PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Current Proposals for the Thames Barrier and the Organization of the Investigations

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Current proposals for the Thames barrier and the organization of the investigations

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A considerable area of London close to the River Thames is liable to flood if the water in the river reaches an exceptionally high level. The very high waters which occur from time to time due to exceptional meteorological conditions are steadily increasing in level. After considering the possible ways of meeting this threat, by raising the existing flood defences, constructing a barrage across the mouth of the estuary, or the provision of a removeable flood barrier, to be closed only when a dangerous surge tide was liable to occur, the third course has been chosen as the best method.

A site in Woolwich Reach has been chosen for a structure with four main openings of 61 m (200 ft), and the rising sector† gate has been selected as the type of gate to be developed for the main openings.

Introduction

The low-lying areas of London adjacent to the River Thames have experienced flooding from the earliest times. Severe flooding was recorded as early as the year 1236 and subsequently on many occasions, particularly in 1663, 1791, 1874, 1875, 1881, 1928, and 1953. In the case of the last flood, that of 1953 120 km² (30 000 acres) of land in the estuary were flooded and a considerable number of people drowned. Floods such as these occur when the level of the sea is raised several metres above the normal high tide level as a result of exceptional meteorological conditions. Figure 1 shows the levels reached by exceptional high waters from 1791 to 1953.

Following the disaster of 1953, a Departmental Committee was set up to examine the problem. The committee, which became known as the Waverley Committee after the name of its Chairman, Lord Waverley, reported in 1954 (Departmental Committee 1954). One of the recommendations was that the effectiveness and practicability of a flood defence structure, sited at a suitable point in the estuary, and which could be operated quickly to close off the waterway, should be investigated as soon as possible.

Consulting Engineers were appointed, and a variety of schemes considered. A site in the middle of Long Reach, some 32 km downstream of London Bridge, was selected, since this reach provided a long straight section of river, which was necessary if vessels were to navigate a structure safely. It was initially considered satisfactory for navigational purposes if two main openings of 152 m, and two subsidiary openings of 76 m were provided. Three main types of structure were proposed, the drop gate, swing bridge, and retractable types. All types effected the actual closure of the river by swinging gates down from the main girder to rest on a sill in the bed of the river. Figure 2 shows the proposed drop gate structure. All these proposals were rejected, as the presence of a centre pier was considered too great a hazard to navigation. The size of opening required was now increased to 427 m, which imposed severe engineering problems. A site was selected at Crayfordness at the western end of Long Reach. This had the disadvantage of being on a bend in the river, but was clear of any berths or jetties. Two types of structure were developed, a high level retractable barrier, and a low level type. The reliability of both these

† This is the official name for the type of gate proposed and derives from the radial nature of the arms supporting the segmental gate.

types was suspect however, and the Government did not decide to go ahead with either scheme. It was felt that the whole idea wanted looking at again from first principles by someone with an impartial background. The Government asked Professor Bondi, then of King's College, London, to review the whole problem. In his report he came to the conclusion that the risk of disaster from an exceptional surge tide was too great to be accepted on the basis of the probability of overtopping the present flood defences, and he recommended that action be taken. He suggested

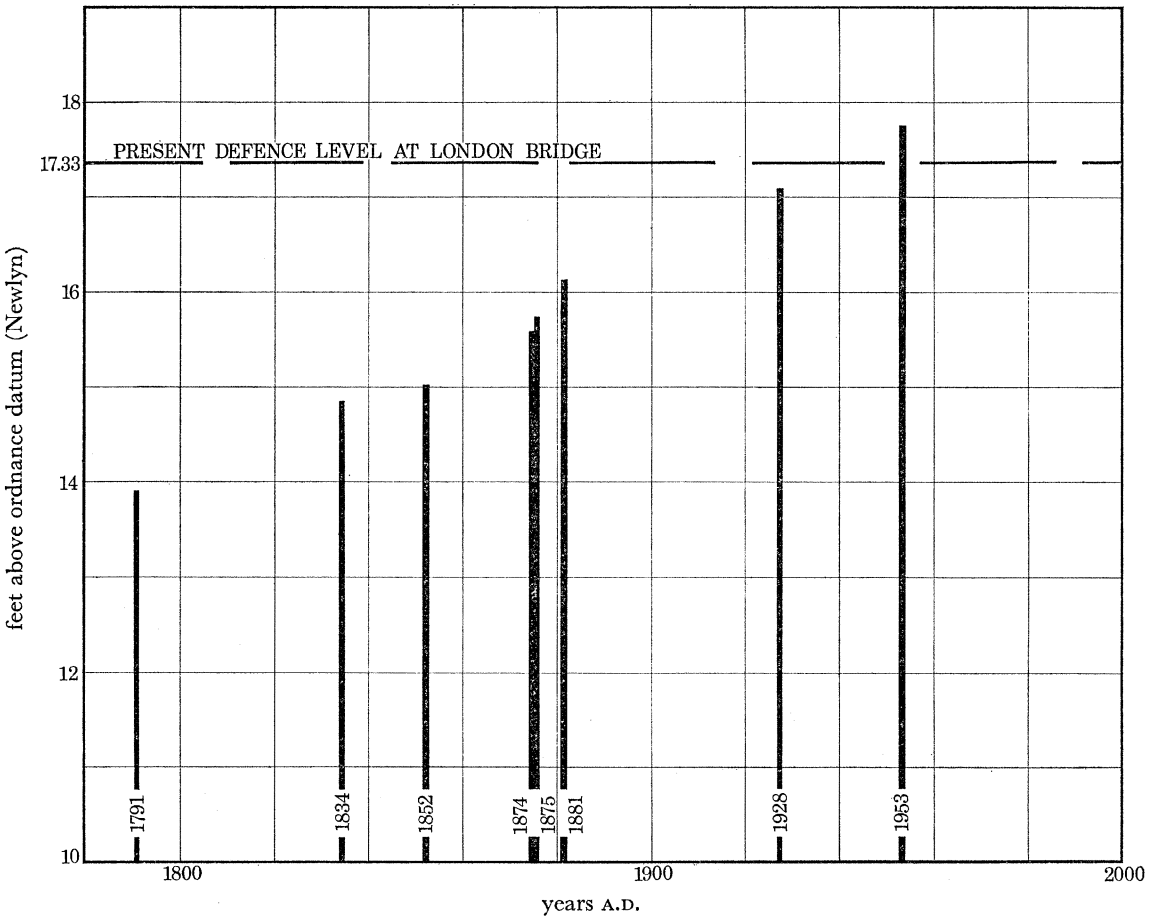

FIGURE 1. Increasing high tide levels at London Bridge.

the investigation into the possibility of construction of a flood defence barrier further upstream of the sites already selected, where navigational problems would not be so difficult, or alternatively, the construction of a barrage upstream of the entrance to the West India Docks. Following the submission of this report, the Greater London Council pressed the Government for a decision on the construction of a barrier to exclude dangerously high tides from the upper estuary and so safeguard London from flooding from this cause. In January 1968, the Government asked the Greater London Council to undertake an urgent investigation into the problem.

The Greater London Council was asked to examine the following:

(*a*) The degree and form of flood protection to be provided having regard to the current development proposals for riverside areas of Greater London; the long term plans of shipping interests; the possibility of combining a new river crossing with a barrier or barrage and the implications of any proposed measures on flood defences elsewhere.

(*b*) The construction of a moveable flood barrier in either Halfway Reach (Dagenham) or Woolwich Reach.

(*c*) The construction of a fixed barrage at some point above the entrance to India and Millwall Docks with provision for the passage of shipping.

(*d*) The relative advantage of the type of structure and locations described in (*b*) and (*c*) and any other suitable sites or other means of flood prevention.

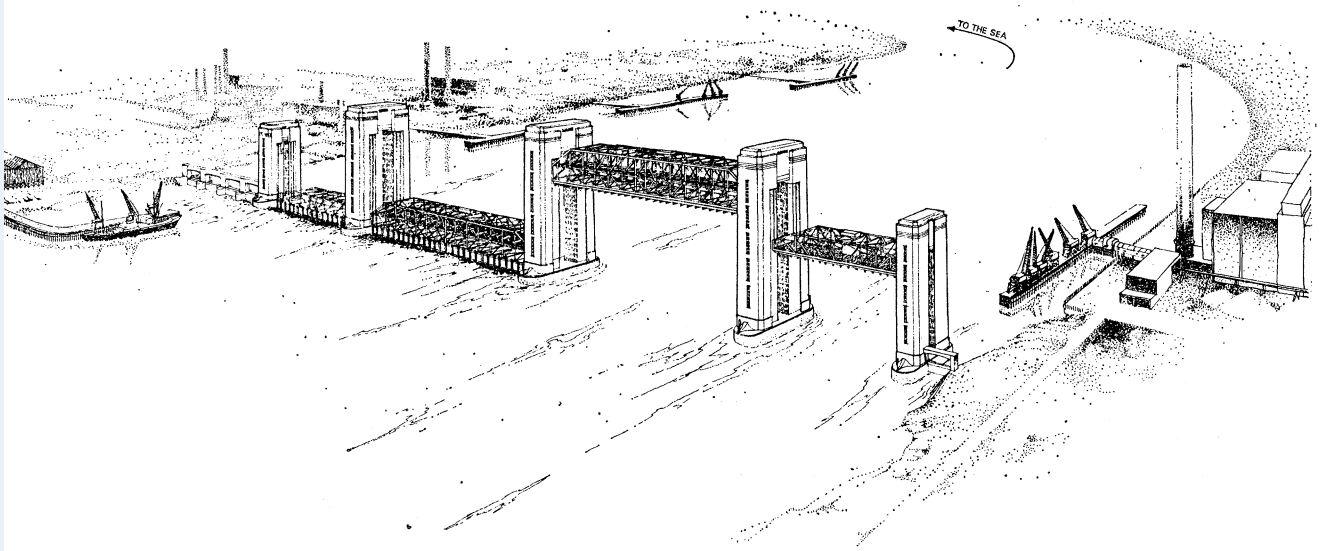

FIGURE 2. Drop gate barrier in Long Reach.

ORGANIZATION OF THE INVESTIGATION

The Greater London Council agreed to carry out the task and set up a small investigation team under the direction of a project manager. To control the progress of the investigation a Policy Committee was formed with representatives of the Ministry of Housing and Local Government, the Ministry of Agriculture Fisheries and Food, the Board of Trade, the Ministry of Transport, the Hydraulics Research Station, the Port of London Authority, the Chamber of Shipping of the United Kingdom, the Essex River Authority, the Kent River Authority, and the Greater London Council. The Chairman initially was Lord Kennet, subsequently after the change of government in 1970, Mr Eldon Griffiths.

Reporting to the Policy Committee, a Steering Committee was formed under the Chairmanship of Mr S. H. Dainty, Director of Public Health Engineering, Greater London Council, to direct the day-to-day progress of the investigation. A number of working parties were constituted to examine and advise on problems arising in the following fields: oceanography and meteorology; navigation and shipping; engineering; pollution and siltation; ground water effects; delays to shipping.

STANDARDS OF PROTECTION

Initially consideration was given to the standard of protection to be provided, and the means of carrying out the investigation. It became clear at an early stage that proposals which provided protection against flooding to a lower standard than a 1000 to 1 chance of serious flooding in any one year would be unacceptable. It was also considered that a standard higher than a 10 000

to 1 chance would probably be unjustifiable. Consideration of the probabilities of tides reaching various levels as calculated by Commander Suthons (Suthons 1963) indicated that the tide with a return period of 1000 years in the 2000 A.D. would reach a level about 0.9 m above the level at Southend of 4.6 m above O.D.(N.) reached by the exceptional tide which occurred on the 1 February 1953. The 10000-year return period tide would reach a level at Southend some 1.5 m above the 1953 level. It was therefore decided to investigate the propagation of tides up the estuary 0.6, 1.2 and 1.8 m above the 1953 tide.

Investigation methods

Two methods of investigating the propagation of tides in the estuary were available. One was by the use of a physical model similar to those constructed in 1953, 1954 (Allen, Price & Inglis 1955; Inglis & Allen 1957) and used in a previous investigation. A mathematical model had been developed by Dr Rossiter of the Institute of Coastal Oceanography and Tides and this offered an alternative method of investigating tidal movement (Rossiter & Lennon 1965). In view of the importance of this aspect of the investigation, it was decided to commission both the construction of a physical model, and the setting up of a mathematical model.

The physical model was constructed at Didcot by the Hydraulics Research Station with a horizontal scale of 1/600 and a vertical scale of 1/60. Dr Rossiter's team at I.C.O.T. set up the mathematical model. Both these models proved most valuable in the investigation.

Barrier schemes

The terms of reference for the investigation called for a number of schemes to be considered, and in addition it was decided to evaluate the cost of the traditional method of protection, that of raising the existing defences, as a basis of comparison with the barrier schemes. Sites chosen for barrier schemes ranged initially from Crayfordness (29 km below London Bridge) upstream to Cannon Street railway bridge, (0.4 km above London Bridge). The cost of raising the existing flood defences was calculated down to Crayfordness. Later sites farther down river were investigated, and in these cases a credit was made for the value of the improved defences upstream of the site saved by the scheme. The initial investigation narrowed the choice down to three sites for more detailed study. These were Cannon Street, Woolwich Reach, and Crayfordness. The Crayfordness site had the attraction of good foundations on the chalk, and also kept the work on existing defences to a minimum. The site was on a bend of the river, and for this reason the navigation authorities demanded an unobstructed opening of 427 m. The types of retractable barrier proposed in 1965 for this site were not considered sufficiently reliable. The effort was therefore made to develop a type of barrier which would have a sufficient degree of reliability, and also provide an opening of sufficient width. The rising drum gate barrier was developed, which had certain advantages. Thirteen gates were proposed, each 33 m across; figure 3 shows the proposed structure. As long as it was possible to operate eleven or more gates, full protection could be provided upstream. The gates were designed as buoyant structures and therefore retraction would depend on maintenance of an efficient seal around the gate, to enable the water to be drained from the recess under the gate. This would obviously be difficult and was a weakness of the design. The main difficulty was in construction because of the very deep excavation necessary in the bed of the river, the bottom of the excavation being about 45 m below high-water level. Construction would also be slow because the cofferdam in which the structure

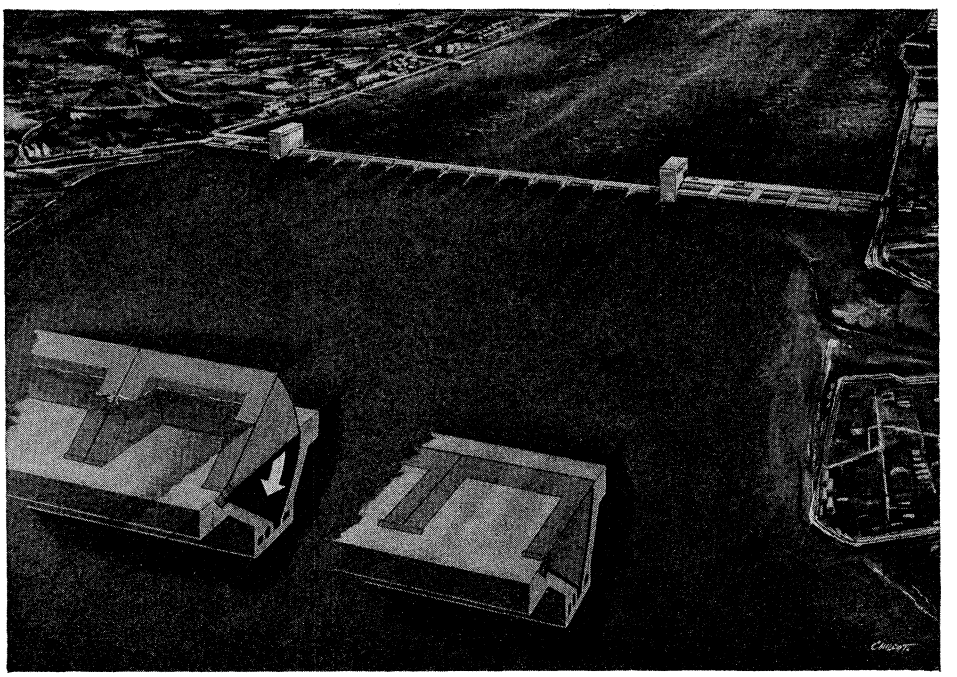

FIGURE 3. Rising drum gate barrier at Crayfordness.

would be built would be restricted to a length of about 105 m so that the waterway would not be unduly restricted and the increase of the velocity of the water past the obstruction would be kept to a reasonable figure.

The site farthest upstream at Cannon Street was also not very attractive, as a considerable length of banks downstream would have to be improved, and in addition the increase of the level reached by a high tide downstream of the structure, when a barrier at this site was closed was a minimum of 0.6 m when the barrier was closed at the preceding low water, and as much as 1.2 m when the structure was closed under the worst conditions on the rising tide.

Of the sites in between, the two possible sites in Woolwich Reach appeared the best. A main opening of 137 m was considered reasonable by the navigating interests, as the reach was fairly straight and the approaches to the structure good. A good foundation in the chalk was possible at moderate depth. The site in the eastern half of the reach was considered first, as an open area for construction purposes was available on the south bank at the old Woolwich Dockyard site. The Greenwich Borough Council planned to use this area for housing however and opposed the proposal for this reason. In addition they took considerable exception to the appearance of the proposed drop gate structure (figure 4). The depth of water at this site was about 14 m at high water, and it was necessary to raise the gate 43 m above high water to clear shipping. Towers over 60 m high were therefore necessary. To overcome these difficulties a further design of gate was developed. This is referred to as the Rising Sector Gate (figure 5). In this design, the segmental-shaped gate, when in the open position, lies in a shallow recess in the sill of the structure. The gate is suspended by arms at each end from bearings in the piers at the sides of the opening. It is closed by pivoting the gate upwards until it is in the vertical position, the suspending arms rotating about the bearings. Closure is therefore a simple operation, and the

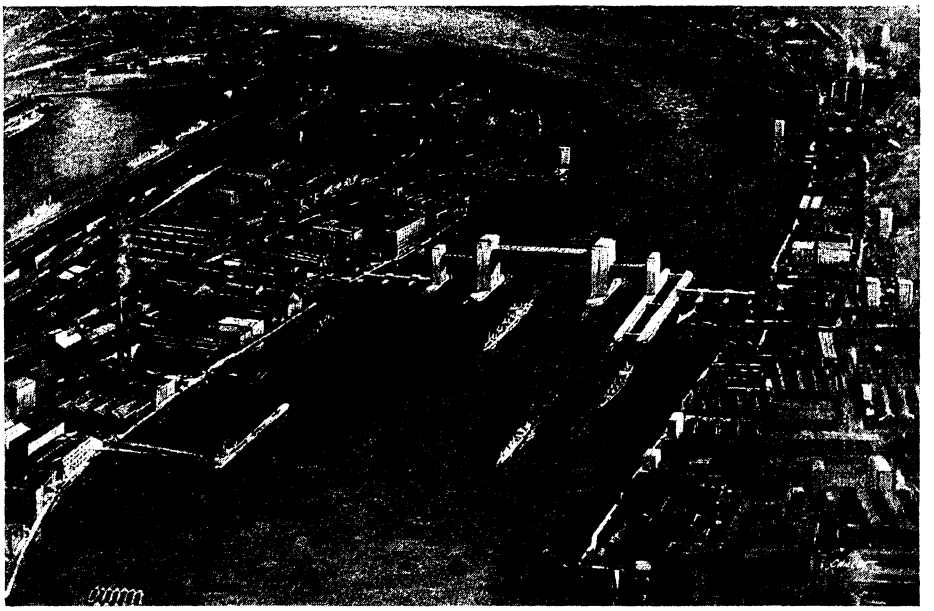

FIGURE 4. Drop gate barrier in Woolwich Reach.

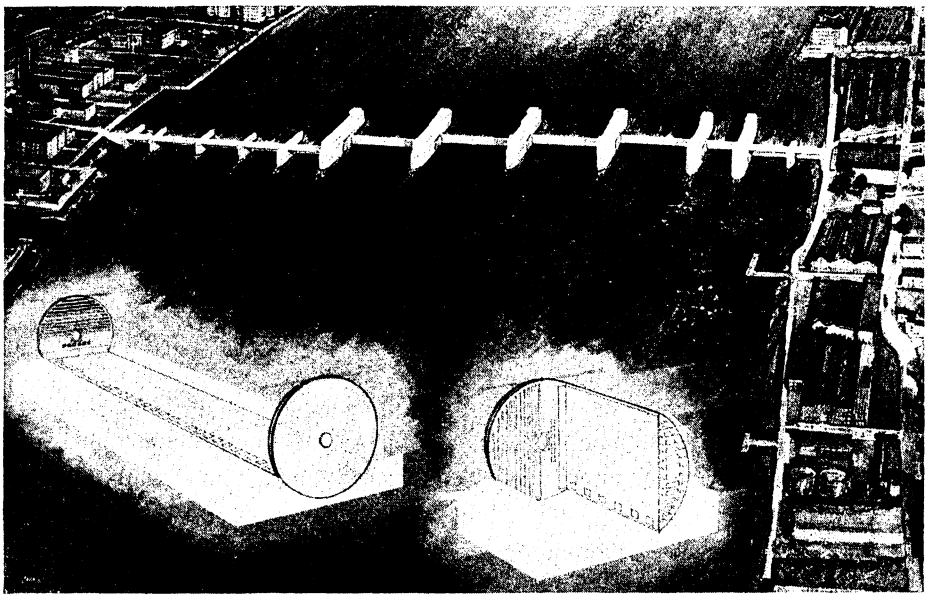

FIGURE 5. Rising sector gate barrier in Woolwich Reach.

operating machinery can be housed in the dry in the piers. The problem of silt can be largely overcome by providing seals for the clearance between the gate and the sill, thus preventing the ingress of material into this space. Provided that the sill is not too low in comparison with the general level of the bed of the river, little difficulty is expected with the accumulation of silt on the gate itself. In addition it is proposed to provide operating machinery of ample power so that it would require a considerable accumulation of silt to interfere with the operation of the gate. The disadvantage of the design lies in the limitation of span of the gate to 60 m or thereabouts.

This limitation arises since the shallow section of the gate allows only a moderate bending moment to be carried, and support is only available from the piers. In the case of the Silvertown site, the use of 60 m openings led to a decision to use four main openings in the structure. This gives a very great increase in reliability in comparison with a structure with a single large main opening, since failure of one of the main gates would not destroy the effectiveness of the structure as a flood protection device, except in the case of a late closure on an exceptionally high surge tide.

Barrier operation

Closure of the barrier has the effect of modifying the levels reached by the incoming tide at points downstream of the structure. Depending on the timing of closure relative to the time of high water, water levels of the high water following closure may be higher or in certain cases even slightly lower, than they would have been if the structure had not been closed. In general, levels are little affected or even slightly reduced if the barrier is closed at or before low water, but levels are increased if the structure is closed several hours after low water. This increase may be over 0.6 m for a barrier at the Silvertown site, closed under the worst conditions. This effect dies away downstream, in the worst case being only a few centimetres 40 km downstream of the structure.

During the early years of the life of the barrier, closures are predicted to be only once or twice per year, but in addition a further two closures per year for exercise purposes would appear prudent. By the end of the century, assuming that the adverse change of mean sea-level relative to the levels of the flood defences continues, closures may increase to ten per year.

Conclusion

The investigation into the defence of the low-lying areas of London adjacent to the tidal Thames, carried out by the Greater London Council, has shown that the problem is best resolved by the construction of a flood defence barrier across the estuary at a site in the western half of Woolwich Reach, combined with improved flood defences along the banks of the estuary downstream of the barrier site. The rising sector gate type of barrier has been selected for further development as the type of structure most likely to provide a reliable and satisfactory device for closing off the estuary when required to meet the threat of a dangerous surge tide.

Acknowledgement is made to Mr S. H. Dainty, Director of Public Health Engineering, Greater London Council, for permission to present this paper, and to colleagues of the Rivers Branch, Department of Public Health Engineering for their assistance in assembling the information.

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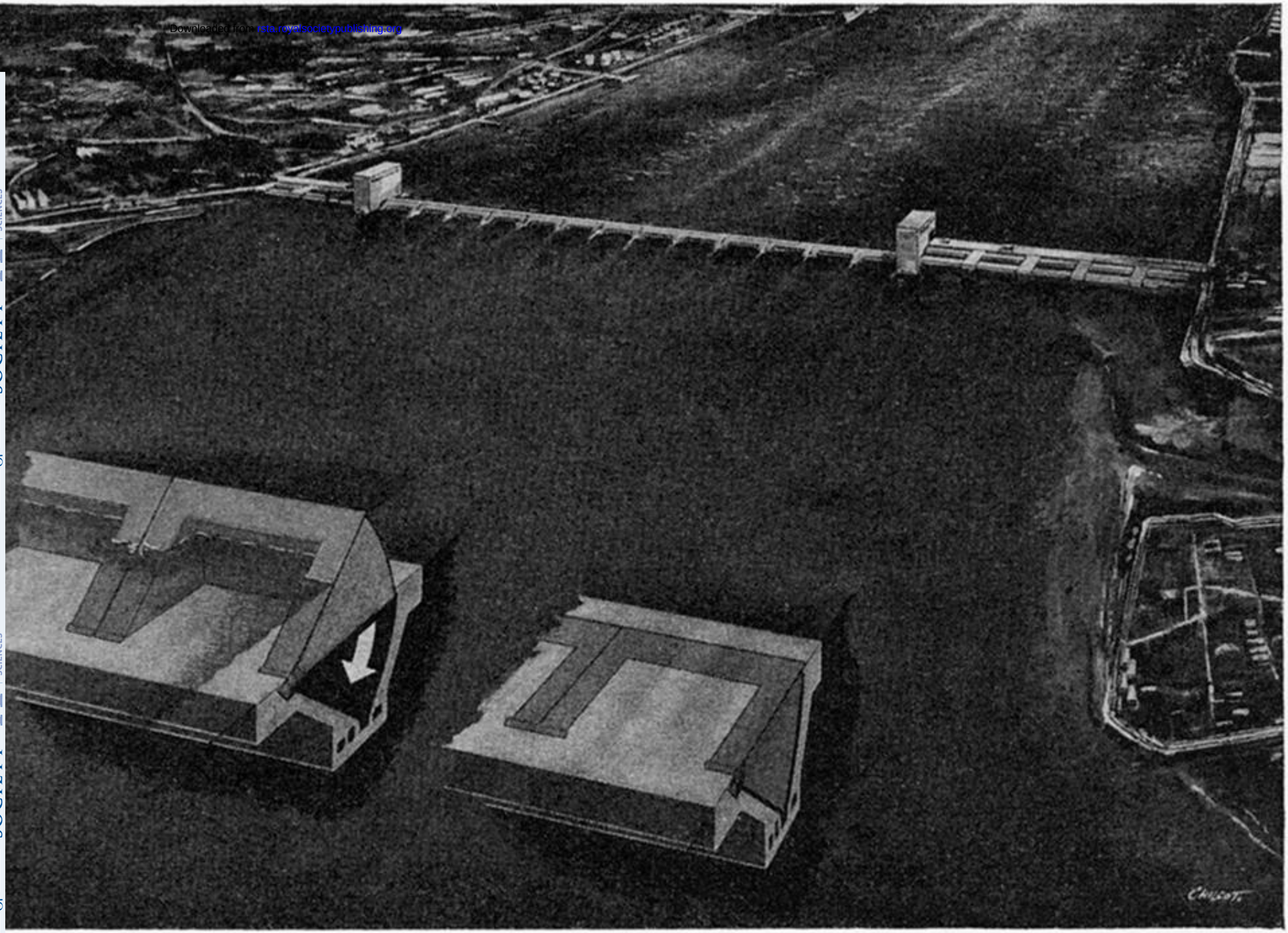

FIGURE 3. Rising drum gate barrier at Crayfordness.

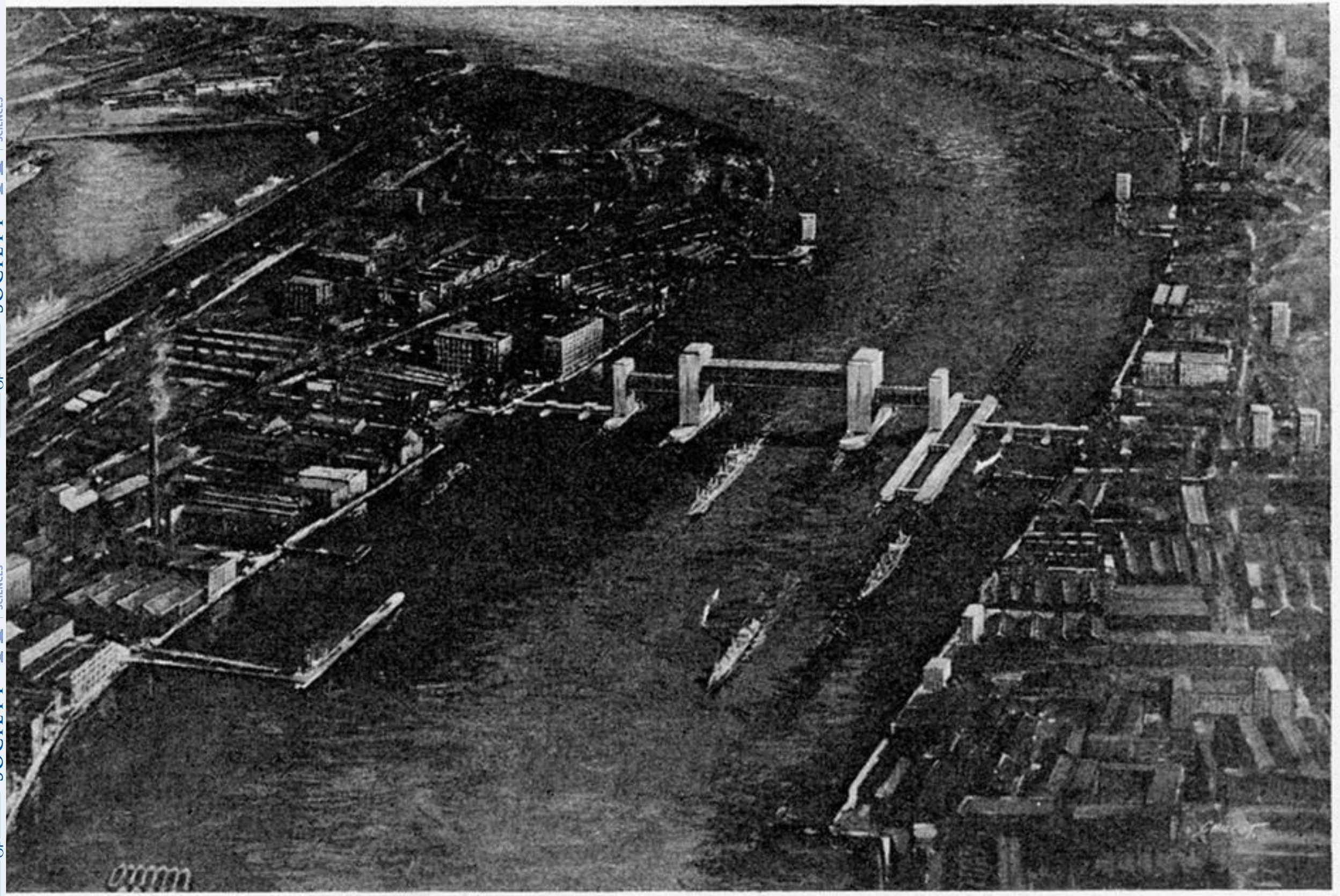

FIGURE 4. Drop gate barrier in Woolwich Reach.

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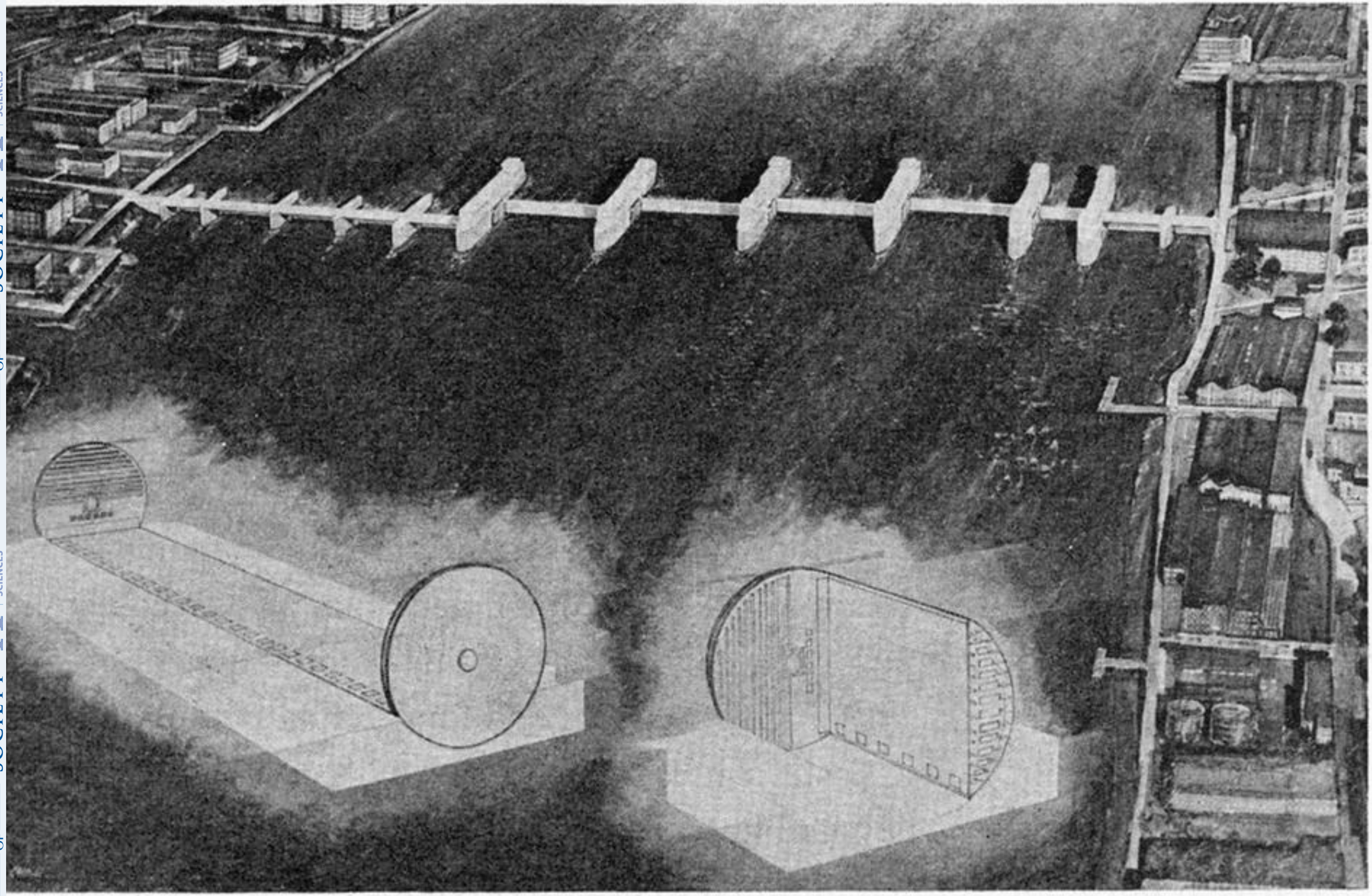

FIGURE 5. Rising sector gate barrier in Woolwich Reach.

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