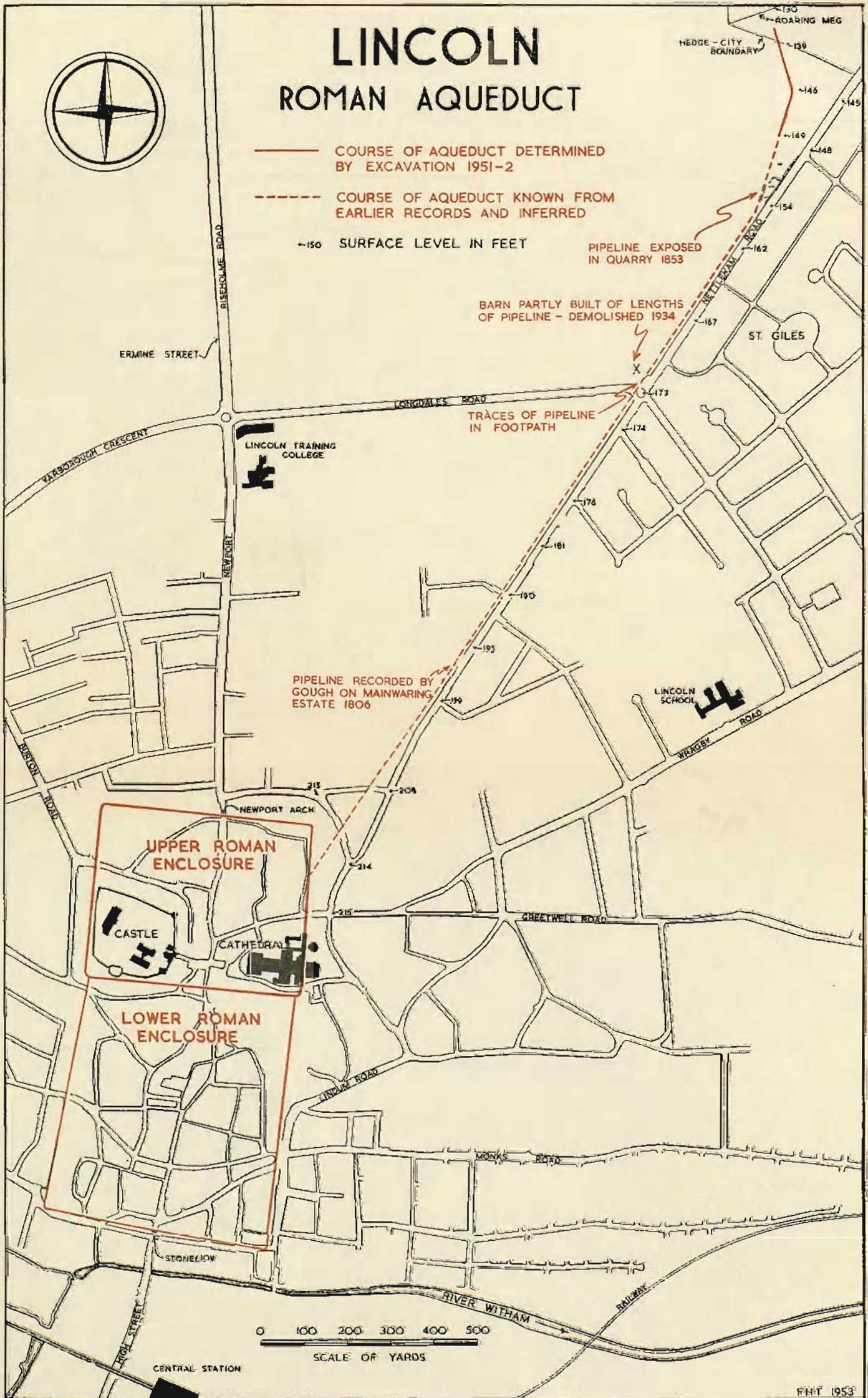
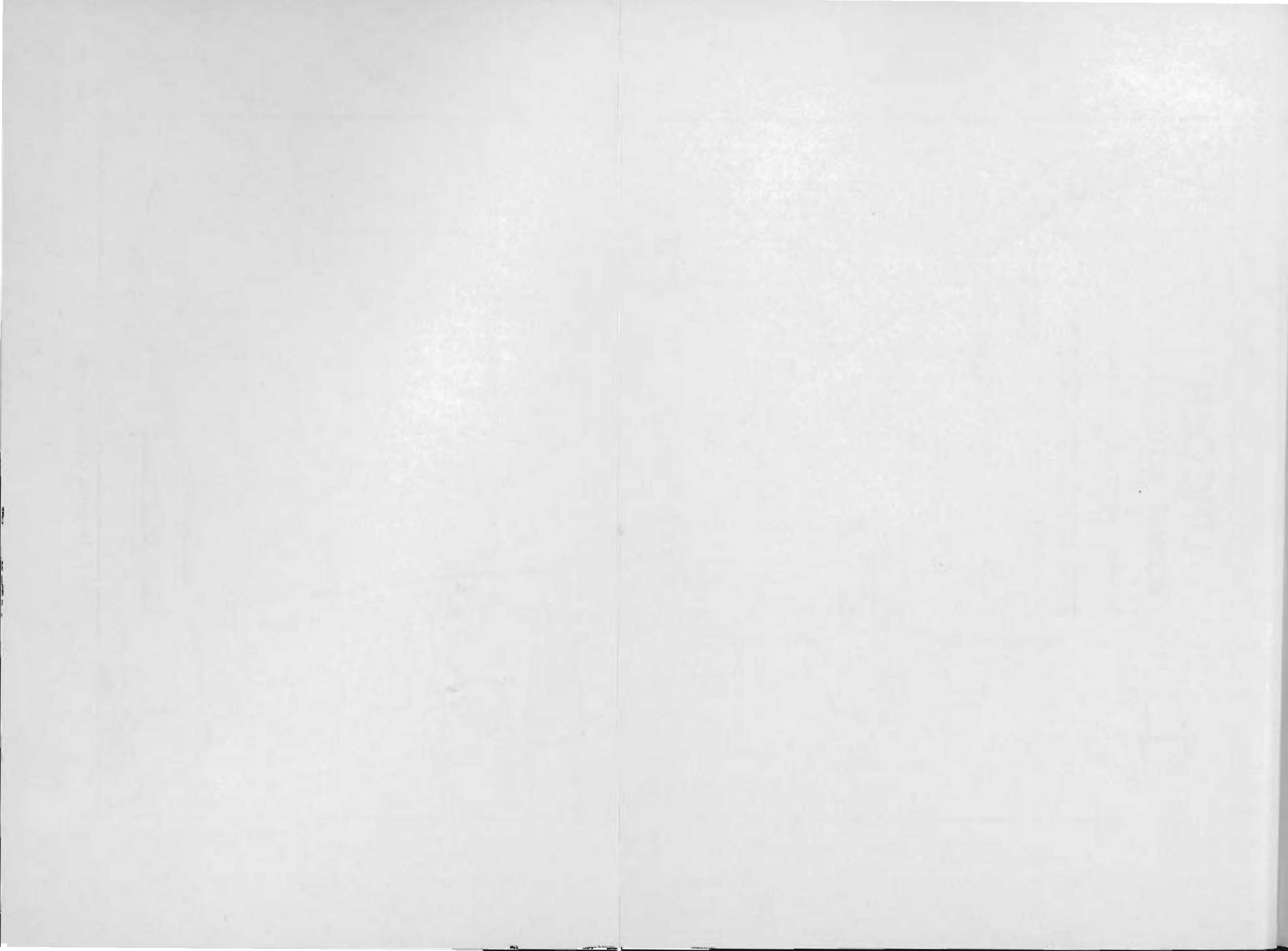


Fig. 1. The Roman Aqueduct at Lincoln



Rochester),¹ *Corstopitum* (Corbridge),² Birrens,³ and Fendoch.⁴ Of these the open channel aqueduct supplying *Aesica* was the most ambitious since it had a length of six miles; however, much of this is the result of the winding course which it adopted in order to achieve a gravitational flow and, by following the contours, it avoided the necessity for any major engineering except at one point. A comparable aqueduct in the civil zone is that which supplied Dorchester, again a winding open channel following the line of the contours.⁵ The discovery of wooden water-pipes in large urban centres such as London,⁶ Silchester,⁷ and Wroxeter⁸ suggests a well-organised water supply system, but the water which they served to distribute was probably only brought from just outside the city walls.

At Lincoln, however, the interplay of topography and strategic necessity presented the Roman water engineers with a problem which demanded a novel approach. Here the Jurassic ridge, running through the county from south to north, is broken by the channel of the Witham, and in order to safeguard such a vital point the Romans found it necessary to place their legionary fortress on the hill-top north of the gap, a site subsequently occupied by the *colonia*⁹ founded in the later years of Domitian.¹⁰ But this upper town, as it is called (fig. 1), lies wholly above the 200 foot contour and its inhabitants, by achieving a commanding position, created for themselves a difficult problem. On the summit of the Jurassic ridge there is little water available by reason of the extreme permeability of the limestone until the water-table is reached at a minimum depth of 40 feet; and post-Roman settlement consequently seems to have followed the spring lines on the lower ground to west and east of the ridge, where the limestone meets respectively the impervious Lias clay and the clay of the Upper Estuarine Series.¹¹ The people of Roman Lincoln were thus faced with the choice either of sinking wells within the town through solid rock for a distance of at least 40 feet, or of bringing surface water to the town from outside. In the latter case there would be no possibility of a gravitational supply since the known sources lay much lower than the level of the town. Nevertheless, this was the course adopted and the water was raised from a lower to a higher level, so constituting a true pressure supply. From a catchment area standing rather over $1\frac{1}{4}$ miles north-east of the upper town at a height

¹ Bruce, *op. cit.*, edn. 2, p. 301.

² *Arch. Ael.*, Ser. 4, xv, 253, 254.

³ *P.S.A.S.*, lxxii (6th Ser., xii), 306-309.

⁴ *Ibid.*, lxxiii (7th Ser., i), 138-140.

⁵ *Ant. Journ.*, xx, 435 and fig. 1 and Pl. LXXII.

⁶ London Museum Catalogue No. 3, *London in Roman Times*, p. 39 and Pl. XII.

⁷ *Archaeologia*, lv, 422-4.

⁸ Birmingham Arch. Soc.: Donald Atkinson, *Excavations at Wroxeter 1923-7*, (Oxford, 1942), pp. 121, 122.

⁹ Excavation has shown fortress and *colonia*

defences to coincide on north and west (*J.R.S.*, xxxix, 57) and east (excavation in East Bight, 1953—to be published) and from the configuration of the ground are likely to have done so on the south.

¹⁰ *Arch. Journ.*, ciii, 29 (dating confirmed by excavation, 1953).

¹¹ *The Water Supply of Lincolnshire*, edited by H. B. Woodward, (Mem. Geol. Survey, 1904), p. 7 and fig. 1. For settlement pattern in relation to spring-lines, see Geological Survey of England and Wales 1 in. Sheet 83 (1886).

of 130 feet above sea-level the water was conveyed, firstly overhead for a short distance by means of a stone substructure and subsequently below ground in earthenware pipes sheathed in concrete, along a steadily rising gradient until it reached the upper enclosure near its north-east corner at an approximate height above sea-level of 200 feet. It is hardly to be supposed that the inhabitants relied entirely on this aqueduct for their supply of water; a number of wells has been recorded in the upper town, principally the so-called 'Blind Well' near the Assembly Rooms in Bailgate, which remained open to a depth of 40 feet until it was filled up in 1772.¹ These are probably medieval in date but some must certainly have been sunk in Roman times.

II. PREVIOUS REFERENCES

Earlier references to the Roman aqueduct at Lincoln are by no means lacking. It seems first to have been observed by the Yorkshire antiquary, Abraham de la Pryme, who in a letter² dated August 3rd, 1700, to Dr. Gale, Dean of York, comments that: "There hath indeed been a small canal, or Roman aqueduct or pipe, discovered about a mile on this side Lincoln, about a foot underground and of about a foot square in cavity, of Roman brick and tile, and plaistered within, conveying water from a certain spring there, unto the city, but I am sorry that I can give you no better an account of it." Nevertheless, the general direction of it seems to have been sufficiently evident for Stukeley to mark on his plan of Roman Lincoln³ a 'subterraneous aqueduct Roman' running towards Lincoln from the north-east by the side of the 'Foss Road'. It is mentioned again by Thomas Sympson, the Lincoln antiquary,⁴ in his *Adversaria*,⁵ written in the second quarter of the 18th century; his account, though detailed, is evidently incomplete, since blank spaces are left in the manuscript to receive the dimensions of the pipes and concrete sheathing, but these were never inserted. A portion of his description is worthy of quotation, since it displays his grasp of the engineering problems involved: 'There must have been some Contrivance for raising the Water a good Deal above its natural Level before it would run to Lindum; the Spring being evidently lower than the Town: and indeed there are some Traces of a Tower or some such Building at the End of the Aquaeduct by the Spring, which one may suppose to have had a Reservoir on its Top for that purpose'.

In 1781 the aqueduct was apparently well enough known to the local inhabitants to be cited as a landmark in the Inclosure Award of that date for the village of Nettleham and to be marked on the Award

¹ *Arch. Journ.*, xci, 126, where, following Gough, it is held to be the reservoir at the delivery end of the aqueduct; but see *Arch. Journ.*, ciii, 37.

² *Surtees Soc.*, lxxvi (1883), 255. (Cf. *Surtees Soc.*, liv (1869), 235).

³ *Itin. Curiosum*, i, p. 88.

⁴ Cf. *Lincs. Notes and Queries*, ix, 65-90.

⁵ Bodleian Library Western MS. 17999, p. 281; I am indebted to Mr. J. N. L. Myres, Bodley's Librarian, for a transcript of the relevant portion.

Map.¹ This is not surprising, since only five years later the Swiss artist Grimm made two sketches of it, one showing an exposure of the underground portion of the work and the other a sectional view of the underground portion near the point where it emerges from the ground and also the beginning of the masonry substructure, still standing, on the other side of the fence forming the city boundary, together with diagrams of the construction of the pipe-line (Pl. VIIA, B).² By 1806, however, much of the substructure seems to have been lost since Gough, writing at that date, remarks that ' . . . on the other side of the hedge of Nettleham enclosure is a mound where were some traces of a tower or some building supposed the place of reservoir . . . ' which he marks on the accompanying map of the aqueduct's course as circular.³ His account, though comparatively detailed, presents certain difficulties since he shows the pipe-line, in its later stages, parting from Nettleham Road and heading towards the Assembly Rooms in Bailgate. No doubt he drew it thus in order to agree with his statement that it connected with the Blind Well, which he regarded as the reservoir in the town.⁴ These errors in observation have tended to affect later thinking on the subject,⁵ but his description of the aqueduct's course retains its value as the earliest detailed account that we possess; later writers dealing with the antiquities of Lincoln followed his version faithfully.⁶

In 1848, when the Archaeological Institute met at Lincoln, a portion of pipe, embedded in its original concrete sheathing, was exhibited in the temporary museum.⁷ This may well have been one of the fragments referred to by John Ross, the Lincoln antiquary, who, describing the aqueduct in 1850, writes: ' Several fragments of these tubular joints, exhumed along the Nettleham Road where the line extended, are still preserved in the walls of modern farm buildings, most of them having the squared mass of cement, in which they were laid, attached to them '.⁸ In 1853 an exposure of the pipe-line *in situ* was made in a quarry, still visible, on the west side of the Nettleham Road almost opposite the Roaring Meg public-house (fig. 1),⁹ an exposure which seems to have still been in evidence in 1859.¹⁰ It is also

¹ Information kindly supplied by Mr. J. T. James, Assistant Surveyor to Lindsey County Council; a copy of the Award Map hangs in the nave of Nettleham Church.

² Preserved in the British Museum Dept. of Manuscripts—Add. MS. 15542, 125 and 126. Dr. J. W. F. Hill kindly drew our attention to the existence of these drawings; there is in the possession of Lord Monson, to whom I am indebted for permission to examine it, a drawing (Monson MSS. CCXIV, 22) almost identical with No. 126, although it shows a greater length of the masonry substructure.

³ Camden's *Britannia* (ed. Gough, 1806), ii, 366 and Pl. X.

⁴ *Ibid.* and see above, p. 108.

⁵ The theory of a tower at the source, in particular, has died hard. Cf. *Arch. Journ.*, xci, 126 and ciii, 37.

⁶ E.g. John Britton, *Beauties of England and Wales*, ix, p. 600; Thomas Allen, *History of the County of Lincoln*, i, p. 106.

⁷ Proceedings of the Archaeological Institute, 1848: *Lincoln Meeting*, p. 30.

⁸ *Annales Lincolnenses*, i, pp. 42, 43, with drawings copied from Grimm and Gough. This manuscript work, formerly in Lord Monson's library at Burton Hall, is now in Lincoln Public Library.

⁹ *Lincoln, Rutland and Stamford Mercury*, Dec. 2nd, 1853.

¹⁰ *Lincoln Gazette*, Jan. 29th, 1859.

worth recalling the discovery in 1857 of what may have been a branch pipe-line running down the hill outside the east wall of the Roman town. In the contemporary account¹ it is described as 'similar to the piping in Nettleham Road'. There is little doubt that the main pipe-line was encountered subsequently at other points, but no record was kept of precise locations beyond the fact that it ran by the west side of Nettleham Road towards Lincoln at no great depth below the surface; it is so recorded on the relevant sheet of the Ordnance Survey 25 in. series.² In 1934 the demolition of North's Farm at the junction of Longdales and Nettleham Roads (fig. 1) revealed that the inner lining of the barn walls was composed of concrete blocks from the pipe-line, with the earthenware pipes still embedded in them;³ this suggests that its course may have been destroyed in this area as a result of farming operations. Finally, there are preserved in the City and County Museum, Lincoln, a fragment of pipe embedded in its original concrete and an actual pipe length, both probably recovered during building activity along Nettleham Road in the second half of the 19th century. The latter (Pl. VIIc) has a length of 3 ft. and a maximum diameter of $7\frac{1}{2}$ ins., except for a length of 4 ins. at one end, where it narrows abruptly to a diameter of 5 ins.; the wall thickness is 1 in. at the broad end and $\frac{3}{4}$ in. at the narrow end, thus giving internal diameters of $5\frac{1}{2}$ and $3\frac{1}{2}$ ins. respectively. When laid, the narrow or spigot end fitted into the broad or socket end of the adjoining pipe length, thus presenting externally a smooth and uniform appearance. This method contrasts with the modern practice of external jointing which is probably more efficient as far as the passage of water is concerned since a uniform diameter is maintained internally, whereas under the Roman system it was continually changing. The Lincoln pipe length compares closely in general appearance with one of the types manufactured at the works depôt of the Twentieth Legion at Holt, Denbighshire.⁴

III. REASON FOR EXCAVATION; ACKNOWLEDGMENTS

Not only had the existence of the aqueduct at Lincoln been known for some considerable time, but at least two writers have, in recent years, urged that it should be thoroughly investigated in view of its unique features.⁵ An opportunity came in 1950 through the exposure of the pipe-line during site-clearance for the Lincoln Corporation housing scheme, known as Ermine Estate, lying north of Longdales Road between the Riseholme and Nettleham Roads (fig. 1). On the west side of Nettleham Road, opposite the Roaring Meg public-house, a

¹ *Lincoln, Rutland and Stamford Mercury*, Nov. 6th, 1857.

² *Lincs.* LXX. 3.

³ Information supplied by the owner, Mr. G. R. C. Harding.

⁴ *Y Cymmrodor*, xli, 134 and fig. 60, 11.

⁵ C. W. Phillips in his *Present State of Archaeology in Lincolnshire* (*Arch. Journ.*, xci, 124-6) and Prof. I. A. Richmond in his *Project for the Excavation of Roman Lincoln* (*Lincs. Architectural and Archaeological Society's Reports and Papers*, New Series, Vol. iii, pt. I, p. 3).

bulldozer stripped off the top half of the pipe-line and exposed the bottom half to view (Pl. VIID and section AX on fig. 2), while a sewer-trench revealed the pipe-line in section at point A (Pl. VIIIE and fig. 2). With the co-operation of the contractor and local authority a limited investigation, on an emergency basis, was made of the exposed length. The results were sufficiently promising to prompt a detailed search for the pipe-line as a whole, with the ultimate aim of tracing it to the source in an effort to discover the means used to raise the water to Lincoln. These tasks were undertaken by the Lincoln Archaeological Research Committee as an excavation programme for the years 1951 and 1952, with results to be described.

It is fitting at this point to tender the Committee's thanks to all those who contributed in various ways to the success of the excavation: to the City Engineer, Mr. A. Adlington and his staff (particularly Mr. J. F. Chambers for assistance in levelling) and the original contractors, Messrs. Sangwin Ltd., for much-appreciated help in the early stages of the excavation, and to the subsequent contractors, Messrs. Tarmac Ltd. (in the person of Mr. R. M. Brant) for the generous provision of mechanical equipment in the later stages; to Messrs. B. G. Bowser and W. P. Pepper, and subsequently Messrs. W. Parker and Sons Ltd., for allowing excavation to take place on their land and tolerating the interference thus caused to their farming programmes; to all those members of the Archaeological Research Committee who devoted their spare time to an excavation which provided little in the way of small finds to act as incentives to regular attendance, and notably to Dr. H. L. Barker and Messrs. N. M. Booth and M. I. Needham, who with Mr. F. T. Baker and the writer undertook the task of supervision; to other volunteer excavators, notably Miss M. J. E. Bagot, a party of boys from the Lincoln School under the Rev. R. P. Baker, a party from the Lincoln Girls' High School under Miss M. T. Freeman, and a team from the Nottingham University Archaeological Society; to Mr. F. Dearnley and F./O. Howard for the provision of aerial photographs of great value, to Dr. J. K. St. Joseph for other aerial photographs taken in the course of excavation, and to Dr. Norman Davey for examining the concrete sheathing of the pipe-line; and, finally, to all those who evinced a lively interest in the progress and results of the excavation by visits, conversation or correspondence and offered suggestions about interpretation, but principally to the Committee's adviser, Professor I. A. Richmond, for unstinting and ungrudging assistance in this respect; to Messrs. G. F. Westcott and F. G. Skinner of the Science Museum, South Kensington, for suggestions, references, and the loan of publications, and to Messrs. Donald Whiteley, the City Water Engineer, C. V. Armitage and W. Rigby of Messrs. Gwynnes Pumps Ltd., and J. G. Wilson of Lincoln Technical College, for their valuable observations on the technical problems involved in the operation of the aqueduct.

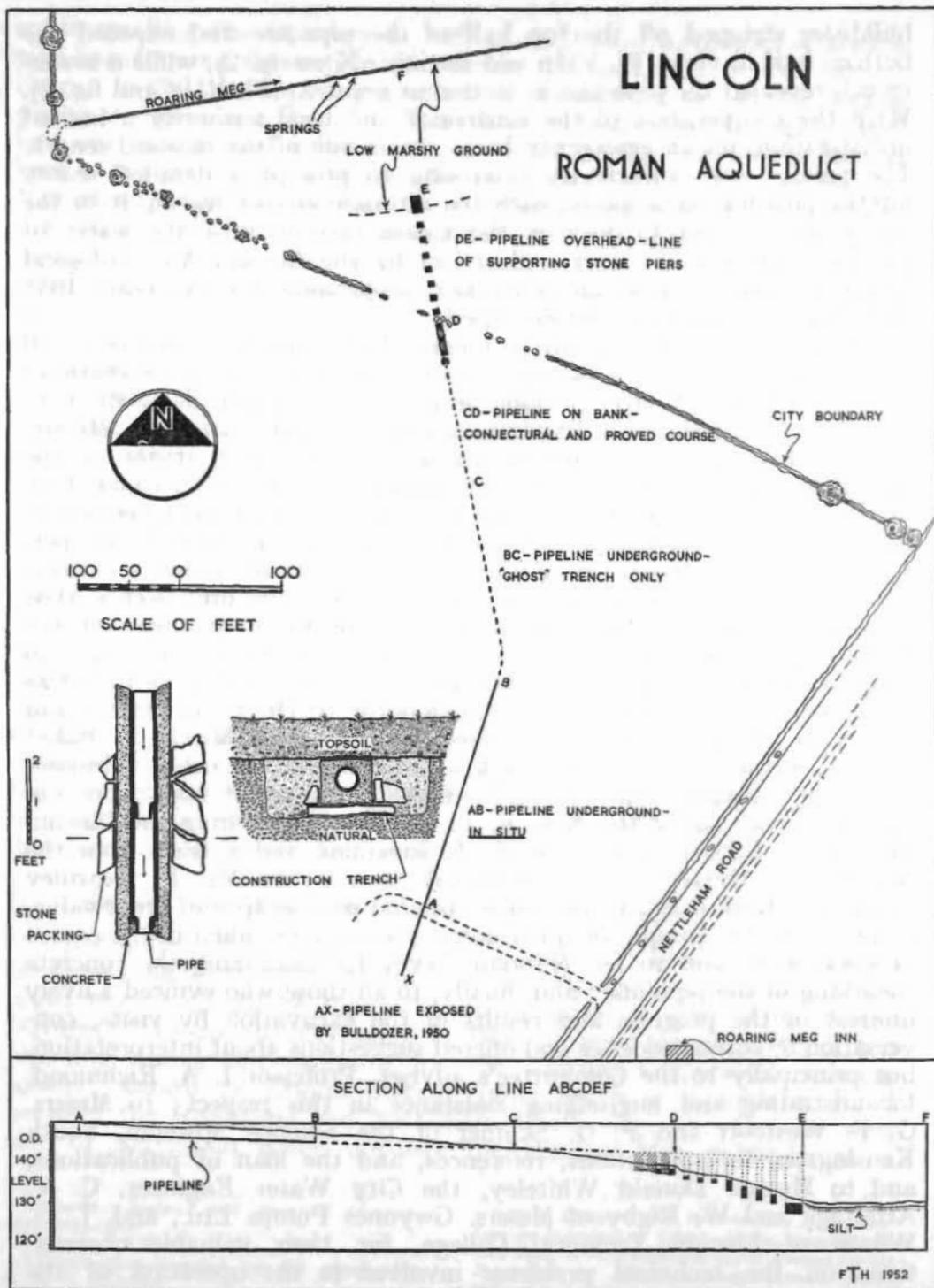


Fig. 2. Plan and section of excavation, 1950-2, with detail of pipe-line

IV. DETAILS OF THE EXCAVATION

A description of the work carried out during 1951 and 1952 may be preceded by an account of the emergency excavation of November, 1950. The surviving bottom half of the sector of pipe-line stripped by the bulldozer confirmed that the pipes comprised 3 foot lengths, each laid with its narrow spigot end socketed into the broad end of the next; the spigot ends lay furthest from the source of flow thus reducing the danger of seepage (fig. 2). The pipe sheathing, an extremely hard, pink concrete, was found to have a width of 15 ins. This mutilated section of the pipe-line was felt to be expendable, and it was dismantled and lifted after making all the necessary records in order to gain as much knowledge of the structure as possible. A portion of the half-pipe and its concrete bed was accordingly carefully raised,¹ exposing a foundation 2 ft. wide of thin limestone slabs on which the concrete had originally been laid (Pl. VIIIA); the slabs which had evidently been carefully chosen for uniformity of thickness had been laid so that their edges approximately coincided, as the result of selection or rough trimming, and they extended 4 to 5 ins. beyond the concrete resting on them. They, too, were then lifted and found to conceal two sand-filled post-holes, one directly beneath the line of the pipe and the other somewhat to the side. An explanation of these features was forthcoming when the City Water Engineer saw them and remarked that their parallels were to be found in modern pipe-laying. The hole beneath the pipe-line would mark the position of a sighting post, used in setting out the line which the pipe was to follow, while the other would represent a second sighting post used in determining the correct gradient for the pipe.²

The length of pipe-line between points X and A was approximately 25 yards, sufficient to infer its further course. It appeared to be travelling to the north-north-east, gradually diverging from the line of Nettleham Road and apparently heading for the low ground beyond the city boundary. In order to check its course three short transverse trenches were cut between points A and B; these encountered the concrete sheathing and so confirmed the presence of the pipe. In each case the bottom of the construction-trench in which the pipe had been laid was approximately $2\frac{1}{2}$ ft. below the present surface, so that its gradient conformed in effect to that of the ground. Between points B and A, a distance of approximately 80 yards, the pipe rose towards Lincoln a matter of 2 feet, a fairly gentle gradient; between these two points also, apart from minor abrasion by the plough, it remained *in situ* and substantially intact.

Another transverse trench cut just beyond B disclosed that the pipe-line had been removed but its original presence was attested by

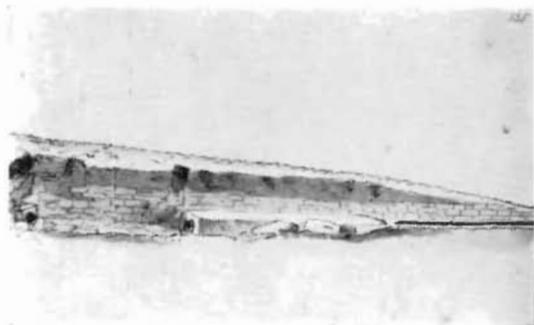
¹ A specimen of the concrete was submitted to the Building Research Station for analysis (see Dr. Davey's report on p. 127).

² Vitruvius (*De Architectura*, viii, 5, 1) has a description of the instruments used to determine levels in laying out aqueducts. Cf. also Ashby, *op. cit.*, p. 37.

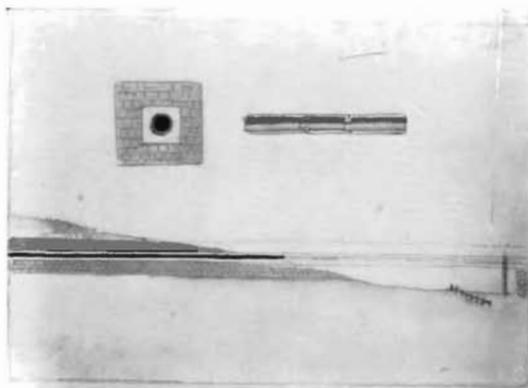
its 'ghost' trench, the construction-trench now filled with soil, in which it had previously lain. But beyond this point trial trenching in a straight line revealed neither pipe-line nor ghost trench. The slope of the ground was, indeed, a little steeper, so that if the pipe had continued at the gradient noted between points A and B it would necessarily have risen closer to the surface, presenting a major obstacle to the plough and inviting removal at an early date. But it was difficult to conceive that cultivation had obliterated every trace of its 'ghost'. The solution of the difficulty came through observation from the air. F./O. Howard had been taking an interest in the progress of the excavation and had examined the ground from above at regular intervals in the course of training flights across the area. The field in which excavation was taking place was ploughed at this time (the spring of 1951), but no trace of the pipe-line appeared as a soil mark until there occurred the combination of three days' sunshine and strong drying winds. The reason for the negative results then became clear; the pipe-line appeared as a white streak in the brown soil, which instead of continuing in a straight course beyond point B changed direction and headed almost due north, just where the ground began to fall away rather more sharply (Pl. VIIIc). Trial trenching established the presence of the 'ghost' trench as far as point C; from there northward it disappeared, and it was argued that the pipe had emerged from the ground at C and run along the surface.

Attention was now turned to the point where the pipe was estimated to cross the hedge forming the city boundary. Two small areas were stripped, one on each side of the hedge (fig. 3), but neither the pipe-line nor any supporting structure was found *in situ*. Its proximity, however, was shown by the occurrence in each area of decayed concrete from the pipe sheathing, resting on the old ground surface and keeping approximately to a line, as if it had fallen after the destruction or collapse of the aqueduct (fig. 3 and Pl. IXB). In the area south of the hedge were also found a pit or large post-hole and near to it a possible sleeper-beam trench (fig. 3 and Pl. IXB), but the function of these remained an enigma.

A long exploratory trench was then cut on the north side of the hedge in a roughly north-westerly direction from the excavated area just described. This encountered in rapid succession the corners of two masonry structures, which further clearance proved to be the rectangular foundations of coursed limestone piers or supports, one measuring 4 ft. 6 ins. by 5 ft. 6 ins., and the other 4 ft. 9 ins. by 6 ft. 4 ins. (fig. 3, Piers II and III, and Pl. XA). Pier II survived to a total height of 1 ft. 8 ins. in five courses, while III, standing at a distance of 9 ft., was 1 ft. 6 ins. high in four courses, with a trace of an offset on its eastern face at the third course. These foundations did not seem to suit a tower but rather a line of similar supports at regular intervals, carrying the pipe-line above ground. On this assumption another pier might be expected 9 ft. north from III. To determine whether this was so before



A



B

A, B. Sketches of Roman Aqueduct at Lincoln made by Grimm in 1786 (*British Museum*)



C. Earthenware pipe from Aqueduct, now in the City and County Museum, Lincoln. ($\frac{1}{8}$)

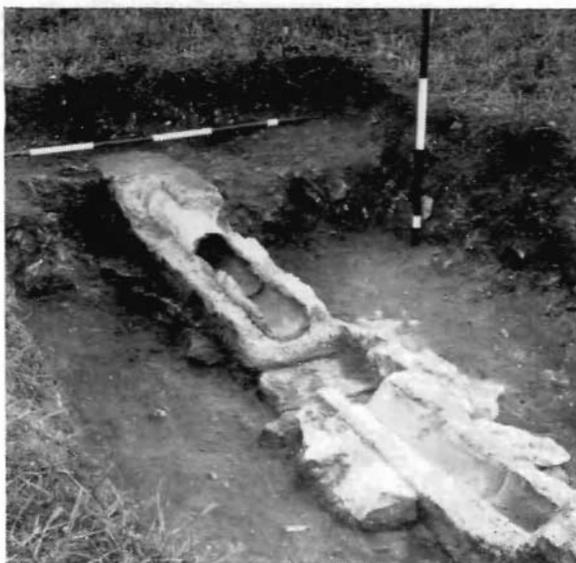


D. Length of pipe-line cut by bulldozer, 1950



E. Section in sewer-trench, 1950, showing pipe and concrete sheathing

(Blocks D and E lent by Institution of Water Engineers)



A. Limestone foundation of pipe-line exposed by excavation, 1950

B. Pipe-line cut to show structural details, 1952

(Block A lent by the Institution of Water Engineers)



C. Air-photograph of Aqueduct, 1951, showing bend at point B as it approaches source (top left corner)



A. Piers IV and V from west



B. Sleeper-beam trench and large post-hole or pit, with concrete from pipe-line beyond, in area of Piers 1-3



A. Piers II-V from South
(Block lent by the Institution of Water Engineers)



B. Piers VI and VII from South with masonry platform, VIII, beyond
(Block lent by Lincoln Archaeological Research Committee)

1951 ended, recourse was had to a mechanical excavator provided by Messrs. Tarmac Ltd., working under close supervision. This quickly removed the fairly considerable quantity of surrounding earth and exposed the foundations of two further piers at 9 ft. intervals (fig. 3, IV and V, and Pl. IXA); Pier IV measured 4 ft. 11 ins. by 5 ft. 6 ins. and stood to a total height of 2 ft. 2 ins. in six courses, with an offset

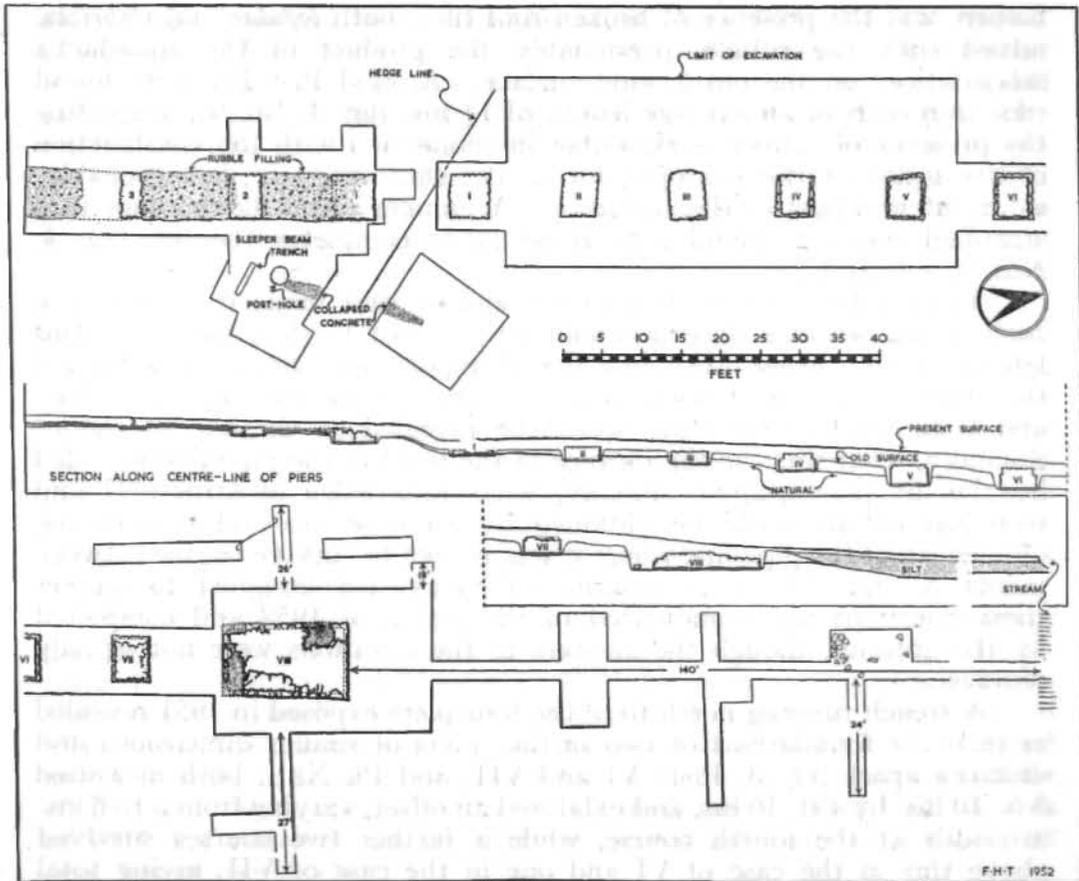


Fig. 3. Plan and section of line of stone piers from source

of a maximum width of 6 ins. on the north, east and south faces of the fourth course, while Pier V measured 4 ft. 11 ins. by 5 ft. 9 ins. and stood to a total height of 2 ft. 5 ins. in six courses, with a 4 in. offset all round at the fifth course. The limestone slabs used for the piers rarely exceeded 4 ins. in thickness or a foot in length, though occasionally more substantial stones were used for quoins. They were only roughly dressed to shape and the courses were laid with joints up to an inch wide, filled with a soft, buff mortar. The quality of the masonry, generally speaking, was

not of a very high order. Looking northwards, the piers were seen to be heading in a straight line, almost due north, towards the stream known as the 'Roaring Meg' and the adjacent low ground (fig. 2). But since the ground continued to fall away beyond Pier V it was considered that further piers remained to be discovered, and the search was deferred until 1952.

Finds in the vicinity of Piers II to V were not numerous. A constant feature was the presence of broken roof tiles, both *tegulae* and *imbrices*, mixed with the rubble, presumably the product of the aqueduct's dilapidation, on the old ground surface. Around Pier III were found nine iron nails of an average length of $1\frac{3}{4}$ ins. (fig. 4, No. 9), suggesting the presence of timber work, either in connection with the construction of the aqueduct (for example, for timber shuttering) or, less probably, as an integral part of the structure. A number of potsherds, none in a stratified position, found near these piers, completes the list (fig. 4, Nos. 2, 3, 6 and 7).

The results of excavation at the end of 1951 made it clear that a further full season's digging would be required to deal with problems left unsolved. These were, in order of importance: firstly, how far did the stone piers extend towards the low ground by the 'Roaring Meg' and what kind of structure would be revealed at the end of them? Secondly, what was the significance of the bend in the pipe-line revealed by the air photograph? Finally, what knowledge of structural and technical details could be obtained by an exposure and dismantling of a length of the pipe-line where it was known to survive *in situ* between points A and B? A programme of excavation designed to answer these questions was commenced in the spring of 1952 and completed by the autumn, though the answers to the questions were not equally conclusive.

A trench running north from the four piers exposed in 1951 revealed in turn the foundations of two further piers of similar dimensions and distance apart (fig. 3, Piers VI and VII, and Pl. XB); both measured 5 ft. 10 ins. by 4 ft. 10 ins. and exhibited an offset, varying from 3 to 6 ins. in width at the fourth course, while a further two courses survived above this in the case of VI and one in the case of VII, giving total heights of 2ft. 8 ins. and 2 ft. 1 in. respectively. As with Piers IV and V, the greater depth of topsoil had contributed to their better preservation. Broken roof tiles, iron nails and a few potsherds were still scattered in their vicinity on the old ground surface, and against the east side of VII fragments of typical concrete sheathing, some retaining the impression of the pipe, were also found. Simultaneously, trenching to the south of II exposed the foundations of yet another pier, I, immediately below the hedge bank, the presence of which had been suspected during the 1951 excavation; this was ill-preserved, consisting mainly of the bottom course of masonry and a few stones of the second, but had apparently been of similar general character to the others, its

measurements being 5 ft. 7 ins. by 5 ft. A sherd of Staffordshire 'combed' ware of 17th-century date was found resting on one of the stones of the upper course, which may suggest the date when robbing or demolition of the structure was in full swing.

The original exploratory trench was now carried northwards from VII, and after the standard interval of 9 ft. there appeared the edge, represented by a single course, of what was assumed to be yet another pier of the standard size. But the other three faces did not appear as expected. Eventually a larger rectangular mass of coursed masonry (fig. 3, VIII, and Pl. XIA) was isolated, heavily robbed at its south end and at a point on the west face near the north-west corner. Its original outline could be easily traced by the mortar bedding of the foundation course, with a length of 16 ft. and a width which gradually increased from just over 9 ft. at the south end to almost 10 ft. at the north. It was best preserved on the east side where it stood to a height of 2 ft. in five courses, the uppermost set back with an offset 9 ins. wide, no doubt originally continued along all four sides. Thus only in its size and greater length in proportion to its breadth did VIII differ from Piers I to VII. A few potsherds and nails were found in its vicinity, mainly on the old ground surface among scattered rubble; in the filling of the construction trench against its south edge was found much of the upper part of a rustic ware cooking-pot (fig. 4, No. 1) of late 1st or early 2nd century date. Despite its isolation and the possibility of intrusion at a point where stone-robbing seems to have been heavy, this must remain the best evidence that was obtained for the date of construction of the whole aqueduct.

On a *priori* grounds and as a working hypothesis the possibility had been envisaged of a tower at the source, sufficiently high to overcome by gravity the difference in level between source and Lincoln. This idea goes back to Thomas Sympson. The modest dimensions of VIII and its relatively slight foundations could scarcely be interpreted as the remains of such a tower, which would need to have stood at least 70 ft. high. But before abandoning the hypothesis the immediate area of VIII was tested to see whether this pier stood alone or formed part of a larger complex.

A main exploratory trench was cut northwards from VIII, ultimately as far as the 'Roaring Meg', and cross-cuts were made at points where there seemed to be superficial indications of further structures. In the event these proved to be no more than scattered lumps of stone and concrete. The most important evidence occurred beneath six to nine inches of topsoil. This was a thick layer of grey silt composed of mixed sand and clay, resting on the undisturbed natural grey clay; its greatest thickness was just over 2 ft., indicating that it had been deposited over a very long period of time. Some 20 ft. north of VIII the bottom of the layer, seen in section, began to rise gradually until it met the topsoil close to the north face of VIII. The evidence thus points to the exist-

ence in Roman times and subsequently of a sheet of water covering the low ground north of VIII, fed by drainage from the surrounding higher ground and also by springs (fig. 2).¹ Normally the edge of this pool seems to have coincided with the north edge of VIII, and it may be asserted with some confidence that in the wetter seasons of the year it probably advanced sufficiently up the slope for the water completely to encircle VIII. The deposition of silt, improved drainage in recent times, and the lowering of the water-table by boreholes, have combined to turn this former pool into relatively solid ground, though still marshy in winter.

Finds from the silt layer, especially in the area just north of VIII, were relatively numerous; the pottery included fragments of cream-ware flagons, probably of late 1st or early 2nd century date, and sherds covering the later part of the Roman period (e.g. colour-coated ware and fig. 4, Nos. 4 and 5). Some glass was also found, a piece of pipe-junction, and as many as 30 iron nails of various sizes (fig. 4, No. 9).

The existence of further structures to the north of VIII was now discounted, but the necessity of exploring to east and west still remained. A series of trial trenches was accordingly cut in each direction (see fig. 3) but gave no hint of any structure. The eastward trench gave the following typical section:—

Surface — 12 ins. :	dark cultivated topsoil.
12 ins. — 24 ins. :	light brown soil—post-Roman.
24 ins. — 29 ins. :	ruddle layer, containing broken roof tiles, pipe-sheathing, nails, pottery, and bronze brooch (fig. 4, No. 8)—destruction layer.
29 ins. — 42 ins. :	light brown sandy soil—ground surface in Roman period.
42 ins. — :	light grey clay—natural.

The destruction layer had spread some distance from the line of piers, as the brooch contained in it was found 16 ft. east of VIII. The search was extended still further afield by means of probing, but without result. VIII thus seems to have been the initial structure of the aqueduct. It stood in isolation, and its function must be interpreted accordingly.

A return was now made to the area south of the hedge forming the city boundary where the post-hole and sleeper-beam trench had been found earlier. An exploratory trench was cut along a projection of the axis of Piers I–VIII in an endeavour to determine whether they were continued by more such piers on the gradually rising ground. Eventually the foundations of three were found (fig. 3, Piers 1, 2 and 3 and Pl. XI B), but while 1 conformed to the standard dimensions, 2 and 3 were only approximately 4 ft. and 3 ft. long respectively.² These three

¹ It is conceivable that the Roman engineers may have aided nature by the construction of a dam further along the 'Roaring Meg', but there is now no trace of such a feature.

² But the outline of 3 was difficult to determine with precision and it may originally have been larger.

piers were linked by a filling of mortared limestone rubble, suggesting that originally the piers and rubble had stood together to the designed height as a solid bank (*substructio*), unlike Piers I to VII, which must have stood free. Their state of preservation deteriorated as they reached higher ground. Piers 2 and 3 had no doubt hindered the plough and had consequently been largely removed. No connection could be established between Piers 2 and 3 and the post-hole or sleeper-beam trench.

Seven short trenches were cut across the assumed course of the pipe-line from point B northwards (fig. 2), to see whether the bend there had any structural significance. All these trenches revealed that the pipe had been lifted in this area but its original presence was attested by the 'ghost' trench mentioned earlier. This, found 6 ins. below the surface, was 4 ft. wide and almost 2 ft. deep, with vertical sides. It was filled with soft yellowish soil containing fragments of tile and concrete, and its regularity emphasised that it was the original construction trench for the laying of the pipe, rather than one cut later for its removal. The bend itself seems to have been the result of a desire to attain high ground as quickly as possible, and so to shorten the distance that the pipe had to travel above ground. Thus damage by external agencies would largely be avoided and constructional work minimised.¹

Finally, a length of 22 ft. of the pipe-line was exposed between points A and B (fig. 2), where it was known to remain *in situ*, in order to make a thorough examination of structural details (Pl. VIII B). The main features, the carefully laid foundation of limestone slabs supporting the internally socketed pipes in their thick sheathing of concrete, were already known from the section exposed by bulldozing between points A and X in 1950. But this later excavation showed in detail exactly how the pipe had been laid. The method seems to have been as follows: a construction-trench was first dug to a width of approximately 4 ft. and to the required depth (2 ft. 4 ins. below the present surface at the point examined) and along the bottom were placed limestone slabs, with an average thickness of 3 ins. to a general width of 2 ft. to act as foundation; on this was erected shuttering, probably of wood, with an internal width of 15 ins., into which the first layer of concrete was poured; the pipe lengths were then laid and the joints carefully sealed with mortar, after which more concrete was poured in to a total height of a little over a foot and the upper surface given a smooth finish. The shuttering then seems to have been withdrawn and the sides of the concrete casing to have been packed at intervals with limestone blocks, presumably to prevent any lateral displacement, and, finally, the construction-trench was filled with soil. The neatness,

¹ There is perhaps the possibility that the bend reflects a difficulty in securing right of

way. On this point and bends in aqueducts generally, cf. Herschel, *op. cit.*, p. 193.

economy and uniformity of the work are a vivid illustration of Roman skill in practical engineering and much impressed a building-contractor working on the nearby housing estate who visited the site.

V. RECAPITULATION AND INTERPRETATION

The preceding account of the excavation has dealt with the various features of the aqueduct as encountered in working towards the source. This order is, of course, contrary to the flow in the duct; and it seems desirable, in considering how the aqueduct was operated, to recapitulate these features briefly in their natural order (figs. 1, 2 and 3).

At the source the evidence points to a pool fed by springs and surface drainage, standing at a height above sea-level of 131 ft. (Ordnance Datum). At, or more probably in, its edge stood a structure now represented by a solid masonry foundation (VIII), approximately 16 ft. long and 9-10 ft. broad, from which ran for 40 yds. a line of seven stone piers (I-VII), of which the surviving foundations average 5 ft. long by 6 ft. wide and occur at regular intervals of 9 ft. These piers, interpreted as the overhead portion of the aqueduct, ran as far as the hedge forming the present city boundary (fig. 2, point D), where the present level is 139 ft. O.D. Thence the pipe-line seems to have run above ground for a further 60 yds. (to point C) but apparently rested on a solid bank, supported on a foundation of mortared rubble and strengthened, at least in its early stages, by further masonry piers at 9 ft. intervals. This stage was represented by three piers (1-3) of diminishing size on the Lincoln side of the city boundary with a connecting filling of mortared rubble; for the rest of its course to point C evidence was largely provided by the air photograph (Pl. VIIIc). At point C, the present level of which is 143 ft. O.D., the pipe-line passed below ground, going gradually deeper until at point B, 66 yds. farther on, the bottom of its construction trench, the sole surviving evidence for this phase, was 2 ft. below the surface. Just north of point B this 'ghost' trench was found to describe a gentle bend to the west in order to take a line coinciding more closely with that later followed by the present Nettleham Road. Between points B and A, a distance of 80 yds., the pipe-line survives *in situ*; shortly after B, the bottom of the construction trench reaches a depth of approximately $2\frac{1}{2}$ ft. below modern surface and thereafter remains constant, conforming to the present ground surface and so maintaining a gentle upward gradient of approximately 1 in 120. The same conditions seem to have held along the original exposure between points A and X, the latter being at a height of 149 ft. O.D. From point X earlier records suggest that the pipe-line pursued a course, after one further slight change of direction to the west, parallel to and on the west side of Nettleham Road as far as the upper Roman town, some 2,000 yds. distant, which it may have reached just south of the north-east angle, there perhaps to discharge into a reservoir (*castellum*), from which

normally it would be distributed, firstly to fountains, secondly to public baths, and only finally to private consumers.¹ Although no measurements have been preserved, it seems likely that it continued at a fairly uniform depth below the surface during the latter, as in the earlier, part of its course, conforming to the steadily rising gradient of the ground. The present level at the point where it may have reached the Roman town (fig. 1) is in the region of 215 ft. O.D. ; if one allows a post-Roman accretion of 10 ft. of soil in this area² and estimates, on the generous side, that the pipe may have lain 4 ft. below the Roman surface at this point, then it follows that there is a rise between source and supply-point of some 70 ft., attained over a horizontal distance of approximately $1\frac{1}{4}$ miles.

It is thus clear that between point C and the upper Roman *colonia* the aqueduct constituted what water-engineers term a 'rising main'; the method of construction, in lengths of earthenware pipe heavily sheathed in waterproof concrete, indicates the measures taken to withstand the resultant pressure, which must have been considerable. The question remains as to what means the Romans employed to force the water up this steadily rising pipe. This can be answered in two ways. The water could have been lifted mechanically to a height of at least 70 ft. at the source, and then allowed to flow by gravity along the pipe-line, which would in essence have formed an inverted siphon. Alternatively, the water could have been drawn direct from the source and pumped up the pipe. Either method was well within the scope of Roman engineering technique and each may now be considered in relation to the evidence produced by excavation.

The principal features required for the first method are, as Sympson observed long ago, a tower at least 70 ft. high, supporting a tank or cistern, and a mechanism to lift the water up to this height. Various devices for raising water were known to the Romans. Vitruvius describes the *tympanum*³ or water-wheel which raised water to the height of its axle, and an improved version⁴ in which buckets mounted on the rim of the wheel carried the water to the full height of the wheel. Greater heights could be reached by an endless chain carrying bronze buckets;⁵ and this no doubt would have been the device used at Lincoln, if in fact a tank mounted upon a tower was adopted. The motive power could be supplied by treadmills or, where the current was strong enough, by the actual flow of water.⁶ The Archimedean screw, also known to the Romans,⁷ may be ignored, since it was capable only of comparatively short lifts.

¹ Cf. Ashby, *op. cit.*, p. 36 ; on the distribution at Lincoln, see p. 124.

² A number of excavations has shown that early Roman levels lie, on the average, approximately 10 ft. below the present surface in the upper *colonia*.

³ *De Architectura*, x, 4, 1 and 2.

⁴ *Ibid.*, x, 4, 3.

⁵ *Ibid.*, x, 4, 4.

⁶ *Ibid.*, x, 5.

⁷ *Ibid.*, x, 6.

Let it be supposed that the large foundation, VIII, discovered at the source represents the base of the high tower which the above method demands. It may be objected that its dimensions are too modest and its foundations too slight ever to have carried safely so high a structure and, in addition, to have carried the weight of a full tank of water.¹ It must also be observed that no trace was found of any mechanism which might have lifted the water to the top of the supposed tower, although it is fair to add that a considerable area in the region of VIII was left unexplored.

But another aspect of this mechanical-gravitational method, apart from the raising of the water to the necessary height, demands consideration. How would the water have travelled on the downward leg of the siphon from the top of the supposed tower to point C, whence it is known for certain that it climbed gradually towards Lincoln? The difference of level between the top of such tower and C is some 60 ft., and the horizontal distance available for this fall is approximately 280 ft., a gradient of rather more than 1 in 5. This is a considerable fall, likely to have caused excessive pressure at the bottom of the siphon, and, although not beyond the scope of Roman water-engineering,² would scarcely have found favour if alternative methods were available. To allow for such a fall the lowest pier, I, would need to have stood 38 ft. high, and at Pier 3 the supporting bank would have been 27 ft. high, figures which are quite unacceptable in view of the ascertained base dimensions. The possibility of a tower, doubtful in itself, must be abandoned in the light of these considerations.

The alternative is that the pipe-line followed a rising gradient throughout its entire length and that the water was taken from the source and pumped to a higher level, as is the common modern practice in similar conditions. Before considering the nature of the pump it may be well to envisage the probable original heights of Piers I-VII and the masonry platform, VIII. These may be inferred by projecting the line of the pipe from point B to the source at the gradient known between points A and B. This produces the following figures, expressed as heights above the present ground surface: Pier I, 4 ft.; Pier IV, 5½ ft.; Pier VII, 8 ft.; and VIII, almost 10 ft. Such figures certainly accord better with base dimensions and suggest that the remains are in fact those of a substructure, offering support to the pipe-line across difficult ground.³ This view receives confirmation from similar structural remains discovered on the Continent. Ernst Samesreuther, in his exhaustive *Römische*

¹ The latter, however, is scarcely a valid objection; a quite small header tank would be adequate, since it would only serve momentarily as a reservoir (the concept of an intermittent supply in which the tank was filled with its outlet shut and then emptied by the opening of the outlet is scarcely feasible, since flow in an inverted siphon depends on the maintenance of a head).

² Vitruvius (viii, 6, 8) describes the use of perforated stone blocks, into which the pipes were socketed, at such points of extreme pressure in inverted siphons.

³ As recommended by Vitruvius (viii, 5, 3); *sin autem intervalla erunt lacunosa, substructionibus erit succurrendum.*



A. Masonry platform, VIII, from North
(Block lent by Lincoln Archaeological Research Committee)



B. Piers 1 and 2 with connecting bank of rubble, from north-west

*Wasserleitungen in den Rheinlanden*¹ illustrates and describes comparable rows of stone pier foundations at Efferen near Cologne,² Mainz,³ and Trier,⁴ although they all belong to aqueducts operating through gravity. Of these, the last supplied the most satisfactory evidence of its original appearance, since the arched connection between two of the piers still survived, showing that it was in fact a low substructure. How the gaps between the piers at Lincoln were spanned is uncertain. No actual voussoirs were found among the debris, which, with the presence of nails, might suggest that they were bridged by timber. However, the nails seem rather small for heavy timber-work, and pipe-line and concrete sheathing would probably have constituted so heavy a load that arching would have been essential. Whatever the method adopted, it is likely that the broken roofing tiles, which were so constant a feature in the vicinity of the piers, represented the original weather-proofing of the pipe-line in its overhead phase.⁵

Piers I to VII are thus satisfactorily explained as the substructure carrying the pipe-line from the low marshy ground at the source to the solid ground at point D. The function to be assigned to VIII must, on these lines, be that of the base to which the pumping machinery was connected and on which the manual or mechanical operation of this machinery took place, perhaps beneath the shelter of some wooden structure, as the nails found in profusion against the foundations suggest. The pump employed would have to perform two tasks, firstly, lift the water from the pool beneath to its own height (i.e. through a vertical distance of at least 10 ft.), and secondly, force it along the pipe to Lincoln, raising it in the process a further 60 ft. The only type of pump known to the Roman world which would meet these requirements is the double-action force pump, described in detail by Vitruvius.⁶ In essence, this consists of twin barrels immersed in the water, in which pistons operate in reciprocating motion so as to give, by means of alternately opening and closing valves, a continuous supply of water to a central delivery pipe.⁷ A few pumps of this type, actually constructed and used in antiquity, exist or are recorded. Perhaps the best known are the pair in the British Museum, found at Bolsena in Etruria.⁸ These are of cast bronze, whereas the normal provincial type consists of a block of wood bored to receive lead pipes, which serve as the barrels in which the pistons operated. Pumps of the latter type are recorded from Silchester,⁹

¹ *Bericht der Romisch-germanischen Kommission*, 26 (1936), 24-157.

² *Ibid.*, p. 75 and Taf. 6, 2.

³ *Ibid.*, p. 85 and Taf. 7, 3.

⁴ *Ibid.*, p. 114, Taf. 8, 1 and 2, and Abb. 43.

⁵ As with the aqueduct of Gorze at Metz; cf. A. Blanchet, *Recherches sur les Aqueducs et Cloaques de la Gaule Romaine*, (Paris, 1908), p. 16.

⁶ *De Architectura*, x, 7, where he ascribes its

invention to Ctesibius of Alexandria and suggests that its main use was to supply water to fountains (*ad salendum aqua subministratur*).

⁷ For a full description of the method, cf. G. F. Westcott, *Pumping Machinery*, (Handbook of the Science Museum, South Kensington), I, p. 36, and II, p. 22 and Pl. II, and *Archaeologia*, lv, 254, and fig. 8.

⁸ *Ibid.*

⁹ *Archaeologia*, lv, 232 ff. and figs. 1 and 2.

from Ehl, near Strasbourg,¹ and from Heiligkreuz, a suburb of Trier,² and seem of very similar dimensions. The Silchester block is 22½ ins. long and the internal diameter of the barrels 3 ins., the Ehl block almost 20 ins. long with a barrel diameter of nearly 3 ins., and the Heiligkreuz block 18 ins. long with a barrel diameter of approximately 2½ ins. It is true that none of these pumps might seem really adequate to force water to a height of 70 ft. over a distance of more than a mile; equally, the dimensions of VIII seem more than adequate to carry a pump of this size. But it may be answered that, if the principle of the force pump was known, there was no obstacle to making a larger version than those recorded except the inherent deficiencies of materials available; while VIII itself may be visualised purely as a platform to serve those who actually operated the pump, in which case its dimensions would not be related, except indirectly, to the size and weight of the pump.

With a view to obtaining expert technical opinion on the subject, a meeting on the site was arranged,³ to which were invited Messrs. C. V. Armitage and W. Rigby of Messrs. Gwynnes Pumps Ltd., Mr. Donald Whiteley, Lincoln City Water Engineer, and Mr. J. G. Wilson, lecturer at Lincoln Technical College. After examining the structural evidence and considering the configuration of the ground and relative levels, they reached a unanimous conclusion that the solution lay in the pumping method (with the qualification that they may have been influenced in their choice by their knowledge of modern methods). There was agreement that the recorded ancient pumps were rather small, but it was emphasised that even the Silchester pump, with duplicate plungers of 3 ins. diameter and a stroke of perhaps 10 ins., would have displaced half a gallon to each complete stroke. Thus at 20 strokes per minute 10 gallons would be displaced and, even if leakage was considerable and an efficiency of only 50% achieved, 5 gallons per minute would flow along the pipe-line. For an assumed population of, say, 5,000,⁴ 16 hours pumping on a two-shift system would supply 1 gallon per head per day. This is rather a paltry allowance. But if a larger and more efficient pump had been used, and this figure were doubled, the supply would have been sufficient to satisfy the population's demand for drinking water, and the balance for domestic use generally could be obtained from surface supplies and wells,⁵ in which case the normal priority of distribution from the *castellum* (see p. 121) would not apply. Such calculations are, of course, extremely hypothetical, and a smaller population would have been correspondingly better supplied; the high figure was

¹ R. Forrer, *L'Alsace Romaine*, (Paris, 1935), p. 54 and Pl. VII, a reference kindly provided by Mrs. Olwen Brogan. The pump is now in the Musée des Antiquités nationales, St. Germain-en-Laye and I am indebted to M. André Varagnac of that institution for a sketch and measurements.

² Samesreuther, *op. cit.*, p. 128 and Abb. 56.

³ Through the good offices of Dr. J. W. F. Hill,

Chairman of the Lincoln Archaeological Research Committee.

⁴ Cf. *Arch. Journ.*, ciii, 66.

⁵ As a comparison, I gather from Mr. C. V. Armitage that modern practice assumes an average daily consumption per head for all purposes of approximately 36 gallons in urban and 15 gallons in rural areas.

deliberately taken in order that the aqueduct should not be supposed as operating under unduly favourable conditions. A final point emphasised by the observers was the lack of solid matter in the pipeline wherever it had been broken open, suggesting that filtration or, more likely, sedimentation, took place before the water entered the pump. The latter process was common in ancient times where the water at the source was turbid, being effected by means of a settling tank (*limaria piscina*).¹ If sedimentation was in fact employed, it supports the view that the aqueduct's main purpose was the provision of drinking water.

In conclusion, it needs to be said that no proof was obtained of exactly how the aqueduct was operated. The foregoing considerations are nothing more than a reasoned statement of the alternatives, on balance in favour of the pumping method. It can, however, be said with certainty that the general principle underlying the construction of the Lincoln aqueduct, that of the rising main, is of sufficient rarity in the ancient world² to make its investigation of more than passing interest and its excavation an undertaking of the first importance.

VI. DATING OF THE AQUEDUCT AND FINDS

The dating of the aqueduct at Lincoln is a matter of some difficulty, since it was not an occupied site in the usual sense and consequently the internal evidence of coins and pottery is largely lacking. Such pottery as was found was concentrated mainly in the area of the stone piers, as might be expected, since here activity would be greatest at the time of the aqueduct's construction and to this point, the visible portion of the work, subsequent visitors or operatives would naturally make their way. However, none of the pottery, with the possible exception of the rustic ware cooking-pot referred to above (p. 117) was found in a critical context, so that it would be unsound to argue that the earliest pottery found represents the original building of the aqueduct and later types denote subsequent visits by maintenance parties and sight-seers. On the other hand, no evidence was forthcoming of any separate occupation in this area either before or during the aqueduct's existence, so that it is perhaps justifiable to postulate a loose relationship between the pottery's range of date and the aqueduct's period of use, and so to arrive at the date of construction in that way.

Viewed as a whole the pottery seems to extend in date from the end of the 1st to well into the 4th century. Nothing was found which could be assigned to the legionary period, and it is tempting to associate the building of the aqueduct with the foundation of the *colonia* in the closing years of the 1st century; the rustic ware rim from the foundation trench

¹ Cf. Herschel, *op. cit.*, pp. 19, 21.

² For a possible example at Silchester, cf. *Archaeologia*, lv, 422-4. Ashby (*op. cit.*, pp. 35-7) argues that the Romans never envisaged the supply of water by pressure because

they always thought in terms of a continuous flow; this was largely true on the evidence available and serves to emphasize the unique quality of the Lincoln aqueduct.

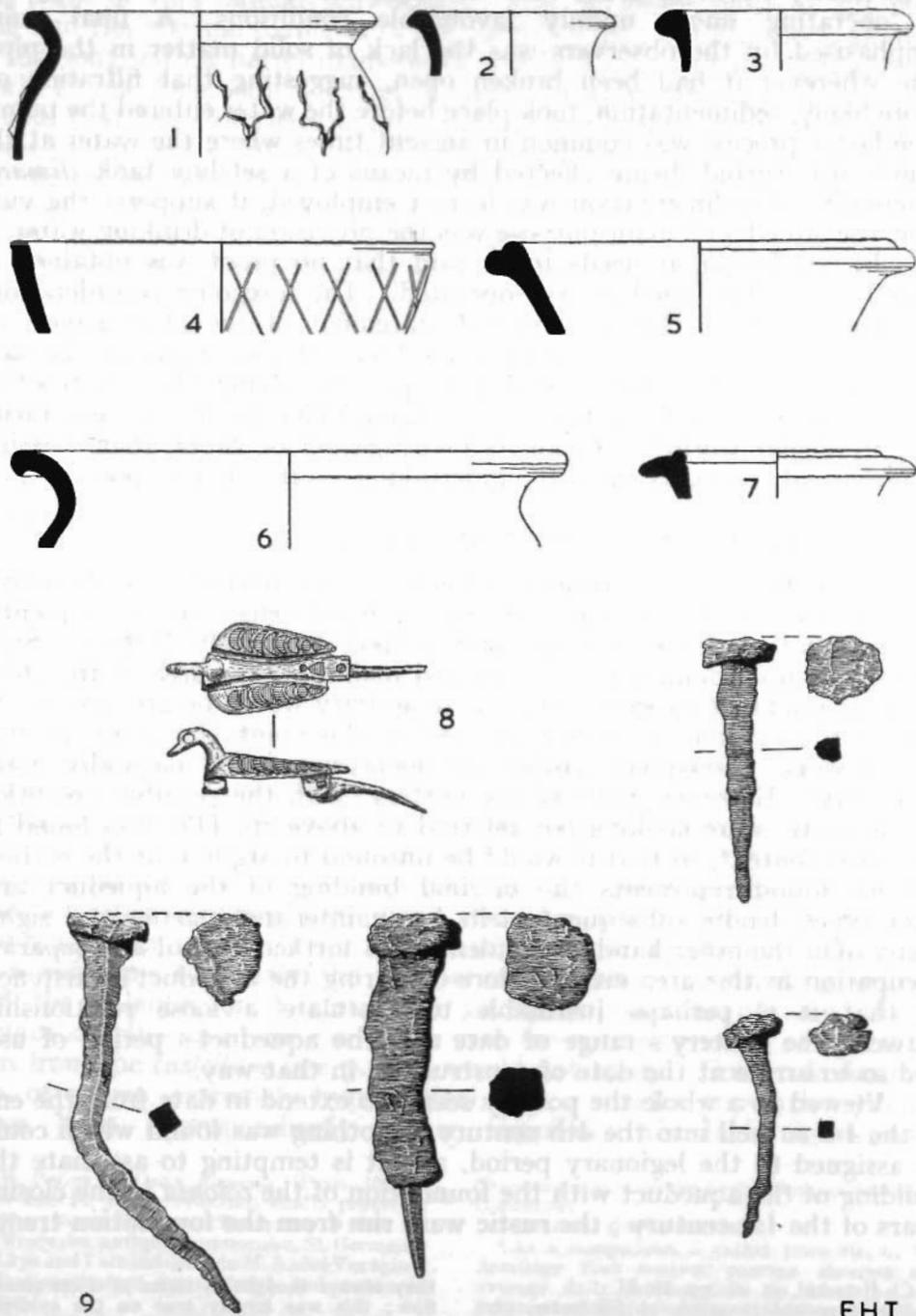


Fig. 4. Roman Aqueduct, Lincoln : pottery and small finds from vicinity of stone piers
(1-7, $\frac{1}{2}$; 8, 9, $\frac{2}{3}$)

of VIII offers some support for this conclusion. A process of induction might yield similar results; a reliable supply of water presumably presented a constant problem at Lincoln, but strategic necessity during the legionary phase would demand that it should be sought within, or only just outside, the fortress from wells and springs. Only with the advent of more settled conditions and the growth of collective enterprise which the foundation of the *colonia* implies would conditions have demanded the building of the aqueduct and the more permanent solution which it provides. But such a dating can remain no more than a reasoned conjecture in view of the slender nature of the evidence.

THE FINDS (fig. 4)

Pottery

1. Upper part of rustic ware cooking pot in sandy black ware with buff surface (originally black but abraded). Plain curving rim, rustication in converging irregular ridges. Late 1st/early 2nd century. From foundation trench against footing on south side of VIII.
2. Rim of narrow-necked jar in grey ware. Flattened rim with sharp outer edge. Probably 2nd century—cf. Kenyon, *Excavations at the Jewry Wall Site, Leicester* (Soc. Ant. Research Rep. No. XV, 1948), fig. 25, 16–20 and p. 98. Found in area of Pier III.
3. Rim of high-necked jar in grey ware. Same type and date as 2. Found in area of Pier III.
4. Platter in hard reddish brown ware with shallow groove below rim and lattice pattern on wall. A type difficult to date with precision, but this probably Antonine—cf. S. N. Miller, *The Roman Fort at Balmuildy*, Pl. XLVII, 16. From trench running north from VIII.
5. Upper part of flanged dish in hard grey ware with dark grey surface. A common late 3rd and 4th century type. From trench running north from VIII.
6. Rim of bowl in grey ware with buff surface. Evenly curved rim, rounded outer edge, slightly undercut, and with greater diameter than maximum girth. Late 3rd or 4th century type—cf. G. Webster and N. Booth, *The Excavation of a Romano-British Pottery Kiln at Swanpool, Lincoln*, fig. 4, D37–43 (*Ant. Journ.* xxvii, 61). Found in area of Pier II.
7. Rim of flanged dish in cream ware with dark brown slip. Dating as 5. Found in area of Pier III.

Metal

8. Bronze brooch in the form of a floating duck with traces of silvering on breast. Crescentic cells on wings filled with blue (horizontal hatching) and green (vertical hatching) enamel. Date probably 2nd century in common with other Romano-British zoomorphic brooches—cf. British Museum *Guide to Antiquities of Roman Britain*, fig. 11, 40–43; London Museum Catalogue No. 3, *London in Roman Times*, fig. 29, 39 and 40; *Wroxeter III*, 1914, Pl. XVI, 13 and p. 25; and the York brooches below. Similar duck-brooches are known from Saltersford, Lincs., (in Grantham Museum—cf. H. Preston, *Romano-British Remains at Saltersford*, (1915), fig 10), Tiddington, Stratford-upon-Avon (W. J. Fieldhouse, T. May, F. C. Wellstood, *A Romano-British Industrial Settlement nr. Tiddington, Stratford-upon-Avon*, (1931), Pl. V), Chester (Grosvenor Museum, Chester), Brettenham, Norfolk (in the Ashmolean Museum, Oxford—cf. *Norfolk Archaeology*, xxvi, 136 and fig. 2, 8), and York (a pair in the Yorkshire Museum found in a cremation burial in association with a coin of Trajan—cf. Raine, *Handbook to the Yorkshire Museum* (1891), p. 147, 1), and there are probably others. This fairly wide distribution suggests that it may have been a mass-produced type, perhaps imported from Belgium or the Rhineland.
9. Examples of the four sizes of iron nail which were found in fair quantity in the vicinity of the stone piers, and especially in the area of VIII. Their approximate lengths seem to have been 4 in., 3 in., 2½ in., and 1½ in., and they all have the round head and square-section shank typical of the Roman period. These nails, in Professor Richmond's opinion, are not large enough to have been used for heavy timbering, but would be very suitable for light temporary shuttering, of inch boarding.

APPENDIX.

ANALYSIS OF THE CONCRETE SHEATHING OF THE PIPE-LINE

A sample of the concrete sheathing was submitted to Dr. Norman Davey of the Building Research Station for analysis and the following comments are extracted from his report:

... It is composed of a mixture of lime and crushed tile. This type of mix was used by the Romans for hydraulic works, or where it was important to resist the penetration of moisture. The compounds of silica and alumina present in the crushed tile combined with the hydrated lime to form stable insoluble compounds of cementitious value such as calcium silicates and calcium aluminates . . .

... the sieve analysis of the crushed tile in the sample submitted ' can be compared ' with the grading of the crushed tile used in similar mortar for bedding tegulae at the bottom of a drain in a Roman building at Chelmsford. For these two samples and others from elsewhere I have found that all but about 5 per cent. of the crushed tile passed $\frac{3}{8}$ in. square mesh sieve and all passed a screen with slots .45 in. wide. There seems little doubt therefore that the Romans were very careful to control the size of material, and must presumably have used a screen of some sort for the purpose, having slots one half inch or *semuncia* (.48 in.) wide, or of ' nail's breadth ' (*anguis latus*) . . .

With regard to the proportions of mix the sample submitted contained the equivalent of about 1 volume of lime (assumed to have been used in the form of a ' putty ') and $1\frac{1}{4}$ volumes of crushed tile. The sample from Chelmsford was rather richer in lime and it may be that the intended mix in both cases was about 1 : 1 . . .