HMS

HEAVY MOVABLE STRUCTURES, INC.

FIFTH BIENNIAL SYMPOSIUM

November 2nd - 4th, 1994

Holiday Inn Surfside
Clearwater Beach, Florida

SESSION WORKSHOP PRESENTATIONS

"THE DESIGN AND CONSTRUCTION OF MUTFORD BRIDGE AND ASSOCIATED WORKS"

by ROGER P. HICKMAN
Mott MacDonald

THE DESIGN AND CONSTRUCTION OF MUTFORD BRIDGE AND ASSOCIATED WORKS

by ROGER HICKMAN
OF MOTT MACDONALD

SYNOPSIS

Mutford Bridge carries the A1117 over the navigation between Oulton Broad and Lake Lothing at Oulton Broad in Suffolk.

The existing swing bridge and its approach spans had reached the end of their useful life, and have now been replaced by a new vehicular bascule bridge.

In conjunction with the bridgeworks, the opportunity has been taken to remodel and improve the road layout in the vicinity, necessitating the construction of approach roads to the new bridge on embankment across Lake Lothing, the provision of two new roundabouts and the reconstruction of a British Rail level crossing.

The scheme also includes provision of new cycleways and pedestrian routes which cross the navigation on a separate timber bascule bridge. The design and construction of the new bascule bridges, and the associated structures and civil engineering works on the scheme are the subject of this paper.

DESIGN

Mutford Lock separates Oulton Broad from Lake Lothing at the inland end of Lowestoft Harbour. The bridge here provides one of only two road crossings of the harbour and is therefore an important link between Great Yarmouth and the south (Fig 1).

To the east lies the busy commercial harbour of Lowestoft, whilst to the west the tidal Oulton Broad forms part of the popular cruising ground known as the Norfolk Broads.

The right of navigation between the two stretches of water has never been extinguished, although it has been little exercised in recent years, and Broads hire craft are not generally permitted to enter the tidal waters of Lowestoft Harbour. However, with the redevelopment in the area generally, it is anticipated that use of the navigation will probably show a modest increase in the future.

HISTORY OF THE LOCK AND THE BRIDGE SITE

It is thought that sometime after Roman times, there was a "Mud Ford" at the location of the present lock. The first record of a bridge, on a map dated 1610, shows Mutford Bridge at "Oldton" crossing what was then a fresh-water spur of the River Waveney; in all probability a previous course to the sea which became blocked at its mouth by the coastal drift experienced along this coastline. This bridge, which was no more than a few planks across a gap in the mud embankment, survived until 1659 when it was swept away by violent storms. A new timber bridge costing £200 was built, which lasted until 1760 when it was replaced by a stone arch bridge. This was swept away in 1791 and replaced by a similar structure.

SUBSTRUCTURE

Borehole data from the site indicated Clay/Silt alluvium overlaid Peat, sand, gravel, mud and clay layers, which in turn overlaid a 2 metre thick band of laminated Silt/Sand/Clay at -10.5m AOD, above a deposit of dark grey sand and shells - the "Norfolk Crag". Calculations carried out by the Suffolk County Council's County Laboratory suggested that the foundations could be formed from medium diameter piles founded in the Norfolk Crag at -16.0m OD. To limit disturbance to the existing bridge, permanently steel cased bored concrete piles of 600mm diameter, either vertical or raked at 1 in 5 pitch, were used throughout. To avoid downdrag anticipated from settlement arising from embankment construction, the piles were coated down to -12.0m OD with a 10mm thick bituminous slip coat. The piles were thus effectively end-bearing.

Bank seats are essentially insitu reinforced concrete pile caps, constructed above MHWST, and form a convenient foundation for the drop arm barriers provided.

The nose pier also comprises an insitu pile cap constructed above MHWST. The level of the top of the insitu portion of this pier was chosen to remain below the swinging soffit of the existing bridge, in order to maintain the pattern of weekly openings. When the scheme was being developed, it was believed closure of the navigation for more than a few weeks would not be permitted, and in order to limit the potential navigation closure period, it was proposed to use a precast bearing shelf on the nose pier for the north approach span, and precast beams for the approach span itself. Using such precast elements, it was envisaged the navigation closure could be limited to a maximum of four weeks, whilst the north approach span was constructed and the new crossing commissioned. In the event, it was decided to carry out repairs to the lock, including the renewal of the lock gates, in conjunction with the bridge reconstruction, and the navigation was eventually closed for several months whilst this work was carried out, which enabled the bearing shelf to be constructed in insitu concrete.

The main pier comprises a two level structure with the upper slab carrying the roadway, and lower apron slab carrying the main bearings of the lifting leaf, the hydraulic cylinders and pumps, and an emergency diesel generator. With the road level adopted, it was necessary to construct the lower apron slab between MLWST and MHWST, rather than entirely above MHWST; the additional cost of this was estimated to be outweighed by savings in the cost of embankment construction.

The wall between the upper and lower slabs is pierced by the superstructure of the lifting leaf, but a dwarf wall at a level of +2.85m OD provides protection against the design flood level of +2.6m OD. Further protection from flooding for the emergency diesel generator and the pump sets is provided by siting them in a compartment separated from the main body of the lower floor by watertight doors.

SUPERSTRUCTURE

The overall superstructure width is 13.800 metres, and carries a 7.300 metre carriageway, a 1.500 metre footway on the west side, and a 4.000 metre footway and cycleway on the east side. The lifting leaf is of steel orthotropic plate construction, using longitudinal closed section trough stiffeners, I section transverse girders at 2.635 metre centres, and twin I section main longitudinal girders at 7.250 metre centres (Fig 6).

Bridge movement is transmitted to the lifting leaf through a welded steel torsion box at the rear of the leaf. This is sufficiently robust to react the loads arising with one cylinder non-operational. The partial counterweight is provided by steel billets bolted to the rear of the torsion box.

The carriageways and footways are surfaced with aluminium oxide chippings in an epoxy matrix spread on the blast cleaned steel surface by squeegee; a fine grade of chippings is used on the foot and cycleways, and a heavier grade on the vehicular carriageways. The steelwork is prepared by blast cleaning and protected with a standard DTp paint system comprising aluminium metal spray and a multicoat epoxy ester/silicon alkyd paint system.

The top deck of the main pier forming the carriageway and footways is of reinforced concrete beam and slab construction, and contains large cast-iron covers and frames to enable the hydraulic cylinders and other large items of equipment to be removed and replaced, should this ever prove necessary.

The superstructure of the approach spans comprises precast prestressed beams, inverted Tee beams being used on the south approach, and hollow box beams, transversely postensioned, on the north.

The operator's control cabin is a timber first floor structure, built above the electrical control room on the western end of the main pier. Access is provided down to the electrical machine room at road level, and from there down to the lower machine room housing the emergency diesel generator and pump sets at the lower apron level.

DRIVE AND CONTROL SYSTEM

The bridge is raised and lowered by two double acting hydraulic cylinders reacting on the lower edge of the torsion box, which also carries the counterweight and houses the main pivot bearings. As the cylinder rods extend and apply a torque about the pivots, the bridge rises and the counterweight rotates so that the thrust of the cylinders remains sensibly constant throughout the movement of the bridge from horizontal to fully raised at 81° elevation. (Figure 3).

The bridge is capable of being raised safely to the fully open position or lowered to the road open position within 60 seconds in wind gust speeds up to 18 metres per second, or within 75 seconds in wind gust speeds up to 27 mps. This represents the maximum operating condition. The bridge is however capable of safely surviving in any position, without the use of any mechanical locking device, in wind gust speeds of up to 45 mps in any direction.

During raising, bridge movement accelerates to full speed over approximately 10 seconds to approximately 10 degrees of elevation, and continues at constant speed to approximately 70 degrees, at which point duplicate limit switches signal the control system to reduce the speed back to creep speed, and further limit switches halt movement at 81 degrees elevation, by signalling the control system to move the directional valves to neutral. The bridge lowering sequence is the reverse of the raising sequence with duplicated pairs of limit switches provided to reduce speed to creep speed and move the directional valves to neutral at 10 degrees elevation and 2 degrees elevation respectively.

Each cylinder is provided with integral counterbalance valves, such that should the operator stop the movement, or the drive pressure fail for any reason, the hydraulic fluid is locked in the cylinders to hold the bridge safely in any position.

BEARINGS

The main pivot bearings are of the plain spherical type, which provide a full self-aligning facility and high load capacity. Each of the landing blocks at the nose end is fitted with hydraulic shock absorbers, which retard the movement at the end of the lowering cycle.

HYDRAULIC SYSTEM

Pressurised fluid to drive the cylinders is provided by a dual pumpset housed on the lower apron slab below the control room. Each pumpset includes a variable delivery pump, electric motor and local valves and pipework to deliver its contribution for the total requirements of the cylinders for the full range from creep to maximum speed. Oil from the pumpsets is delivered via solenoid operated directional valves to two common headers, one for raising and one for lowering the bridge, to ensure that both cylinders receive equal volume and pressure as required.

The maximum operating pressure within the system excluding the cylinders, is 200 bar, and pipework is sized so that flow rates do not exceed 5 metres per second.

Each main pump is of fixed speed with an infinitely variable output and of the axial piston with swash plate and pulling motor design. Each pumpset has an output of 300 litres per minute at 100 bar (full speed) or 30 litres per minute at 200 bar (creep speed), when driven at 1450 rpm by a 75 kW electric motor.

Each hydraulic cylinder is sized to allow for a maximum operating load of 1000 kN in compression, or a peak load with the bridge raised, but in stationary mode, of 1500 kN in either tension or compression. Maximum working pressure is limited to 250 bar.

The output pressure of each pumpset is monitored, and indicated at the control desk, to reveal any possible fault condition.

ELECTRICAL INSTALLATION

The electrical machine room, sited at road level beneath the Control Room, houses the main electrical equipment, comprising a combined incoming supply panel, a motor control centre and a hydraulic panel, all purpose-built to provide the control of the drive motors, distribution valves, traffic control lights and barriers. A programmable logic controller (PLC) is included to monitor the signals arising from the control desk, the various positional limit switches and condition monitors on the pumpsets and the bridge, in order to control performance and to indicate to the operator as the operating cycle proceeds.

An autostart standby diesel generator is provided to cover for mains power failure. The set is sized to maintain continuously for 8 hours before refuelling, the bridge power requirements including one hydraulic pump drive and ancillaries, all the control supplies, domestic supplies and lighting, and is capable of accepting these power requirements within 12 seconds of a mains failure from a cold start.

The control cabin houses a control console to give the operator full control of road and pedestrian traffic and operation of the bridge with good all-round vision. This is supplemented by a 3 camera CCTV system to assist the bridge operator to monitor the progress of pedestrians at both the vehicular and pedestrian bridges.

Wind speed measurement is provided by an anemometer and wind direction indicator, with facilities for remote readout and an audible alarm. The audible alarm is activated when wind gust speeds reach 60 mph (27 mps) this being the maximum operating wind speed.

A VHF radio system is also provided for communication between the bridge operator and waterborne traffic. "Navigation" traffic lights driven from the PLC, are mounted both sides of the bridge to assist in the movement of waterborne craft. In addition red and green fixed navigation lights are provided on the fendering on the approach to the bridge from the east.

TRAFFIC AND PEDESTRIAN CONTROL

The existing bridge had manually operated gates, but the new bridge is provided with powered drop-arm barriers, wig-wag flashing lights and audible signals.

Mutford Bridge is a busy one for pedestrians as well as vehicular traffic, and a natural congregation area for sightseers. For this reason separate drop-arm barriers across the footways and cycleways are provided, complete with their own warning lights, audible signals and a tannoy system, together with guide handrailing to discourage jay walking.

The vehicular and pedestrian barriers and lights are interlocked with the bridge controls so that the bridge cannot be raised until all the barriers are fully lowered, and the barriers cannot be raised until the bridge is fully lowered. The safety interlock to release the barriers is activated by a rapid pressure rise in the hydraulic system as the bridge is driven into the hydraulic nose loading shock absorbers. Movement of the traffic barriers is arranged so that they stop immediately on release of the RAISE or LOWER button and may thereafter be made to continue or reverse as required.

On the advice of the ABP, the A12 bridge operators and because this section of road is a frequently used emergency vehicular route, an "Emergency Raise Trailing Barrier" switch was incorporated. This allows the bridge operator to raise the trailing barriers only to allow the passage of an emergency vehicle at any time before the bridge starts to lift without aborting the sequence.

Bridge movement is arranged such that on release of the "spring to neutral" joystick the bridge stops rapidly and holds position. After an 8 second delay movement is possible in the forward or reverse direction. The delay is necessary to prevent any oscillation buildup at the natural frequency of the bridge/hydraulic system.

FENDERING

Only fairly small vessels are able to use the lock, and hence modest arrangement for fendering are adequate.

Greenheart piles driven into the channel bed are supported at the top by buckling vee type rubber fender units mounted either on the substructure of the bridge, or on steel walings spanning between the substructure and the lock walls. At the eastern end, lead in guide fendering is similarly provided, supported on steel walings and steel cylinder piles.

EMBANKMENT CONSTRUCTION

From the new vehicular bridge southwards for approximately 150 metres, the new road crosses tidal Lake Lothing on embankment. The vertical alignment falls from +4.075m OD at the bridge to +2.050m OD at the crest of the existing flood embankment surrounding Lake Lothing.

The bed of Lake Lothing slopes gently down from 0.00m OD at the toe of the flood embankment, steepening towards the approach channel to Mutford Lock, to a dredged bed level of -4.200m OD through the navigation. The embankment height therefore varies from 2 metres at the flood embankment to 8 metres adjacent to the bridge. It was proposed to infill the area between the present shoreline and the new road to enable a short link road to be constructed between the new road and Bridge Road.

Lake Lothing is underlain by a sequence of very soft organic Clay/Silt alluvium and Peat to between 2.5 metres and 4.5 metres below bed level, followed by Glacial Sand and Gravel, and laminated Sand/Silt/Clay. Very dense Norfolk Crag underlies the site below elevation -12.5m OD.

Data obtained by the Suffolk County Laboratory indicated a design shear profile within the organic Clay/Silt alluvium increasing from 1 kN/m^2 at bed level and by 1 kN/m^2 per metre of depth; in consequence it was calculated shear failure could occur if the embankment was raised by more than 0.5m in a single lift. The organic Clay/Silt has a low permeability with laboratory measured coefficients of consolidation of $0.3m^2$/year and in the absence of any macro fabric it was anticipated the field consolidation rates would approach the laboratory values. Staged embankment construction on this stratum would have required a construction period in excess of one year which was unacceptable.

The underlying Peat was also found to be in a very soft condition, and a design strength of 7 kN/m^2 was indicated by the site investigation. Assuming the alluvium was removed, it was considered staged construction and surcharging would also be required on the underlying stratum, with a minimum period of 18 weeks to raise the embankment safely, followed by a settlement period under surcharge. The laboratory test results also indicated possible tertiary settlement of 30mm - 40mm within the first 3 - 4 years, continuing at a slightly reduced rate thereafter, which would have posed a long term maintenance liability.

It was therefore decided to excavate both the Clay/Silt alluvium and the Peat, and replace them by hydraulically placed granular material. With the removal of these upper strata, it was considered the embankment could be raised at up to 1 metre per week. Above a level of +0.500m OD, ie above MLWST, it was intended granular fill would be placed conventionally, and compacted by rolling. Some settlement was expected, particularly in the laminated Silt/Sand/Clay layers overlaying the Norfolk Crag. It was therefore decided to install vertical drains on a triangular 2 metre grid, down to a level of 1 metre below the base of these layers, to speed settlement. Additionally, a modest surcharge was introduced by filling up to finished road level at the time of embankment construction. It was considered a period of about 6 months would be required after completion of embankment construction for the rate of settlement to be reduced to an acceptable level.

To monitor and control the rate of settlement, instrumentation was installed and monitored prior to, during, and subsequent to embankment construction.

To monitor natural ground water level, two standpipe piezometers were installed at the southern end of the embankment, in the crest of the existing flood embankment. These were commissioned prior to commencing dredging operations.

To monitor excess pore water pressure beneath the embankment, ten pneumatic piezometers were installed in a trench in the laminated Silt/Sand/Clay layer in the deepest part of the embankment, about 15 metres behind the south abutment of the new bridge. These were led to a terminal cabinet located on a universal beam driven into the bed to provide the necessary support. These pneumatic piezometers were installed and commissioned after completion of dredging operations and before commencing the construction of the embankment.

Settlement of embankment construction was monitored via twelve settlement plates installed in the fill material as filling proceeded.

Embankment slopes generally were 3:1, steepening to 2:1 either side of the navigation, and protected with precast "Dytap" revetment mattresses. In the event, random rock armour replaced the specified mattress protection in some areas, as described later in this paper.

Whilst the height of the embankment was above the designated flood level (+2.6m OD) over most of its length, at the southern end the embankment fell to below this level. A wall was therefore provided along the top of the full length of the embankment on the seaward side, fulfilling the joint purpose of a flood prevention wall and a vehicle containment barrier. This wall comprises a reinforced concrete core clad with brickwork containing flint cobble infill panels, and forms an attractive feature of the scheme.

On the north side of the new bridge, a similar dredging and filling operation was required, but of reduced extent. To maintain waterborne access to an adjacent boatyard, the embankment on the north-east corner was retained with a sheet pile wall, tied back via the capping beam into a reinforced concrete anchorage constructed in the body of the embankment.

PEDESTRIAN BASCULE BRIDGE

As part of the decision to provide improved pedestrian and cycle routes through the area, a separate pedestrian and cycleway bridge across the lock is included in the scheme. The existing reinforced concrete walls of the lock barrel reconstructed in 1964 provided a suitable foundation for the structure, an overhead bascule bridge with a clear width between parapets of 3 metres and a span length of 8.600 metres, constructed of "Ekki" hardwood timber (Fig 7).

Initially it was proposed to raise and lower this bridge by a hand-operated winch, but later it was decided to provide powered operation, using small hydraulic cylinders similar to the vehicular bascule bridge. The bridge is operated from within the control cabin of the main bridge, from where the bridge operator has a good view of proceedings.

Because timber structures of this type are of specialist manufacture, outline sizing of the timber components only was carried out at tender stage, and the detailed design was entrusted to the nominated subcontractor, the "category 2" check being carried out by Mott MacDonald. The substructure and the mechanical components were, however, fully designed.

REPAIRS TO THE LOCK

While the road scheme was being developed by Mott MacDonald on behalf of Suffolk County Council, a parallel exercise was being undertaken by Robert West and Partners on behalf of Associated British Ports, the then lock owners, to establish the condition of the lock and the extent of any necessary repairs.

The road scheme envisaged minor repairs to the brickwork of the lock walls in the vicinity of the existing bridge, principally rebuilding loose or missing brickwork and underwater grouting of cracks and fissures using a cementitious grout.

However, by the time the contract for the road scheme had been placed, it had been decided jointly by Suffolk County Council and Associated British Ports to renew the timber lock gates, together with other repair work to the lock, and this additional work was added to the roadworks and bridgeworks contract.

CONSTRUCTION INTRODUCTION

A wide range of engineering disciplines were encompassed by this project. The main Contractor, AMEC Civil Engineering Limited (formerly Fairclough Civil Engineering Limited) carried out civil works including piling operations and employed a number of sub-contractors during the course of the Works. Watson Steel Limited (formerly Robert Watson Limited) an AMEC Group company, were responsible for bascule bridges fabrication and erection. Mechanical and electrical work was in turn sub-contracted out to Mac Scott Bond Limited and L.E.C Marine. Fabrication and erection of the timber pedestrian bridge was carried out by Sarum Hardwoods Limited. Building work, principally the control cabin, was carried out by AMEC Building Limited (formerly Fairclough Building Limited). Timber piling and fendering, lock gate fabrication and installation and culvert construction were carried out by John Martin Construction while Lancaster Earthmoving carried out earthworks including land based dredging.

CONSTRUCTION OPERATIONS AND METHODS

Work started on site at Oulton Broad on 25 February 1991. Demolition works started at the south end of the scheme to make way for the site establishment and worked through the site to the north end with the exception of a presbyterian church to which access could only be gained in January 1992.

Once the site was cleared sufficiently for access, the main civil works commenced. The first major operation was the construction of a temporary sheet pile wall around the edge of Lake Lothing to allow dredging and filling operations to proceed. The need to safeguard the lock against vibration set up by piling operations had been recognised by the designers and at an early stage a substantial system of strutting was installed together with a steel stoplog that would retain the waters of Oulton Broad should any catastrophic collapse of the old gates or brick walls adjacent to the lock occur. In fact, a section of the underwater brickwork in the old lock did collapse and it was necessary for the diving team who were on site installing the props to carry out an underwater video survey and effect some repairs to the collapsed area. There was no loss of water from Oulton Broad.

With the sheet piling complete, the main dredging and filling work to form the embankment for the new road could proceed. This operation was delayed by local residents of Somerleyton who objected to extraction of sand from that area. Eventually after some delay, the Contractor gained agreement to extract from Henham, some twelve miles to the south. This site was also used as a disposal area for all the peat and silt which was extracted from Lake Lothing. The peat when first extracted was too wet to be carried on the public highway so was stockpiled and allowed to dry before being removed from site.

This operation continued through the spring and summer of 1991 and the fill level was surcharged up to the level of the finished road to assist consolidation. Wick drains were installed after completion of filling through pre-bored holes. Piezometers to measure changes in pore water pressure within the cohesive materials at depth were installed and regularly monitored. Total settlements were measured from settlement plates installed within the embankment. Monitoring continued throughout the year until settlement had ceased, thus allowing further works to proceed.

The side slopes of the embankments were protected from tidal and wave action by the "Dytap" articulated revetment system installed as concrete block mats laid on the slope and anchored down.

Completion of the filling of the embankments gave land based access for the piling rigs to commence piling for the piers and abutments. The 22 mm thick steel walled 600 mm dia. tubes were driven by vibrating hammer to a depth of -16.00 OD, some 2.5 metres into the hard shelly sand layer, known locally as the Norfolk Crag. Soft material was then airlifted out to the level of the top of the Crag, before concreting. A combination of vertical and raking piles resisting the vertical and horizontal forces on the structure imposed a strict sequence in which the piling could be carried out.

Larger 1200 mm dia hollow steel tube piles were driven to support the fendering required to protect the structure from accidental collision damage and these also house navigation and directional indicators. The majority of the fendering is however traditional greenheart timber which is connected to the structure by rubber shock absorber units.

The permanent sheet piling required to retain the fill material on the north side of the navigation was installed this period. This sheet pile wall is tied back by 60 mm dia galvanised steel tie rods grouted into plastic sleeves to precast anchor units embedded within the embankment. The anchor units were precast above the high tide line in sections up to 35 tonnes in weight and positioned by crane in order to minimise the constraints of working within the tidal zone.

The steel lifting deck fabricated in Bolton, Lancashire was delivered to site in seven sections in early 1992 by road and installed in the following sequence, using a Liebherr LTM 1400 mobile 400T Crane with its front outriggers positioned over the southern abutment. The "tail end" of the bridge consists of the torsion box, main bearings and kentledge, a total of 140 tonnes of solid steel billets welded together. The torsion box and bearings were first lowered onto the holding down bolts, temporarily secured, and the three kentledge boxes then bolted on. Ram stools and main hydraulic rams were then assembled and connected to a temporary hydraulic powerpack.

This complete section was then rotated into a vertical position to allow the roof slab of the main pier to be concreted. The torsion box was then rotated back to the horizontal position to allow the remaining three deck sections to be site welded in a 48 hour continuous welding operation. The control cabin was built during this period. Installation of the mechanical and electrical equipment continued with testing and commissioning was complete at the end of July 1992. The bridge was opened to traffic on 5 August 1992. The pedestrian bridge was also installed and commissioned. Once the new road bridge was opened, demolition of the existing bridge took place and the area landscaped. The repair work to the lock and installation of the new lock gates which had been fabricated off site was also undertaken at this time. Final paving and landscaping of the areas was completed for a colourful official opening ceremony on Tuesday 17 November 1992.

PUBLIC RELATIONS

Public relations in general were an important feature of this scheme; without local co-operation some of the more difficult tasks would have become well-nigh impossible and it was most certainly in the interests of the project to maintain good relationships with local residents. Very keen control was exercised over such issues as Sunday working, late night working, disturbance from noise and dust, disruption to traffic, arrangements for pedestrians and cyclists, and suggestions from local residents incorporated where possible. In addition, visits by various local and regional organisations took place and the general public were appraised of progress via public announcements. A scheme information board erected on the old bridge generated a great deal of public interest while the local libraries distributed many hundreds of the information leaflets produced.

MUTFORD BASCULE BRIDGE AND ASSOCIATED ROADWORKS
REFERENCE LIST OF PRINCIPAL QUANTITIES

eArea of site clearance	3.65 hectares
Number of structures demolished	17 No.
Dredged excavation	36,761 m^3
Other excavation	13,072 m^3
Fill to be imported	56,657 m^3
Total fill to be placed	69,389 m^3
Topsoiling	5,281 m^2
Steel sheet piling	4,218 m^2
CIP piling	1,280 m
Tubular piling	61 m
Fencing generally	1,071 m
Drains	2,750 m
Ducts	2,991 m
Manholes and Chambers	59 No.
Gullies	114 No.
Full road construction	7,686 m^2
Total wearing surface	9,732 m^2
Kerbing	4,976 m^2
Footway	6,191 m^2
Paving	5,794 m^2
Brickwork	1,716 m^2
Concrete work	1,442 m^2
Formwork	3,969 m^2
Reinforcing steel	283 tonnes
Structural steel	248 tonnes
Bearings	82 No
Road signs	96 No
Street lamps	63 No

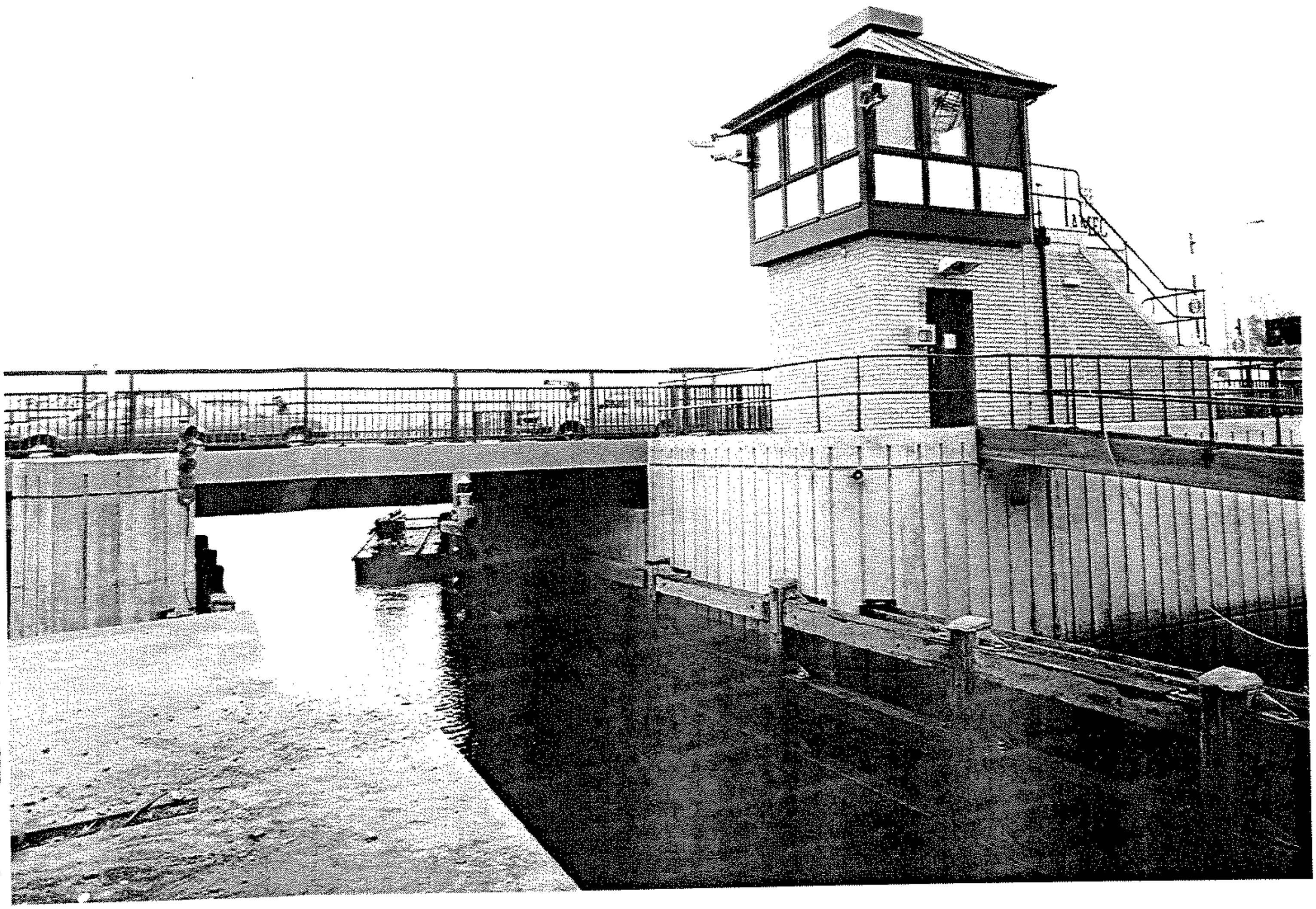
AUTOBIOGRAPHICAL PARAGRAPH

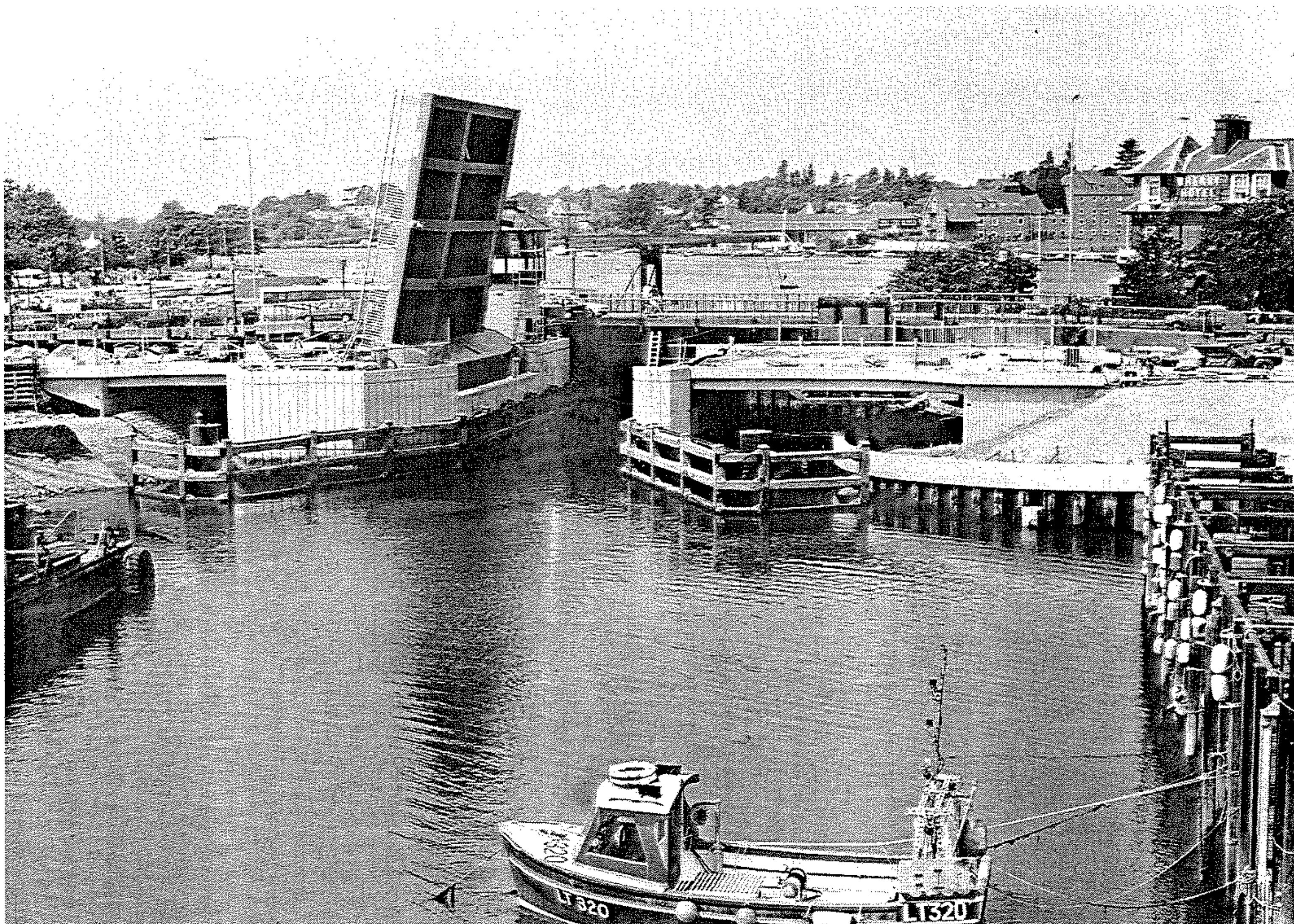
ROGER P HICKMAN

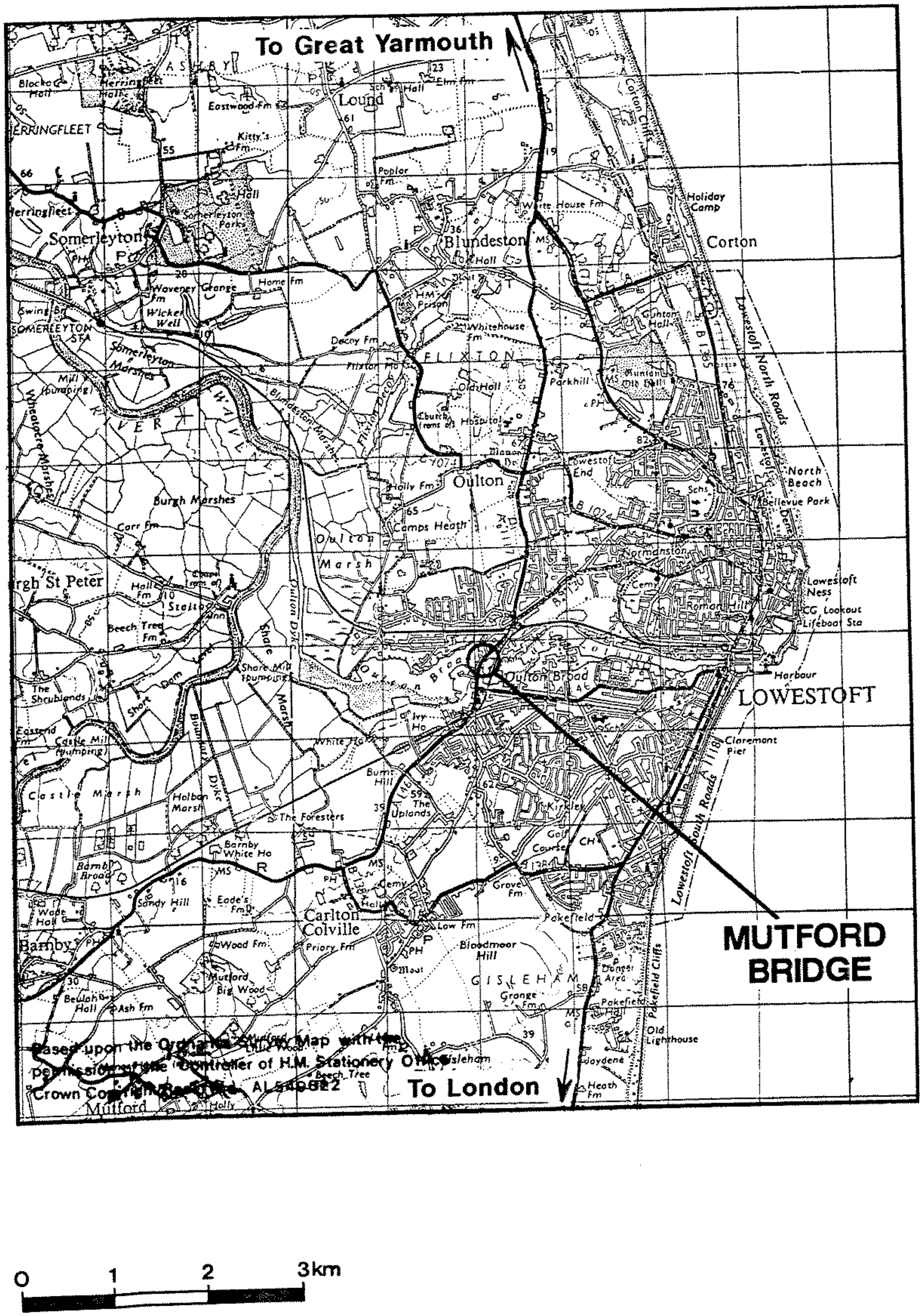
Roger Hickman is an Associate in the International firm of Consulting Engineers, Mott MacDonald.

After graduation in 1966, he worked for 10 years with British Rail, responsible for design and supervision of bridgeworks throughout the Southern Region.

In 1976 he joined the Consulting Engineers Husband & Co (later amalgamated with Mott MacDonald) and has been engaged on the design of bridges and heavy industrial structures such as colliery winding towers, ship unloaders and roll-on/roll-off ship ramps both in the United Kingdom and Overseas. He has been involved with the refurbishment of many movable bridges, including the large swing bridges over the Caledonian Canal and Crinan Canal in Scotland, and the design of new bascule bridges over the River Yare in Norfolk, the River Parrett in Somerset and the Mutford Bascule Bridge, which is the subject of this paper.

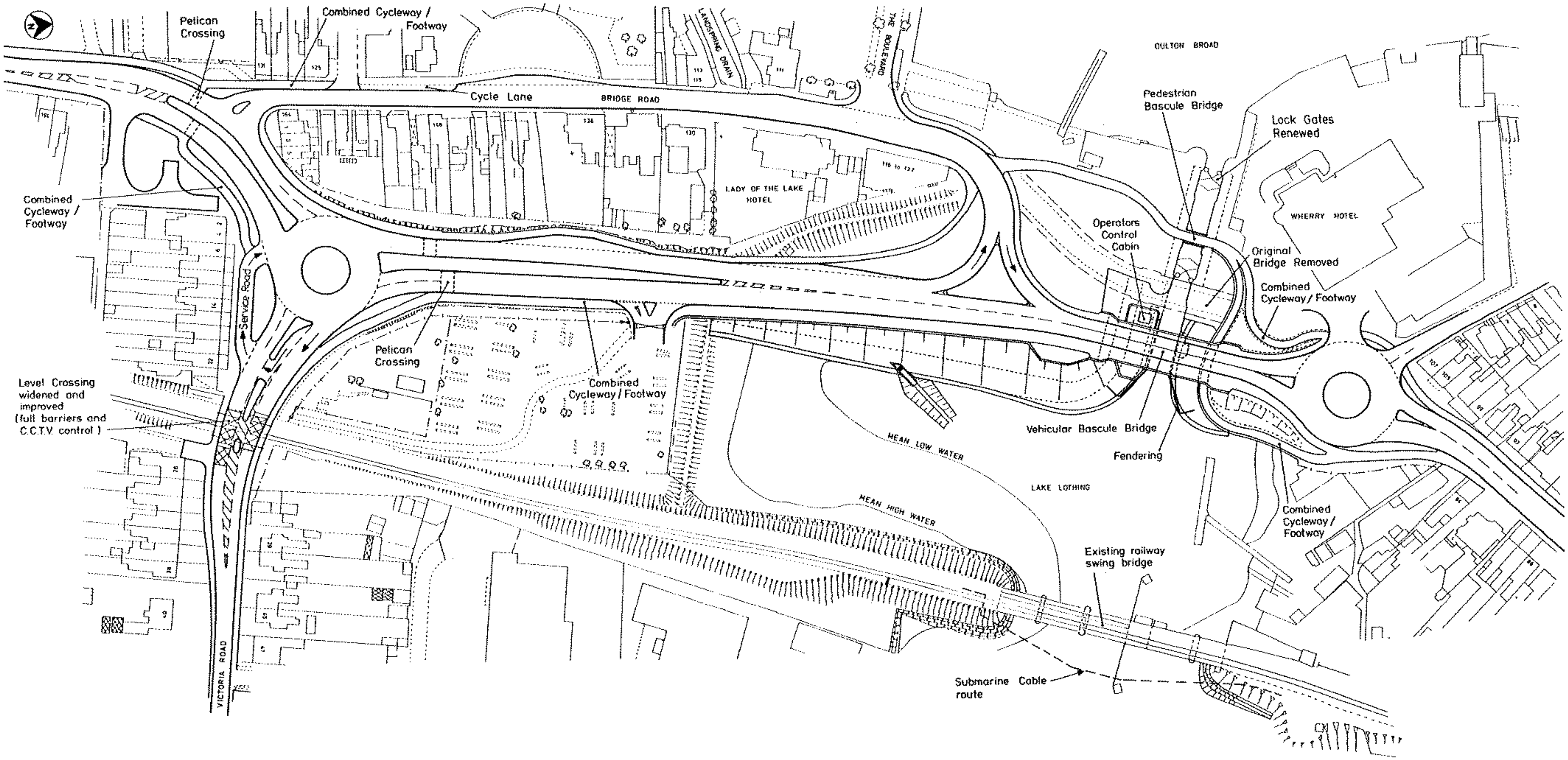



LT 320
LT320



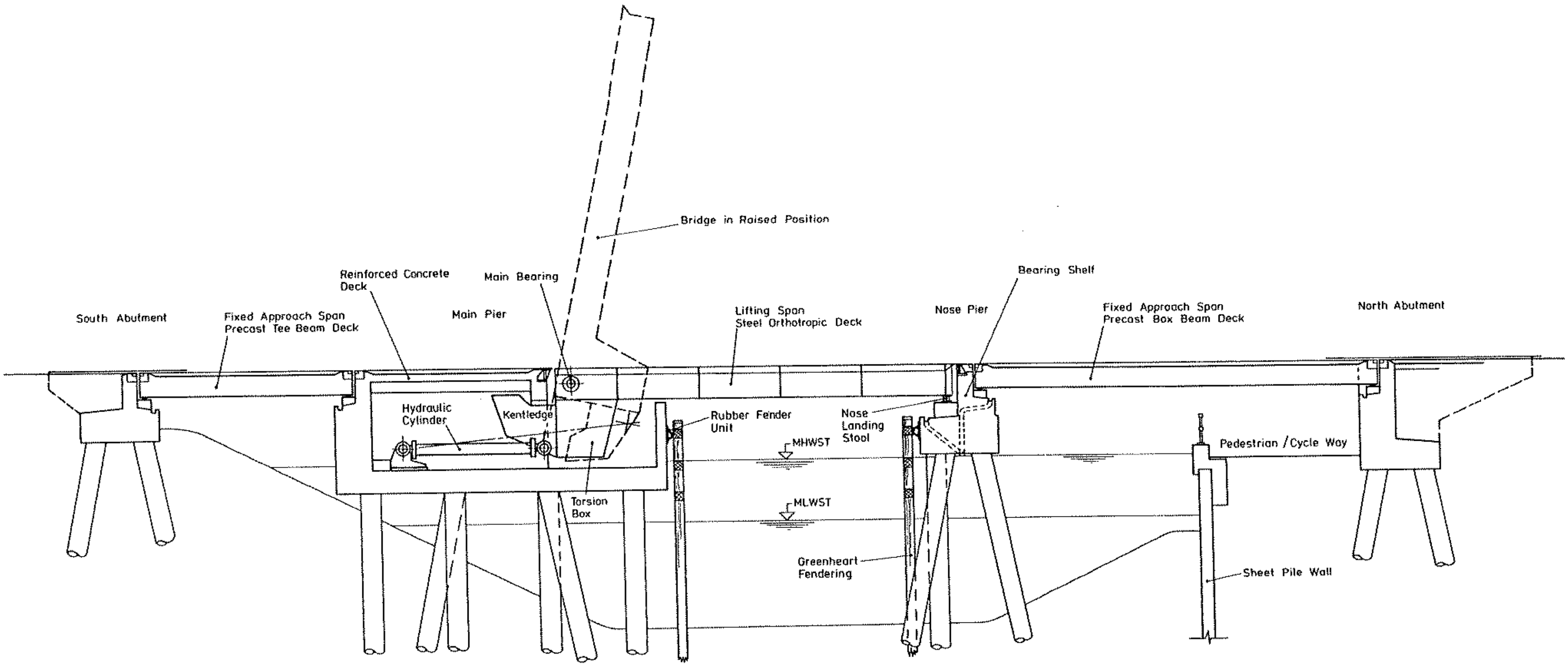
Location Plan

Figure 1



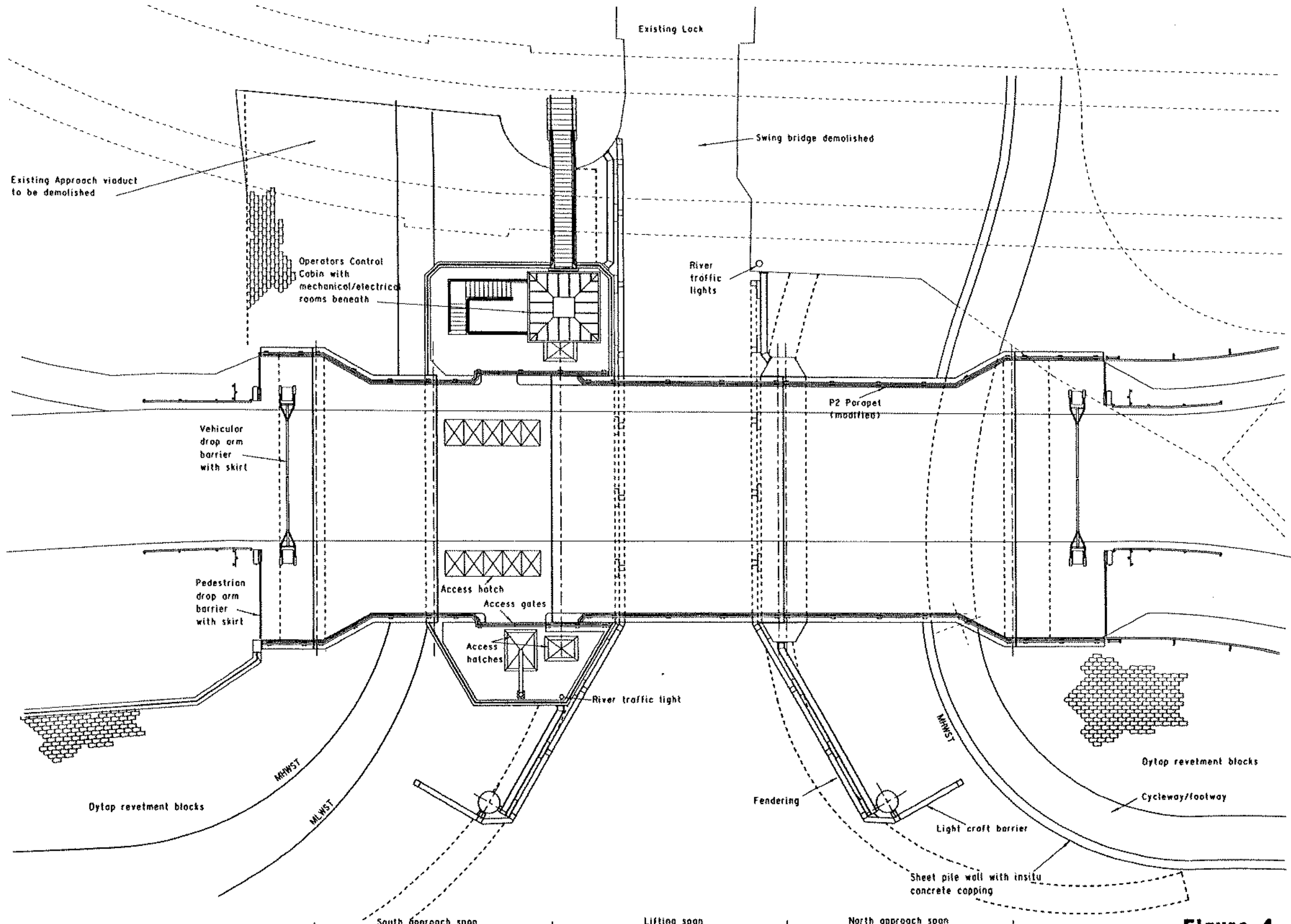
PLAN OF SCHEME

Figure 2



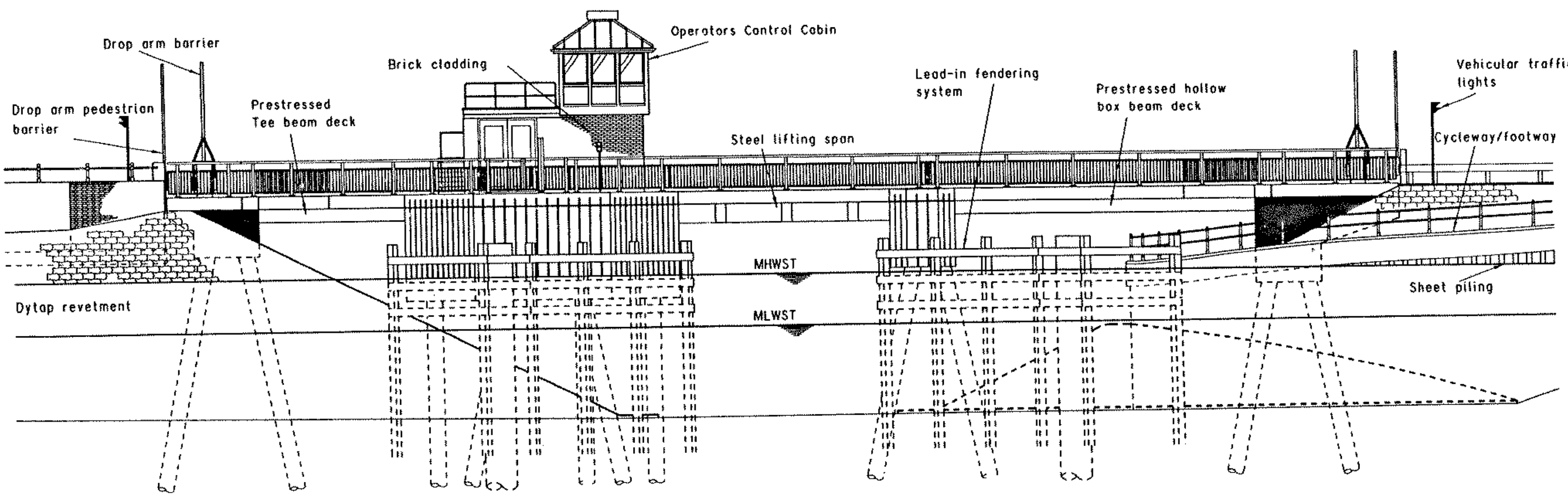
SECTION THROUGH VEHICULAR BASCULE BRIDGE

Figure 3



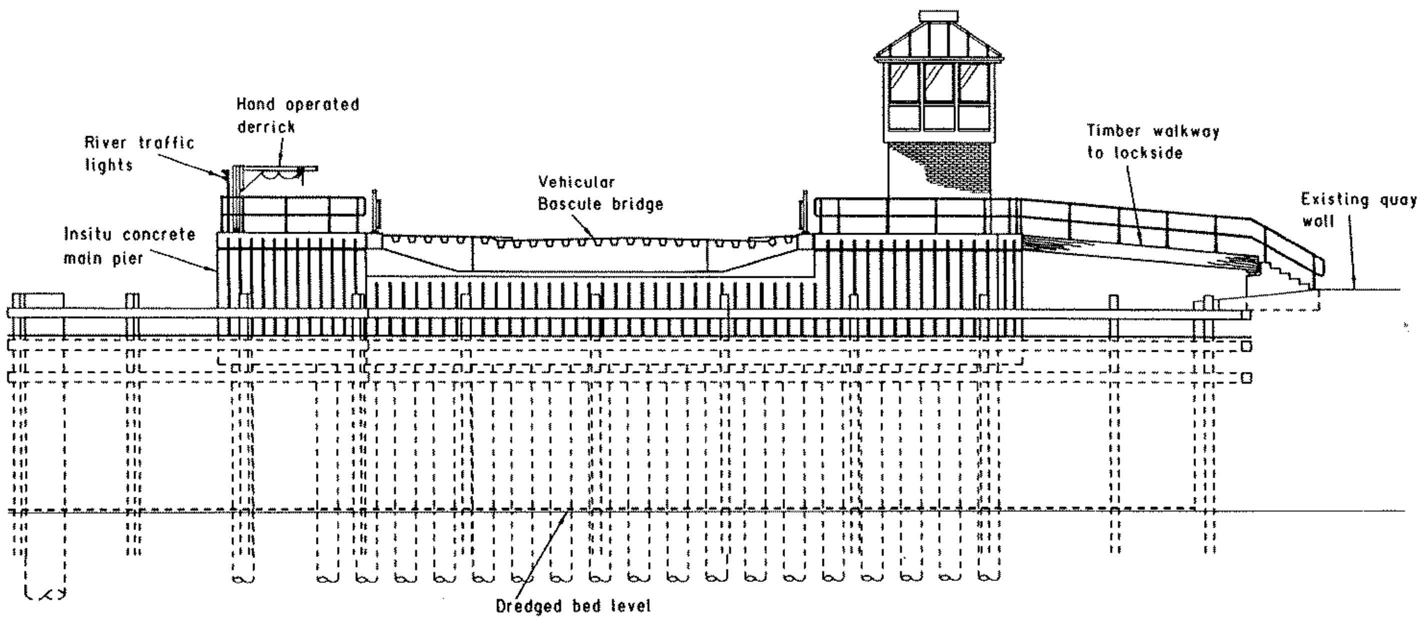
PLAN OF VEHICULAR BASCULE BRIDGE

Figure 4



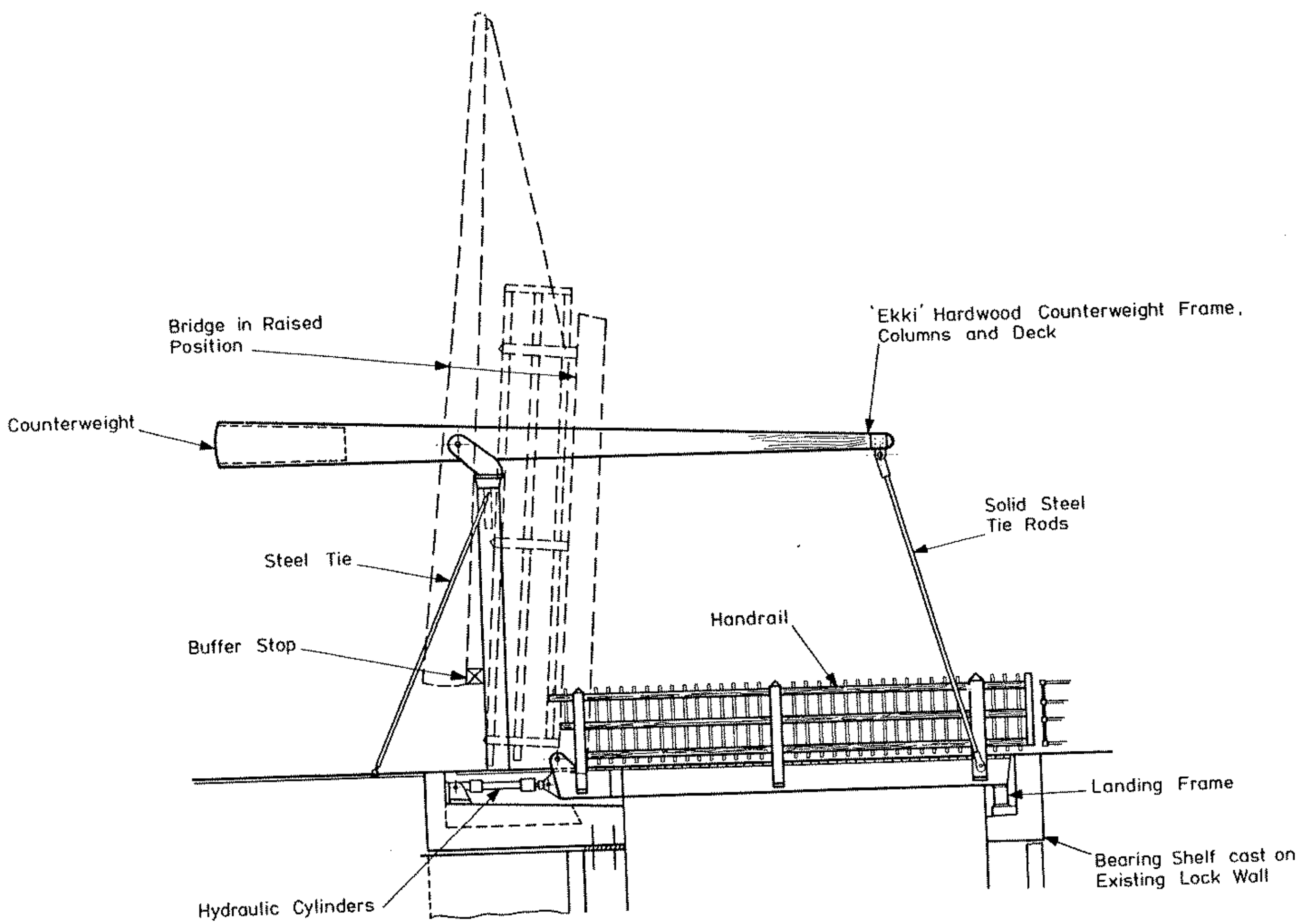
ELEVATION ON VEHICULAR BASCULE BRIDGE

Figure 5



TRANSVERSE SECTION ON VEHICULAR BASCULE BRIDGE

Figure 6



ELEVATION ON PEDESTRIAN BASCULE BRIDGE

Figure 7