APPENDIX 13

GEOTECHNICS LTD. DESK STUDY AND GROUND INVESTIGATION REPORTS

Desk Study at Brunswick Quay, Liverpool

Project No. PN030371
April 2004

1.0 INTRODUCTION

A desk study was undertaken by Geotechnics Ltd at the site of a proposed high-rise residential/retail development. The desk study was carried out to the instructions of Nickson Davis on behalf of the Client, Maro Developments Limited. This report describes the work and presents the data obtained.

2.0 OBJECT AND SCOPE OF THE INVESTIGATION

The object of the desk study was to seek information which may already exist about the site, its history, geology and ground conditions. On the instructions of Nickson Davis, some parts of the desk study are to be undertaken by other specialists and reported separately. A detailed study of the site history is to be prepared by the Curator of Port History, National Museums - Liverpool. Aspects relating to the hydrology/hydrogeology of the site; such as groundwater vulnerability, aquifer vulnerability, flooding, watercourses and drainage are to be reported by Enviros Limited.

On the instructions of Nickson Davis, a search of available service records relating to the site was undertaken by Geotechnics Ltd.

3.0 PRESENTATION

The sources of information used for the desk study, description of the site and a summary of the data obtained from the study are presented in Sections 4 to 11. The factual data so obtained are presented in Appendices 1 to 6 of this report.

The records and drawings acquired during the services search are presented in Appendix 7.

Attention is drawn to the General Notes and Investigation Procedures presented in Appendix 8 to aid an understanding of the procedures followed and the context in which the report should be read.

4.0 SOURCES OF INFORMATION

The sources of information used during the Desk Study comprised the following:-

British Geological Survey
Landmark Information Group

5.0 THE SITE

5.1 Location

The site is located on the north western bank of the River Mersey, in the Toxteth area of Liverpool. It is situated approximately 2.5 kilometres south of Liverpool Lime Street railway station. The approximate Ordnance Survey National Grid Reference for the site is SJ 347 882 and an extract from the relevant 1:50,000 Scale O.S. Map (Sheet No. 108) is included as Appendix 1.

5.2 Description

The site is located between the southern part of the Brunswick Dock and the River Mersey. It lies immediately eastward of the "80 foot lock", which forms the entrance to the Brunswick Dock from the River Mersey. The "80 foot lock" is still used by pleasure craft, moored locally in the Brunswick Dock.

When first built, the river entrance of the Brunswick Dock comprised two locks, namely the existing "80 foot lock" and on its eastern side, the wider "100 foot lock". The

"100 foot lock" has since been infilled and a tarmac-surfaced car park constructed upon it. Massive sandstone blockwork and cast iron bollards, evident on both sides of the car park, clearly show the position of the former lock walls. The present car park area forms the western half of the site.

The eastern half of the site, situated between the infilled "100 foot lock" and the Brunswick Dock is largely occupied by the "South West Brunswick Dock" building. This brick-built, pitched-roof building is a former tobacco warehouse, constructed with its eastern elevation rising just behind the concrete wall of the Brunswick Dock. This building presently houses many small business units which collectively make up the (Imex Spaces) Brunswick Small Business Centre.

The northern half of this building contains various offices with the main entrances on its western elevation, whilst the southern half contains various workshop units, with limited vehicular access into the building from archways at its southern end.

The site is accessed off the northern side of Atlantic Way, which itself is linked to Sefton Street (locally known as "The Dock Road") by Brunswick Way. From Atlantic Way a narrow access road runs northward providing access to the car park area.

A small, two-storey, flat-roofed office building (known as "E Block") is located in the south western corner of the site, between the access road and the main (South West Brunswick Dock) building. The areas between the access road/car park and the main building are largely paved with some landscaping including small trees and shrubs.

Most of the site is relatively level, at a similar elevation to the access road/car park. An exception to this is the slightly lower area surrounding "E Block". A series of steps has been provided in the footpath from this area to the main building.

The brick buildings are generally in a fair condition. However, at the northern end of the main building, the concrete dock wall is cracked. The crack has had a glass slide tell-tale cemented over it to indicate any recent outward movement. The crack is slightly rust-coloured, suggesting possible corrosion of steel reinforcement within it. The quality of the concrete is variable with the rounded gravel of the aggregate being clearly visible in places where the cement matrix is largely absent.

The water level within the Brunswick Dock is maintained at a relatively stable level whilst that within the River Mersey has a tidal variation.

To the north of the site, on the far side of the "80 foot lock", is a four-storey residential development whilst to the south, on the opposite side of Atlantic Way, a new steel-framed building is under construction.

The site covers a total area of 122,100 sq.ft. (about 11,343m²). The eastern elevation of the South West Brunswick Dock Building is about 147m in length, whilst its southern elevation is approximately 45m long. The car park area is rectangular measuring approximately 86m x 30m.

The site area is shown on the Proposed Layout Plan in Appendix 2 and also on the Borehole Location Plan in Appendix 3.

6.0 SITE HISTORY

Past uses of the site can have important geotechnical implications. Extracts of relevant historical maps have been obtained from the Landmark Information Group and copies are included in Appendix 4.

The history of the site based on these maps may be summarised as follows:-

Prior to 1850

The 1850 Ordnance Survey map shows the Brunswick Dock with two graving docks at its southern end. An entrance from the River Mersey to the Brunswick Dock is shown provided via the Brunswick Half Tide Basin.

Between 1882 and 1890

During this period, the Toxteth Dock and its

river entrance were built to the south of the Brunswick graving docks. The Toxteth Dock was linked to Brunswick Dock via the construction of Union Dock, to the east of the Brunswick graving docks.

Between 1899 and 1908

A new river entrance to the Brunswick Dock was built at its southern end, comprising the "80 foot" and "100 foot locks". The Brunswick Half Tide Basin was no longer linked to the Brunswick Dock.

Between 1913 and 1927

Brunswick Dock was extended southwards by the removal of the two graving docks and the Union Dock. The South West Brunswick Dock Building was constructed between the "100 foot lock" and the Brunswick Dock. The western dock wall of the Brunswick Dock was built up from the centre of the western graving dock. The Toxteth Dock river entrance was removed and new link to Brunswick Dock constructed.

Between 1982 and 1990

The link between Toxteth Dock and Brunswick Dock was removed. The "100 foot lock" was infilled and a car park constructed upon it. The South West Brunswick Dock Building was converted into the Brunswick Enterprise Centre.

A detailed study of the site history is to be provided by the Curator of Port History, National Museums - Liverpool.

7.0 SITE GEOLOGY

The British Geological Survey was contacted to provide available borehole and map records relating to the site.

For this particular site, it has been possible to utilise the following:-

(1) Geological Survey Map 1:50,000 (Sheet No. 96) Solid Edition, dated 1974

(2) Geological Survey Map 1:50,000 (Sheet No. 96) Drift Edition, dated 1975

(3) "British Regional Geology – The Pennines and Adjacent Area" British Geological Survey, Third Edition, (1978), HMSO

(4) Previous Borehole Records.

The 1:50,000 Scale maps show the site to be underlain by Alluvium overlying rocks of the Sherwood Sandstone Group (the Keuper Basement Beds) which are Triassic in age.

The records of two previous boreholes put down at the site have been obtained from the BGS to give an indication of the ground conditions in the local area and are presented in Appendix 5. These boreholes were carried out by Osiris-Cesco Ltd., to the instructions of Ward Ashcroff and Parkman, on behalf of the Merseyside Development Corporation. They were carried out during the period 22nd February 1984 to 10th March 1984.

The locations of these boreholes are indicated upon the plan presented with the Envirocheck Report in Appendix 6. On this plan Borehole No.1 is given the Map ID of 47 whilst Borehole No.2 is given the Map ID of 48.

These boreholes were sunk within the "100 foot lock" prior to it being completely infilled to enable the present car park to be constructed. It should be noted that on the record for Borehole No. 2 it is stated that the cable percussion boring rig was mounted on pontoons. In both cases the concrete sill of the lock was penetrated to enable the underlying sandstone to be cored.

Granular Made Ground

The presence of a 10.00m thickness of granular made ground within Borehole No. 1 indicates that by early 1984 some infilling of the southern end of the lock had occurred. This granular fill is described as medium dense silty sandy gravel comprising brick debris, sandstone and timber. However the significant amount of chiselling recorded would indicate cobble/boulder sized material was also contained within it. Hydrocarbon contamination and organic

debris was also noted within this fill material.

Alluvial Deposits

Beneath this made ground, alluvial deposits were encountered. These comprised a 1.50m thick layer of medium dense black organic silty sand with hydrocarbon contamination overlying a layer of soft to firm laminated dark grey and brown organic clay/silt. This alluvium extended to 14.20m depth where the concrete lock sill was struck at an elevation of 3.32m below chart datum.

Borehole No. 2, which was drilled overwater from pontoons in the northern part of the lock, did not reveal any granular fill but encountered a 10.00m thick sequence of varied alluvial deposits. These are described as generally loose dark grey-brown very silty sand with layers of very soft to soft organic clay and silt. These alluvial materials were also found to have been deposited upon the concrete lock sill, encountered at an elevation of 2.32m below chart datum.

Concrete Lock Sill

The concrete lock sill was 1.10m thick at the location of Borehole No. 1, whereas within Borehole No. 2, a 0.40m thick layer of concrete was recorded overlying a 1.40m thickness of timber.

Sandstone

Within 0.50m of the base of the concrete sill in Borehole No. 1 red and black silty sand layers were initially noted. These are possibly representative of completely weathered sandstone which may have been reworked prior to the construction of the lock sill. Beneath these "sand" layers and also directly below the timber within Borehole No. 2, the sandstone bedrock was struck. This strata is described as red completely weathered uncemented becoming weakly cemented silty fine grained sandstone. This sandstone was proven for 1.30m within Borehole No. 1 and for 1.00m within Borehole No. 2.

Groundwater

A medium inflow of groundwater was noted at 4.50m depth within Borehole No. 1. Borehole No. 2 was drilled overwater and neither groundwater inflows nor water levels are given on the borehole record.

The Envirocheck Report presented in Appendix 6 indicates a high risk of compressible ground at the site. This is due to significant thicknesses of made ground and soft alluvial (possibly organic) deposits underlying the site.

8.0 MINING

8.1 Coal Mining

The site is not in an area affected by coal mining nor are any coal-bearing strata known or expected to be present at the site. This is confirmed within the Envirocheck Report and by the geological data.

A Coal Mining Report is therefore not required.

8.2 Brine Pumping

The Envrocheck Report and geological scenario indicates that the site is not in an area affected by brine pumping.

9.0 ENVIRONMENTAL CONSIDERATIONS

Data obtained from the Landmark Information Group was examined to provide information on environmental aspects relating to the site. The following notes should be read in conjunction with the Envirocheck Report presented in Appendix 6.

9.1 Discharge Consents and Pollution Incidents

There are four discharge consents and a single recorded pollution incident indicated within 250m of the site. The discharge consents relate to the discharge of the following to the River Mersey Estuary:

i) sewage (final/treated effluent), operated by B A T Industries Ltd, located at the southern end of the former "100-foot lock".

ii) surface water, operated by Merseyside Development Corporation, located near the south western corner of the Brunswick Enterprise Centre and

iii) sewage (unspecified), operated by United Utilities Water Plc, located about 100m south of the Brunswick Enterprise Centre.

The single recorded pollution incident that occurred within 250m of the site comprised an accidental spillage/leakage of diesel oil to the Brunswick Dock. This spillage/leakage occurred on 2nd January 1991 and was classed as a "Category 3 - Minor Incident". The incident occurred on the eastern side of the Brunswick Dock (near the site of the present-day Royal Naval Training Ship, HMS Eaglet).

9.2 Registered Radioactive Substances

There are four instances of registered radioactive substances within 250m of the site. These relate to Chubb Fire Ltd and Integrated Radiological Services Ltd., situated at Century Buildings off Tower Street on the Brunswick Business Park to the south east of the site.

9.3 Groundwater Vulnerability

The geological classification for the rock strata beneath the site is Major Aquifer. The soil classification for the superficial deposits at the site is Soils of High Leaching Potential (U); a worst case vulnerability classification (H) is assumed until proved otherwise.

9.4 Landfill and Waste Transfer Sites

Merseyside Waste Disposal Authority record a landfill site to the west of Brunswick Enterprise Centre although its last reported status is unknown, the types of waste buried and the date of closure of this landfill are not supplied and its positional accuracy are unknown. It is possible that the landfill site being referred to in this instance is the infilled "100 foot lock" immediately west of the Brunswick Enterprise Centre.

There is a single registered waste transfer site recorded at No. 6 Shed South End (East Side), the licence dated 1st April 1977, having been held by Transwaste (N.W.) Ltd. The licence which authorised the transfer of solid industrial and construction non hazardous waste (excluding asbestos) is no longer operative. In fact the site to which it refers has been redeveloped and is presently occupied by Harry Ramsden's Restaurant.

9.5 Hazardous Substances

The Envirocheck Report indicates that there are no records of any hazardous substances within 250m of the site.

9.6 Radon

Less than 1% of homes are indicated to be above the action level for radon as set by the National Radiological Protection Board. The British Geological Survey indicate that no radon protective measures are necessary.

9.5 Industrial Land Use

There are a total of 15 various businesses listed as being on the site with a further 10 industrial premises located within 250m of the site.

9.6 Fuel Stations

The Envirocheck Report indicates that there are no fuel stations within 250m of the site.

9.7 Sensitive Land Uses

The Envirocheck Report indicates that there are no environmentally sensitive areas within 2 kilometres of the site.

It should be noted that aspects relating to the hydrology/hydrogeology of the site, such as groundwater vulnerability, aquifer vulnerability, flooding, watercourses and drainage are to be reported in detail by Enviros Limited.

10.0 PRELIMINARY ENVIRONMENTAL ASSESSMENT

10.1 General

In order to make a preliminary assessment on the potential contamination risks at the site, the data available has been considered in the context of the source - pathway - receptor model. The identified contamination sources are listed in Section 10.2, the potential receptors in 10.3 and an assessment of the potential risks in Section 10.4

10.2 Sources of Contamination

The potential contamination sources identified during this study are typically those associated with previous activities carried out at such a dockland site. Spillage/leakage of fuels and/or various cargoes being transferred from ships to the warehouses may have led to contamination of the site.

Materials used as backfill behind the dock and river walls may have contained contaminants.

More recently, the materials used to infill the "100 foot lock" may also have been contaminated to some degree.

The River Mersey has in the past been contaminated with effluents from industrial activities carried out along the river. River water may therefore have carried some contaminants into the ground beneath the site.

10.3 Receptors for Contaminants

The following receptors for any contamination have been identified:-

(1) End Users of the site. The proposed development of the site is likely to be for residential/retail use.

(2) Construction Workers.

(3) Surface Water Features, the closest being the Brunswick Dock to the east and the River Mersey to the west

(4) The aquifer underlying the site.

10.4 Preliminary Assessment

For contamination/harm to occur to a receptor it is necessary for there to be pathway linking the contamination source with the receptor along which migration of the contaminants may take place. The integrity of a pathway together with the presence of a source and receptor will have an important bearing on the assessment of the risk that damage may occur to a receptor. If no pathway exists there can be no risk. An assessment of the risk would also take account of the severity of any consequences of any contamination.

As the site is to be covered by buildings and hard cover there is to be no pathway for contamination to affect the end users of the site however appropriate health and safety measures should be taken to safeguard site workers during construction.

Measures should be considered to prevent any migration of contaminants (existing beneath the site) to the River Mersey or Brunswick Dock or to the underlying sandstone aquifer that could be brought about by construction processes.

11.0 PROPOSED GROUND INVESTIGATION

It is recommended that a detailed ground investigation is carried out to provide the necessary information for the design of the proposed development.

It is understood that the proposed development will comprise the following:

i) Block A – a 50 storey high residential tower block with a triangular footprint with sides about 45m in length,
ii) Block B – a 10 storey high residential block with a triangular footprint with sides about 35m in length and
iii) Block C – a 10 storey high residential block with a polygonal footprint, up to about 110m in length and about 30m in width.

The ground floor of the tower block is to include some retail units.

The three buildings are to rise from a podium slab constructed across much of the site to form a central courtyard and garden area. Below the podium it is proposed to construct a lower ground floor undercroft car park. The surface of this car park is to be about 1.5m below the level of the existing car park area at the site. It is understood that the proposed car park level will not extend beneath the 50 storey tower.

The proposed buildings are to be of framed construction with the anticipated maximum column loads in the region of 10MN.

The extent of the development proposals are shown on the Proposed Layout Plan supplied by Nickson Davis, presented in Appendix 2.

Currently site investigation works are limited to the external area around the South West Brunswick Dock Building. Access to the interior of this building is precluded to conventional drilling equipment, either physically (i.e. insufficient space/headroom) or prohibited due to the excessive disruption to business tenants that would be created by such investigative work.

The following exploratory work is envisaged:

(1) A total of six cable percussive boreholes with rotary cored follow-on to a nominal depth of 40.00m. Standpipes to monitor the gas and groundwater levels to be installed in each of the boreholes.

(2) Laboratory testing comprising classification, strength and compressibility determinations.

(3) Contaminant analyses comprising the following:
i) the (now withdrawn ICRCL suite) of contaminants,
ii) tests for hydrocarbon concentrations DRO and PRO/BTEX and
iii) BRE Special Digest (SD1) tests to enable the ACEC Class for the site to be determined.

At present, boreholes have been drilled at four locations around the South West Brunswick Dock Building. The locations of these boreholes are indicated on the Borehole Location Plan presented in Appendix 3.

Upon demolition of the former warehouse building it is envisaged that two further boreholes are to be sunk to investigate the eastern half of the site.

12.0 CONCLUSIONS

It is anticipated, given the expected loadings for such a high-rise development, that large diameter bored piles, socketed to a suitable depth within the sandstone bedrock, should provide a suitable foundation to the proposed structure.

Such piling could be hindered by the presence of buried obstructions, such as large blocks of cemented brickwork or concrete. Structures such as the massive concrete sill of the "100 foot lock", the existing sandstone blockwork dock wall and the sloping wall of the former western graving dock will all require special

attention from the piling contractor.

Contamination at the site is likely to have been derived from:

i) past dockland activities,
ii) possible contaminated materials used to infill behind the river and dock walls,
iii) possible contaminated materials used to infill the "100 foot lock" and
iv) from water-bourne contamination within the River Mersey.

As the site is to be covered by buildings and hard cover there is to be no pathway for contamination to affect the end users of the site however appropriate health and safety measures should be taken to safeguard site workers during construction. Measures will also be required to prevent or at least limit any contamination of surface or groundwater.

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John Knowles BSc, MSc, PGCE, FGS
Senior Engineer

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Colin Dodd BSc,MSc,CEng,MICE
Principal Engineer

Ground Investigation at Brunswick Quay, Liverpool

Project No. PN030371
April 2004

1.0 INTRODUCTION

A geotechnical and environmental investigation was undertaken by Geotechnics Ltd at the site of a proposed high-rise residential/retail development. The investigation was carried out to the instructions of Nickson Davis on behalf of the Client, Maro Developments Limited. This report describes the work and presents the data obtained together with an evaluation of their significance in relation to the proposed works.

2.0 OBJECT AND SCOPE OF THE INVESTIGATION

The object of the investigation was to obtain information on ground and groundwater conditions relating to the design of the proposed works within the limitations posed by borehole numbers, locations, depths, methods adopted and the scope of approved insitu and laboratory testing. A geotechnical and environmental interpretation and evaluation of the data obtained was also commissioned.

3.0 PRESENTATION

A description of the site and a summary of the procedures followed during the investigation process are presented in Sections 4 to 6. The factual data so obtained are presented in Appendices 1 to 7.

Attention is drawn to the General Notes and Investigation Procedures presented in Appendix 9 to aid an understanding of the procedures followed and the context in which the report should be read.

4.0 THE SITE

4.1 Location

The site is located on the north western bank of the River Mersey, in the Toxteth area of Liverpool. It is situated approximately 2 kilometres south of Liverpool Lime Street railway station.

The approximate Ordnance Survey National Grid Reference for the site is SJ 347 882 and an extract from the relevant 1:50,000 Scale O.S. Map (Sheet No. 108) is included as Appendix 1.

4.2 Description

The site is located between the southern part of the Brunswick Dock and the River Mersey. It lies immediately eastward of the "80 foot lock", which forms the entrance to the Brunswick Dock from the River Mersey. The "80 foot lock" is still used by pleasure craft, moored locally in the Brunswick Dock.

When first built, the river entrance of the Brunswick Dock comprised two locks, namely the existing "80 foot lock" and on its eastern side, the wider "100 foot lock". The "100 foot lock" has since been infilled and a tarmac-surfaced car park constructed upon it. Massive sandstone blockwork and cast iron bollards, evident on both sides of the car park, clearly show the position of the former lock walls. The present car park area forms the western half of the site.

The eastern half of the site, situated between the infilled "100 foot lock" and the Brunswick Dock is largely occupied by the "South West Brunswick Dock" building. This brick-built, pitched-roof building is a former tobacco warehouse, constructed with its eastern elevation rising just behind the concrete wall of the Brunswick Dock. This building presently houses many small business units which collectively make up the (Imex Spaces) Brunswick Small Business

Centre.

The northern half of this building contains various offices with the main entrances on its western elevation, whilst the southern half contains various workshop units, with limited vehicular access into the building from archways at its southern end.

The site is accessed off the northern side of Atlantic Way, which itself is linked to Sefton Street (locally known as "The Dock Road") by Brunswick Way. From Atlantic Way a narrow access road runs northward providing access to the car park area.
A small, two-storey, flat-roofed office building (known as "E Block") is located in the south western corner of the site, between the access road and the main (South West Brunswick Dock) building. The areas between the access road/car park and the main building are largely paved with some landscaping including small trees and shrubs.

Most of the site is relatively level, at a similar elevation to the access road/car park. An exception to this is the slightly lower area surrounding "E Block". A series of steps has been provided in the footpath from this area to the main building.

The brick buildings are generally in a fair condition. However, at the northern end of the main building, the concrete dock wall is cracked. The crack has had a glass slide tell-tale cemented over it to indicate any recent outward movement. The crack is slightly rust-coloured, suggesting possible corrosion of steel reinforcement within it. The quality of the concrete is variable with the rounded gravel of the aggregate being clearly visible in places where the cement matrix is largely absent.

The water level within the Brunswick Dock is maintained at a relatively stable level whilst that within the River Mersey has a tidal variation.

To the north of the site, on the far side of the "80 foot lock", is a four-storey residential development whilst to the south, on the opposite side of Atlantic Way, a new steel-framed building is under construction.

The site covers a total area of 122,100 sq.ft. (about 11,343m^2). The eastern elevation of the South West Brunswick Dock Building is about 147m in length, whilst its southern elevation is approximately 45m long. The car park area is rectangular measuring approximately 86m x 30m.

The site area is shown on the Borehole Location Plan in Appendix 7 and also on the Proposed Layout Plan in Appendix 8.

5.0 PROCEDURE

5.1 General

The procedures followed in this site investigation are based on *BS 5930 (1999) - Code of Practice for Site Investigations*. The descriptive scheme used for soils and rocks is also based on this standard. The Borehole Records are included in Appendix 2.

The approximate positions of the investigation points are shown on the Borehole Location Plan in Appendix 7.

Records were not related to Ordnance Datum and the depths quoted are in metres below ground level.

5.2 Boreholes

The original brief and design for the intrusive investigation was based on six (6No.) boreholes to be sunk by cable tool and rotary techniques to a nominal 40m below ground level.

For this stage of the investigation, five (5No.), 150mm diameter boreholes were sunk by Cable Percussion Tool techniques to depths varying between 15.70m and 17.05m below ground level. These boreholes were extended utilising Open Hole and Rotary Coring techniques to depths varying between 17.40m and 41.00m below ground level. The borehole positions were agreed with the Engineer. The work was carried out during the period between 22nd January and 3rd March 2004.

A further two (2No.) boreholes are planned when the existing buildings have been demolished and access cleared.

Representative disturbed and undisturbed (U100) samples of the soils encountered were obtained at regular intervals and Standard Penetration Tests (SPTs) undertaken in appropriate deposits, in order to allow inspection and obtain a measure of the engineering properties of the proved strata.

The drilling equipment on this particular contract utilised compressed air/mist and foam (as deemed most appropriate) as the flushing medium. The strata descriptions in the Open Hole sections of the Borehole Records are the Drilling Foreman's estimate based on sediment and chipping returns in the flushing medium. The rate of penetration is also used as an indicator of the type of material being drilled, particularly where there is a loss of flush returns, but does not allow definitive classification in terms of geology or degree of disturbance.

Where rock quality had improved sufficiently, Rock Coring commenced at depths varying between about 15.70m and 19.00m below ground level. Rock cores, retained in plastic liner tubes, were extruded horizontally and placed into suitable core boxes. Photographs of the individual core boxes are included in Appendix 3.

On encountering groundwater, boring operations were suspended for at least 20 minutes in order to record any rise in water level. Full details of groundwater observations during site work are included on the Borehole Records.

Long-term monitoring was made possible by the installation of gas monitoring standpipes as follows:-

BH1A: 50mm diameter slotted pipe and gravel filter installed from 17.00m to 2.00m.

BH3: 50mm diameter slotted pipe and gravel filter installed from 19.00m to 1.6.00m.

BH4: 50mm diameter slotted pipe and gravel filter installed from 26.00m to 20.00m

Full details of the monitoring of the installations are included in Appendix 6.

6.0 LABORATORY TESTING

6.1 Geotechnical

The laboratory testing schedule was formulated by Geotechnics Ltd and approved by Nickson Davis in order to relate to the proposed development. The tests, where appropriate, conform to *BS 1377 - Methods of Test for Soils for Civil Engineering Purposes (1990)* and were carried out in Geotechnics Limited's UKAS accredited Laboratory (Testing No. 1365). Any descriptions, opinions and interpretations are outside the scope of UKAS accreditation.

The tests undertaken can be summarised as follows:-

BS 1377 (1990) Test No.		**Test Description**
Part 2		
3.2	1 No.	Moisture Content Determination
4.3 & 5.3	1 No.	Liquid and Plastic Limit Determination
7.2	1 No.	Bulk Density Measurement
9.2 & 9.3	15 No.	Mechanical Analysis – Sieving
Part 5		
3	1 No.	One-Dimensional Consolidation Properties Determination. Consolidation Test
Part 7		
9	1 No.	Shear Strength Measurement - 100mm diameter (Multi-Stage) Quick Undrained Triaxial

Compression Test.

Samples of rock core were tested in-house using the Point Load Test apparatus to assess rock strength. In addition a small number of core samples were tested in an external laboratory using a Uniaxial Compressive Strength test frame to obtain direct strength parameters.

The results of these tests are presented in Appendix 4.

6.2 Chemical/Contamination

Selected samples of soil and groundwater were tested in external laboratories for a number of determinands in order to check on any potential site contamination. The determinands were specified by Geotechnics Limited in order to compare with the CLEA guidelines and the (now withdrawn) ICRCL *59/83 (Second Edition)*.

As instructed by Nickson Davis, the schedule of chemical/contamination testing was approved by Enviros Limited, specialist hydrological and hydrogeological consultants.

The following determinands were analysed:-

Table 3 Group A : Arsenic
Cadmium
Hexavalent Chromium
Total Chromium
Lead
Mercury
Selenium

Table 3 Group B : Water Soluble Boron
Copper
Nickel
Zinc

Table 4 : Polyaromatic Hydrocarbons
Phenols
Free Cyanide
Complex Cyanide
Thiocyanate
Sulphate
Sulphide
Sulphur
pH

Additional tests include:
Analysis of soil samples for individual PAH's & BRE Special Digest (SD1) tests to include:

Soluble Sulphate
pH level
Magnesium
Chloride
Nitrate
Sulphur

The results are tabulated in Appendix 5.

7.0 DESK STUDY

7.1 General

A desk study was undertaken by Geotechnics Ltd to the instructions of Nickson Davis on behalf of the Client, Maro Developments Limited. The desk study is presented in a separate report but the site geological scenario, prepared from published data, is reproduced here for clarity.

7.2 Geology

The British Geological Survey was contacted to provide available borehole and map records relating to the site.

For this particular site, it has been possible to utilise the following:-

(1) Geological Survey Map 1:50,000 (Sheet No. 96) Solid Edition, dated 1974

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These boreholes were sunk within the "100 foot lock" prior to it being completely infilled to enable the present car park to be constructed. It should be noted that on the record for Borehole No. 2 it is stated that the cable percussion boring rig was mounted on pontoons. In both cases the concrete sill of the lock was penetrated to enable the underlying sandstone to be cored.

Granular Made Ground

The presence of a 10.00m thickness of granular made ground within Borehole No. 1 indicates that by early 1984 some infilling of the southern end of the lock had occurred. This granular fill is described as medium dense silty sandy gravel comprising brick debris, sandstone and timber. However the significant amount of chiselling recorded would indicate cobble/boulder sized material was also contained within it. Hydrocarbon contamination and organic debris was also noted within this fill material.

Alluvial Deposits

Beneath this made ground, alluvial deposits were encountered. These comprised a 1.50m thick layer of medium dense black organic silty sand with hydrocarbon contamination overlying a layer of soft to firm laminated dark grey and brown organic clay/silt. This alluvium extended to 14.20m depth where the concrete lock sill was struck at an elevation of 3.32m below chart datum.

Borehole No. 2, which was drilled overwater from pontoons in the northern part of the lock, did not reveal any granular fill but encountered a 10.00m thick sequence of varied alluvial deposits. These are described as generally loose dark grey-brown very silty sand with layers of very soft to soft organic clay and silt. These alluvial materials were also found to have been deposited upon the concrete lock sill, encountered at an elevation of 2.32m below chart datum.

Concrete Lock Sill

The concrete lock sill was 1.10m thick at the location of Borehole No. 1, whereas within Borehole No. 2, a 0.40m thick layer of concrete was recorded overlying a 1.40m thickness of timber.

Sandstone

Within 0.50m of the base of the concrete sill in Borehole No. 1 red and black silty sand layers were initially noted. These are possibly representative of completely weathered sandstone which may have been reworked prior to the construction of the lock sill. Beneath these "sand" layers and also directly below the timber within Borehole No. 2, the sandstone bedrock was struck. This strata is described as red completely weathered uncemented becoming weakly cemented silty fine grained sandstone. This sandstone was proven for 1.30m within Borehole No. 1 and for 1.00m within Borehole No. 2.

Groundwater

A medium inflow of groundwater was noted at 4.50m depth within Borehole No. 1. Borehole No. 2 was drilled overwater and neither groundwater inflows nor water levels are given on the borehole record.

The Envirocheck Report presented in the desk study indicates a high risk of compressible ground at the site. This is due to significant thicknesses of made ground and soft alluvial (possibly organic) deposits underlying the site.

8.0 INTERPRETATION

8.1 Ground Conditions Proved

Infilled "100 Foot Lock" (BH's 1, 1A and 2

refer)

Proven ground conditions have shown that for the area of the infilled "100 foot lock", beneath the tarmac and limestone gravel sub-base of the existing car park which extend to about 0.60m depth, coarse granular made ground was encountered. This fill largely consists of demolition rubble and extends to about 11.50m depth, where it is found to be resting upon alluvial deposits. Within BH2 this alluvium initially comprises loose to medium dense black organic very silty sand however below 14.50m its composition is similar to that noted in BH1 and BH1A; as it becomes a firm black organic clay with bands of silt and sand.
The concrete sill of the "100 foot lock" was struck at 17.00m depth and proven to be 1.10m thick at the location of BH1A; having been laid directly onto the underlying sandstone bedrock. Sandstone was encountered throughout the remaining depth of BH1A which was terminated at 41.00m below ground level.

Between the River Wall and former Warehouse Building (BH's 3 and 4 refer)

At BH3 beneath a concrete footpath, a varied sequence of granular made ground, containing a further two concrete layers, was noted to 4.80m depth. (The greatest thickness of concrete was encountered between 2.50m and 3.70m depth).

Cohesive made ground comprising firm red-brown slightly gravely sandy clay including sandstone and brick fragments was revealed to 12.50m depth where red-brown mottled black silty sand was encountered. This sand layer, thought probably to be the base of the made ground, extends to 13.20m below ground level.

A 0.30m thickness of apparently natural glacial till was noted beneath the made ground, immediately prior to sandstone bedrock being struck.

Within BH4, underlying a 0.60m thickness of pavement construction materials and concrete, granular fill was generally encountered to 8.00m depth. This fill consists largely of loose to medium dense red-brown sand and gravel of sandstone and overlies a varied alluvial sequence of organic silt, sand and gravel deposits which extends to rockhead at 15.70m depth.

At BH3 and BH4, the sandstone was penetrated to depths of 39.00m and 40.70m, respectively.

8.2 Soil Parameters

Based on the results of visual inspection, in situ and laboratory testing, the following soil parameters should be used for design purposes.

Made Ground: Generally loose/soft, inconsistent and heterogeneous, potentially compressible, potential for further degradation and possibly chemically aggressive in nature.

Organic Alluvial Deposits: Soft/firm, intermediate to high plasticity, moderately to highly compressible, grading to sand and gravel in places.

Glacial Till (where present): Stiff, low plasticity, slightly compressible.

8.3 Rock Parameters

Based on the results of visual inspection, in situ and laboratory testing, the following rock parameters are deemed appropriate for the sandstone bedrock and can be used to classify the rock mass for engineering purposes following the method proposed by Bienawski (1976):

Strength of intact rock material (U.C.S.): 1MPa
Drill core quality RQD: <25%
Spacing of joints: <50mm
Condition of joints: Slightly rough surfaces, Separation <1mm, Soft joint wall rock
General groundwater conditions: Water under moderate pressure
Joint orientation: Very favourable for foundations (i.e. mainly horizontal)

Using the above data on the rock mass, the sandstone falls into Rock Mass Class IV, described as Poor Rock, with a typical lower

bound friction angle for the rock mass of 30°.

8.4 Groundwater

Inflows of groundwater were encountered across the site as described below:

BH1 3.60m Slow inflow, rising to 3.55m In 20 minutes

BH1A 3.90m Slow inflow, rising to 3.75m In 20 minutes

BH2 3.50m Medium inflow, rising to 3.40m in 20 minutes

BH3 7.00m Very slow inflow, no rise in 20 minutes

BH4 8.00m Slow inflow, rising to 6.90m in in 20 minutes

It should be noted that the addition of water to the boreholes when rotary coring/open-holing using a mist or foam flush may have masked minor inflows.

Readings taken on 21st March 2004 show the water level within the standpipes to be 3.63m (BH1A), 10.96 (BH3) and 12.23m depth (BH4).

The significant difference in the water levels observed BH's 1, 1A and 2, sunk in the infilled "100 Foot Lock", and BH's 3 and 4 which were sunk between the walls of the former lock and Brunswick Dock, can perhaps be explained by the presumed impermeability of these walls.

It is suggested that there is hydraulic conductivity between the Brunswick Dock and the infilled lock. Therefore water levels within BH's 1, 1A and 2 are closely related to the water level within the Brunswick Dock.

In order to function properly, the lock and dock walls and sills would need to be impervious, thereby enabling water to be impounded within the dock or lock as required. This may explain the lower water levels noted within BH's 3 and 4 which may be related to the adjacent river water level and exhibit a tidal variation.

9.0 EVALUATION

9.1 Proposals

It is understood that the proposed development will comprise the following:

i) Block A – a 50 storey high residential tower block with a triangular footprint with sides about 45m in length,

ii) Block B – a 10 storey high residential block with a triangular footprint with sides about 35m in length and

iii) Block C – a 10 storey high residential block with a polygonal footprint, up to about 110m in length and about 30m in width.

The ground floor of the tower block is to include some retail units.

The three buildings are to rise from a podium slab constructed across much of the site to form a central courtyard and garden area. Below the podium it is proposed to construct a lower ground floor undercroft car park. The surface of this car park is to be about 1.5m below the level of the existing car park area at the site. It is understood that the proposed car park level will not extend beneath the 50 storey tower.

The proposed buildings are to be of framed construction with the anticipated maximum column loads in the region of 10MN.
The extent of the development proposals are shown on the Proposed Layout Plan supplied by Nickson Davis, presented in Appendix 8.

9.2 Foundation Design

It is anticipated that prior to construction, the existing buildings will be demolished and their foundations and floor slabs removed.

Given the expected loadings for such a high-rise development, shallow footings and/or ground treatment/improvement

options are not considered feasible. Large diameter bored piles, socketed to a suitable depth within the sandstone bedrock, should provide a suitable foundation to the proposed structure.

Such piling could be hindered by the presence of buried obstructions, such as large blocks of cemented brickwork or concrete. Structures such as the massive concrete sill of the "100 foot lock", the existing sandstone blockwork dock wall and the sloping wall of the former western graving dock will all require special attention from the piling contractor. In such circumstances, conventional excavation and breaking out may not be practical or economic due to the depths involved, and consideration should be given to the use of large diameter down-the-hole hammer or diamond rotary drilling techniques to allow the piles to extend beyond these obstructions.

The design of piles will depend on such factors as the required working load and foundation layout. Connecting ground beams could be installed between pile caps upon which walls could be constructed.

The carrying capacity of piles is fundamentally related to their method of emplacement and individual piling contactors have their own formulae specific to their individual techniques. It is recommended that early discussions are held with experienced specialist contractors for advice on the applicability of their own particular proprietary techniques to these specific site conditions.

Such specialists should also be consulted to advise on a method of working during pile installation that would preclude (or reduce to acceptable levels) the downward migration of any contaminants into the underlying sandstone aquifer.

Nevertheless it is possible to use general formulae to give a first approximation.

The results of the Point Load Index tests carried out on suitable samples throughout the recovered rock cores are presented in Appendix 4. For those tests performed axially, a mean value for the Point Load Index (Is_{50}) of 0.1MPa is derived

Using the approximate relationship:

Unconfined Compressive Strength (UCS) =10 x Is_{50}.

Considered appropriate for such very weak/weak rock, a typical value for the UCS of the intact rock of 1MPa is obtained.

Ignoring any skin friction due to the overlying made ground and alluvial materials and using the rock parameters listed in Section 8.3 above, a 1.5m nominal diameter pile would need to be socketed about 9.5m into the sandstone bedrock in order for it to carry an allowable working load in the region of 10MN.

Greater working loads should be achieved by taking the piles deeper as this would lead to an additional contribution to skin friction over the length of the pile embedded within the sandstone. It would also normally be expected for the bedrock to become stronger and more intact with depth, leading to an increased end-bearing resistance. However, based upon the rock core recovered a significant improvement in rock strength and quality with depth is not apparent.

For a 1.5m diameter pile socketed about 9.5m into the bedrock the unfactored skin friction provided by the sandstone is estimated to be about 15MN.

Given the considerable height of the structures, they are likely to be subjected to significant wind loadings, which will create uplift forces on piles beneath the windward side of the buildings. These uplift forces will be resisted by the skin friction on the piles.

An additional contribution to this resistance to uplift could be provided by the use of rock anchors extending from the base of the piles or by under-reaming the piles. Increasing the base-area of the piles should lead to a greater end bearing resistance and enable a shorter length of embedment to be specified.

Specialist piling contractors should be

consulted to confirm the suitability and load carrying characteristic of the various pile types available. Allowance should be made for pile loading and integrity testing.

The retaining walls surrounding the proposed undercroft car park will either be piled or supported on piles. The design of these retaining walls will be largely dependent upon the effective stress parameters of the engineered fill, which it is to retain. Further testing will be required or assumptions made based on the materials chosen for the engineered fill.

Consideration should be given to any possible adverse effects that piling may have on any neighbouring structures with particular regard to vibrations.

9.3 Ground Floor Slabs / Pavement Design

It is understood that the podium slab and floor slabs to the three buildings are to be suspended from the piled foundations in order to eliminate any differential settlement problems that would be envisaged with floor slabs bearing onto the variable made ground.

It is however intended for the pavement/floor slabs of the undercroft car park (outside the footprints of the three buildings) to be ground-bearing and not carried by the piles. Such a proposal is considered acceptable given that the pavement/floor slabs are only to be lightly-loaded (i.e. for car parking only) and the proposed formation level is to be in excess of 1.5m below the existing ground level (thereby leading to an actual reduction in the applied vertical stress).

The made ground is considered to be variable, with its range of particle sizes so large so as to make California Bearing Ratio testing neither practical, nor sensible. It would therefore be considered prudent to adopt a CBR of 2% for this material, as a preliminary design value. Capping and sub-base layer thicknesses should be designed to suit. At formation level, proof rolling should be carried out, and any soft spots, large obstructions or other deleterious material removed and replaced with suitably compacted selected granular fill.

Following excavation of the made ground to achieve the required formation level the provision of a suitable piling platform will be required. Such a platform could possibly be designed so as to be further utilised as a suitable formation for the pavement/ground bearing slabs. It is recommended that testing of the proposed formation (such as plate load testing) is carried out prior to pavement/floor slab construction.

Flexible joints between ground-bearing floor slabs and walls/columns supported on piles should be provided to cater for any differential settlement. To prevent steps occurring a hinged ramp could be used at the main entrance to undercroft car park.

To cater for the effects of differential settlements which may occur within the made ground consideration should be given to providing generous falls (with regard to drainage in order to prevent backing up of drains) and the use of flexible joints to pipes and ducts particularly at their exits from the proposed building and entries into manholes/inspection chambers.

9.4 Excavation, Support and Groundwater Control

Excavations within the made ground revealed by this investigation should be within the capacity of conventional hydraulic plant. However pneumatic tools will be required to break out any obstructions such as buried blocks of cemented brickwork or concrete contained within the made ground.

Support to the sides of excavations should be in accordance with the recommendations of CIRIA Report 97, 1983. Close-boarded support will be required for excavations in excess of 1.20m depth within granular materials or soft cohesive deposits. Shallower excavations will need support or battering back to a safe slope angle (gradient no steeper than 1 vertical to 2 horizontal), if they are to remain open for extended periods or if personnel are expected to enter.

Groundwater inflows into shallow excavations less than 3.60m deep are not thought likely to be significant. Deeper excavations may encounter more significant inflows due to recharge from the adjacent river and dock. Hence in such circumstances sheet-piled coffer dams would be necessary.

All formations should be protected from mechanical disturbance and assumed to be frost-susceptible.

9.5 Chemical Attack on Buried Concrete

Laboratory tests on samples taken across the site have shown the Characteristic Value for water soluble sulphate to be within Design Sulphate Class DS-2 of BRE Special Digest 1, "Concrete in Aggressive Ground", 2001. The Characteristic pH Value is 7.62, the site is considered to be "brownfield", groundwater is mobile and the soils are not expected to be pyritic. The ACEC Class for the site is therefore AC-2. Only concrete meeting the requirements of this classification should be used for sub-surface work across the site.

Consideration should be given to any possible adverse effects that brackish groundwater may have upon construction materials. This may lead to increased chloride concentrations and potential attack on buried steel.

9.6 Chemical Contamination

Assessment of Contamination

Selected samples of soil from beneath the footprint of the proposed buildings were tested for the ICRCL (now withdrawn) suite of contaminants. The ICRCL guidelines have now been replaced by CLEA, the latter including soil guideline values (SGVs). SGVs are currently only available for the following contaminants:

Arsenic
Cadmium
Chromium
Mercury
Nickel
Selenium
Lead

Where SGVs are not yet published it is necessary to compare contaminant levels with other guidelines such as the former ICRCL guidelines, Dutch tables, EA tables or Kelly tables.

Classification of Contaminant Levels

In the samples tested, the relevant SGVs were generally not exceeded for "Residential without plant uptake" use. Comparison of the remaining results with the (now withdrawn) ICRCL guidelines show the recorded concentrations of these determinands to be below the threshold trigger levels for buildings, hard cover and landscaped areas with the exception of total sulphur, total sulphate and sulphide. However only the concentration of sulphide recorded from BH1 at 12.00m to 12.50m depth was over the action level.

As the site is to be largely covered by buildings and hard cover and where landscaping is proposed an appropriate thickness of clean topsoil is to be provided, there is to be no pathway for this contamination to affect the end users of the site. However appropriate health and safety measures should be taken to safeguard site workers during construction.

The samples tested recorded levels of total petroleum hydrocarbons (TPH) well below the Dutch Intervention Value of 5000mg/kg. Therefore it is suggested that no remedial action needs to be taken with respect to these results.

Effects on New Planting

Elevated levels of copper, within BH4 between 1.20m and 1.70m depth indicates a possibility of phytotoxic attack on certain plant species where landscaped areas are directly above the made ground. Hence a sufficient thickness of clean topsoil should be placed in order to accommodate the root systems of the species being planted. It is notable that for some of the samples recovered from below 10.00m depth, the levels of phytotoxic contaminants, copper,

zinc and boron were also elevated above the relevant threshold concentration.

Groundwater

For the groundwater sample tested from BH1, the levels of selenium, phenols, ammoniacal nitrogen, chloride and sulphate exceeded the maximum concentrations of the Water Supply (Water Quality) Regulations 1989, the standard for drinking water quality.

Detailed analysis and interpretation of the hydrological and hydrogeological situation, particularly the effects of piling into the sandstone aquifer, is being carried out by Enviros Limited under the terms of their brief.

Waste Disposal

The comments made above relate to the materials remaining in place and their effects on possible end users of the site. Different criteria apply where material are to be taken for disposal off site. The criteria applied depends on the licence conditions of the individual landfill sites and also on the discretion of the individual site operators. In general, new landfill sites apply the Environment Agency Interim Guidance thresholds whereas older sites use the Kelly classification.

Applying the Environment Agency Interim Guidance thresholds, results for sulphide, sulphate and pH have been measured above the Upper Threshold Concentrations for some of the samples tested. As such, these guidelines would require disposal of excavated material at an Engineered Landfill site.

Applying the Kelly guidelines, results for copper, boron, pH and sulphide have been measured in Class C (contaminated) and D (heavily contaminated). Two sulphide results recorded concentrations within Class E (very heavily contaminated). The remaining results lie within the less contaminated classes.

It would clearly be advantageous to establish an early dialogue with local landfill operators to establish what criteria they would apply in accepting excavated spoil from the site.

Disposal costs could be mitigated by applying a more systematic approach to material testing during construction. Only those localised "hot spots" of potentially contaminated spoil need go to an Engineered Landfill site, whereas uncontaminated material would not require this specialist disposal.

It is understood that chemical contamination at the site is to be examined in more detail by Enviros Limited.

9.7 Gas Monitoring and Protection Measures

Whilst monitoring for noxious/explosive gases in standpipes installed in BH1A and BH4 a maximum methane concentration of 0.1% by volume was recorded within BH1A on 25th February 2004. Otherwise no methane and no carbon dioxide were detected within these instruments during the monitoring.

A flow of gas was noted when boring below 12.50m depth within BH3 and below a similar depth within BH4. The response zone for the standpipe installed within BH3 coincided with zone over which gas emissions were noted. Hence subsequent monitoring of this instrument revealed methane concentrations as high as 88.6% by volume with a flow rate beyond the range of the monitoring equipment (>99.9litres/hour). Carbon dioxide was not detected when taking these readings and the level of oxygen was seriously depleted. A maximum oxygen concentration of only 5.3% by volume was recorded on 1st April 2004.

A 3 metre high gas stack was installed over BH3 to safely vent the gases to the atmosphere.

The presence of organic-rich alluvial material has been noted within the borehole logs from this and previous investigations. It would appear from this investigation that more or less isolated pockets of gas are likely to be encountered during construction works, particularly any piling required.

In considering that the gas is being generated from isolated zones of organic-

rich material within the alluvial soils there is an inference that the volume of gas could be finite within the timeframe of project construction. It would appear that gas is being generated not from the backfilled lock, but from the zone between the walls of the former lock and Brunswick Dock, presumably where these walls are confining the gas built up.

In the short term, monitoring of the vent stack in BH3 is continuing, although there is no sign of the methane concentration or flow rate decreasing significantly as yet. During construction, other pockets of gas may well be encountered, so that site monitoring and alarm systems will be required. Wells would probably be useful in promoting the venting of this gas to air, and the earlier that these can be installed then the sooner gas can be expelled.

In the medium to long term, concern then focuses on the potential for further gas migration which could affect the proposed structures.

Car parks and other hardstanding areas are predominantly sealed, and in addition any permeating gases would vent to the atmosphere. The underground car parking areas are presumably tanked against water ingress, and have through ventilation to clear exhaust fumes, again effectively venting gas to the atmosphere. Any service ducts/chambers or other confined spaces at or below ground level are expected to be ventilated and gas tested prior to entry, as standard practice anyway. Water/gas proof membranes and minimised service penetration through ground floor slabs will be required, again providing protection for these areas.

During construction, the gassing situation should be monitored and this assessment kept under review. Further measures may be required if the gas continues to be generated.

.....
Colin Dodd BSc MSc CEng MICE
Principal Engineer

.....
John Knowles BSc, MSc, PGCE, FGS
Senior Engineer

APPENDIX 14

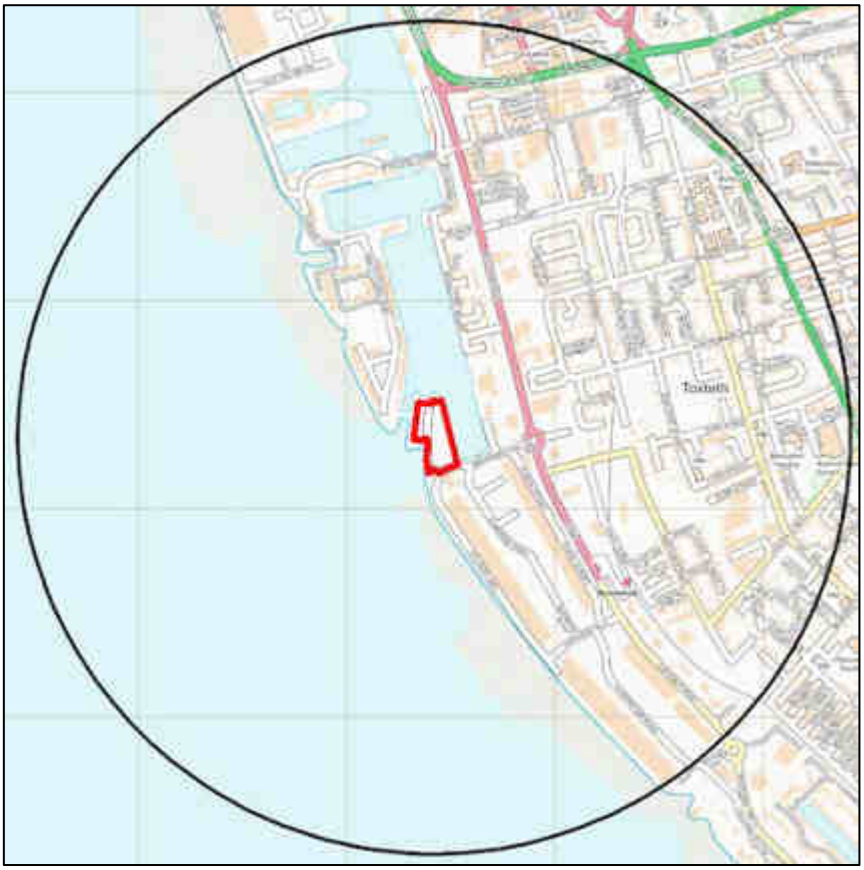
DETAILED UNEXPLODED ORDNANCE (UXO) THREAT & RISK ASSESSMENT REPORT

Landmark Information Group Ltd
Imperium, Imperial Way
Reading, Berkshire
RG2 0TD
United Kingdom

T: +44 (0)844 844 9952
W: www.envirocheck.co.uk

Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

Meeting the requirements of *CIRIA* C681 'Unexploded Ordnance (UXO) A guide for the Construction Industry' Risk Management Framework



6 ALPHA PROJECT NUMBER	P6474	**ORIGINATOR**	S. Barratt
LANDMARK ORDER NUMBER	157908433_1	**REVIEWED BY**	B. Wilkinson (6th March 2018)
CLIENT REFERENCE	2939	**RELEASED BY**	L. Askham (7th March 2018)
SITE	Brunswick Quay, Liverpool, Merseyside		
RATING	**HIGH** - This Site requires further action to reduce risk to ALARP during intrusive activities.		

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Acronyms and Abbreviations

AA	Anti-Aircraft
AAA	Anti-Aircraft Ammunition
ALARP	As Low As Reasonably Practicable
AOD	Above Ordnance Datum
ARP	Air Raid Precaution
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
bgl	Below Ground Level
BGS	British Geological Survey
BH	Borehole
BPD	Bomb Penetration Depth
CDP	Cast Driven Piles
CFA	Continuous Flight Auger
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetration Testing
CS	County Series
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
GI	Ground Investigation
GIS	Geographic Information Systems
GL	Ground Level
GP	General Purpose
GPS	Global Positioning Systems
HAA	Heavy Anti-Aircraft
HE	High Explosive
HO	Home Office
HSE	Health and Safety Executive
IB	Incendiary Bomb
kg	Kilograms
km	Kilometres
LAA	Light Anti-Aircraft
LCC	London County Council
LE	Low Explosive
LSA	Land Service Ammunition
m	Metres
MoD	Ministry of Defence
mm	Millimetres
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OD	Ordnance Datum
OS	Ordnance Survey
PM	Parachute Mine
PoW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RN	Royal Navy
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
TA	Territorial Army
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V Weapons	*Vergeltungswaffe* – Vengeance Weapons
WD	War Department
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Study Site

The Client has defined the Study Site as "Brunswick Quay, Liverpool, Merseyside". The Site is located at NGR 334710, 388170.

Risk Level

HIGH

Potential Threat Sources

The most probable UXO threat is posed by WWII *German* HE bombs, whilst IBs and *British* AAA projectiles (which were used to defend against *German* bombing raids) pose a residual threat.

Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.

Key Findings

During WWII, the Study Site was situated within *Liverpool County Borough,* which recorded 21 HE bomb strikes per 100 hectares, a low level of bombing. However, given that the Site was situated within a primary bombing target during WWII, the localised bombing density may in fact have been much greater.

Luftwaffe aerial reconnaissance photography associated with the Site identified a dock (located on-site, 310m to the north and 450m to the north) and a gas works (located 360m to the south-west) as primary bombing targets. In addition, a dock (located 175m to the north-west), a warehouse (located 205m to the north-east) and a mill and timber yard (located 320m to the east) may have been considered secondary bombing targets. Furthermore, research also identified a barrage balloon site (located 670m to the south-east) and a pillbox (located 990m to the south-east), which were likely to have been targeted in an attempt to reduce *Luftwaffe* aircraft losses.

ARP records associated with the Site did not note any HE bomb strikes within it. Nonetheless, seven were identified 130m to the north, 140m to the north-east, 155m to the south, 165m to the south, 250m to the north, 300m to the north-east and 325m to the north. In addition, IB's were recorded 165m to the east, 195m to the north-east and 245m to the north.

Official bomb damage mapping was not available. However, written records identified "extensive damage" to *Brunswick Docks* and "considerable damage" from the parachute mine that fell in the river opposite the docks. In addition, photographic evidence showed considerable bomb damage to *Brunswick Docks*.

Pre-WWII mapping (1938) associated with the Site shows that it was located within a densely developed docklands area during WWII, with the Site itself being part of *Brunswick Docks* with a large structure in the eastern sector. As a result, it is plausible that the docklands authorities inspected the Site for UXB entry holes following any raids. However, given that evidence suggests the Site sustained extensive bomb damage, bomb damage debris may have concealed a UXO entry hole and therefore, may have gone unnoticed. In addition, it is likely that any UXO that fell within the dock would have gone unnoticed.

The Site has undergone some post-war redevelopment with the removal of a small structure and the rebuilding of another small structure in the southern sector in the 1970s. In addition, in the 1990's the dock was infilled, and the large structure on-site was demolished in 2006. Consequently, it is considered likely that any UXO within the foundations of post-war buildings would have been discovered and removed, however, the potential for deep buried UXO to be present within remaining areas is assessed to be extant. Given that the Site was identified as a primary bombing target which sustained extensive bomb damage, the following risk mitigation measures are recommended as a minimum, in order to reduce risks ALARP, during intrusive works in all previously undisturbed ground i.e. that which has not previously been excavated, probed, drilled or otherwise intrusively disturbed since it had potentially become contaminated with UXO. These mitigations measures are not required within any post-war fill used for the dock, however if intrusive works extend below the infill, the appropriate mitigations should be applied.

EXECUTIVE SUMMARY (…continued)

Recommended Risk Mitigation

All Groundworks in All Areas:

1. Operational UXO Emergency Response Plan; appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or confirmed UXO discovery (this plan can be supplied by *6 Alpha*);

2. UXO Safety & Awareness Briefings; the briefings are essential when there is a possibility of an UXO / UXB encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of an UXO / UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXO / UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The Safety & Awareness briefing is an essential part of the *Health & Safety Plan* for the Site and helps to evidence conformity with the principles laid down in the *CDM* regulations 2015 (this briefing can be delivered directly, or in some cases remotely, by *6 Alpha*).

Trial Pits, Window Sampling, Trenching and Excavations into Previously Undisturbed Ground:

3. Non-intrusive UXO Survey and/or EOD Banksman Support; Where 'open' intrusive works into previously undisturbed ground are proposed and where the extent is considered to be within the capabilities of non-intrusive UXO survey equipment and implementation of this is assessed as likely to prove effective, a non-intrusive geophysical UXO survey should be trialed and, if it proves successful, should be employed to survey site-wide, or in specific areas where 'open' intrusive works are to be implemented to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. If the survey proves partially or wholly ineffective, an EOD Engineer should be present in the UXO Banksman role to monitor ongoing 'open' intrusive works to identify any suspicious items that may be UXB or UXO related (this service can be provided by *6 Alpha*).

Piling and Boreholing into Previously Undisturbed Ground:

4. Intrusive UXO Survey; Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the *assessed average bomb penetration depth* or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by *6 Alpha*).

N.B. the average BPD is assessed to be 7m below ground level during WWII, and therefore intrusive works carried out within post-war infill of the dock does not pose a risk (recommendations 1 & 2 required only). If however, the intrusive works extend below the post-war infill and into the original ground/sea bed that was present during the war, then the appropriate UXO mitigations will need to be applied in this ground (recommendations 1, 2 3 and/or 4).

For further information, please contact Envirocheck:

Website: http://www.envirocheck.co.uk

Telephone: +44 (0)844 844 9952

Email: customerservice@envirocheck.co.uk

ASSESSMENT METHODOLOGY

Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this Site, by employing a process advocated for this purpose by *CIRIA*. The *CIRIA* guide for managing UXO risks in the construction industry (C681) not only represents best practice but has also been endorsed by the *HSE*. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to ALARP at best value.

UXO hazards can be identified through the investigation of local and national archives associated with the Site, *MoD* archives, local historical sources, historical mapping as well as contemporaneous aerial photography (if it is available). Hazards will have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. The amalgamation of information is then assessed to enable the researcher to provide relevant and accurate risk mitigation practices.

The assessment of UXO risk is a measure of *probability of encounter* and *consequence of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other 'sensitive receptors', such as equipment) to the hazard, at the moment of encounter.

If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce them to ALARP. We advocate the adoption of the legal ALARP principle because it is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the Client's tolerability of UXO risk. In essence, the principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. This does not mean that there is never a requirement for UXO risk mitigation, but that any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits and that consume disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXB and UXO risks will rarely be reduced to zero (nor need they be).

Important Notes

Key source material is referenced within this document, whilst secondary/anecdotal information may be available upon request.

Although this report is up to date and accurate at the time of writing, our databases are continually being populated as and when additional information becomes available. Nonetheless, *6 Alpha* have exercised all reasonable care, skill and due diligence in providing this service and producing this report.

The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and third party data sources. Wherever possible, *6 Alpha* has sought to corroborate and to verify the accuracy of all data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. *National Archive* or other library sources), and over which *6 Alpha* cannot exercise control.

STAGE ONE – SITE LOCATION AND DESCRIPTION

Study Site

The Client has defined the Study Site as "Brunswick Quay, Liverpool, Merseyside". The Site is located at NGR 334710, 388180. The Site location and Site boundary are presented at *Figures 1* and *2* respectively.

Location Description

The Study Site is situated within *Liverpool County Borough* and covers an area of 1.1 hectares (ha).

Furthermore, the Site is bounded by:

- North: *Liverpool Marina;*
- East: *Brunswick Way* and *Liverpool Marina;*
- South: *Atlantic Way* and industrial facilities*;*
- West: *River Mersey*.

Aerial Photography (Current) (*Figure 3*)

Current aerial photography corroborates the information above and shows that the Site is situated within a densely developed dockland and urban area.

Proposed Works

The Client has described the following:

- Ground Investigations:
  - Shallow Trial Pit up to 1m below ground level,
  - Medium Trial Pit between 1m and 5m below ground level,
  - Deep Trial Pit greater than 5m below ground level,
  - Window Sampling up to 1m below ground level,
  - Shallow Trenching up to 2m below ground level,
  - Shallow Bulk Excavation up to 2m below ground level,
  - Deep Bulk Excavation greater than 2m below ground level.
- Borehole Depth: Rotary holes to 30m/40m;
- CPT testing / Cable percussion holes to 10m/15m;
- Piled foundations to 30/40m bgl.

Ground Conditions

It is important to establish the specific ground conditions in order to determine the maximum *German* UXB penetration depth as well as the potential for other types of munitions to be buried.

If the Site investigations and/or construction methodologies change, and/or if a specific methodology is to be employed, and/or if the scope of work is focused upon a specific part of the Site, then *6 Alpha* are to be informed so that the prospective UXO risks and the associated risk mitigation methodology might be re-assessed. Certain ground conditions may also constrain certain types of UXO risk mitigative works e.g. magnetometer survey is adversely affected in mineralised and made ground.

The Client has described the ground conditions as follows: *"Docklands area. Ground conditions are highly variable. In places - infilled dock - made ground to approx. 11.5m underlain by alluvium to 17m bgl underlain by concrete to 18m bgl underlain by sandstone bedrock. In places - approx. 8m of made ground underlain by alluvium or glacial till to approx. 15m underlain by sandstone bedrock. In places - concrete dock walls with granite to approx 8m bgl."*

It is important to establish the provenance of made ground, where this is recorded as being part of the site ground make-up, in order to accurately determine the ground levels at the time when the site may have become potentially contaminated with UXO and so as to accurately determine the average / maximum bomb penetration depths and make appropriate recommendations aimed at reducing the risk to ALARP.

STAGE ONE – SITE LOCATION AND DESCRIPTION (…continued)

Ground Conditions

BGS borehole log 'SJ38NW966 – South Docks Phase III Liverpool 30A' (located on-site), recorded the following strata:

Depth bgl (m)	Strata	Description
0m to 0.15m	Made Ground	Fill
0.15m to 4.0m	Made Ground	Ash, stone, brick, slate etc.
4.0m to 6.50m	Made Ground	Sand, sandstone pieces etc.
6.50m to 8.80m	Clay	Very soft/soft black silty clay with layers of sand and silt and organic zones
8.80m to 10.80m	Sand	Medium dense grey organic silty sand and sandy silt
10.80m to 13.30m	Clay	Stiff to very stiff grey and brown sandy clay with stone inclusions and grey fissures. Softened upper zone.
13.30m to 15.05m	Sandstone	Soft to firm dark grey and red sandstone. (Oxidises to red)

STAGE TWO – REVIEW OF HISTORICAL DATASETS

Sources of Information Consulted

The following primary information sources have been used in order to establish the background UXO threat:

1. *6 Alpha*'s *Azimuth* Database;
2. *Home Office* WWII Bomb Census Maps;
3. WWII and post-WWII aerial photography;
4. Official Abandoned Bomb Register;
5. Information gathered from the *National Archives* at *Kew*;
6. Historic UXO information provided by *33 Engineer Regiment* (Explosive Ordnance Disposal) at *Carver Barracks, Wimbish*.

Potential Sources of UXO Contamination

In general, there are several activities that might contaminate a site with UXO but the three most common ways are: legacy munitions from military training/exercises; deliberate or accidental dumping (AXO) and ordnance resulting from war fighting activities (also known as the Explosive Remnants of War (ERW)).

During WWII, the *Luftwaffe* undertook bombing campaigns all over the *UK*. The most common type of UXO discovered today is the aerially delivered high explosive (HE) bomb, which are comparatively thick-skinned and dropped from enemy aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the UXO to penetrate the ground, often leaving behind it a UXB entry hole. These entry holes were not always apparent and some went unreported, leaving the bomb buried and unrecorded. More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia V1* and *V2* rockets, Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

Although the *Luftwaffe* had designated primary bombing targets across the *UK*, their high-altitude night bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were sometimes struck.

As the threat of invasion lingered over *Britain* during WWII, defensive actions were undertaken. The *British* and *Allied Forces* requisitioned large areas of land for military training and bomb storage (including HE bombs, naval shells, artillery and tank projectiles, explosives, LSA and SAA). Thousands of tonnes of these munitions were used for the *Allied Forces* weapon testing and military training alone. It has been estimated that at least 20 per cent of the *UK*'s land has been used for military training at some point.

The best practice guide for dealing with your UXO risks on land (CIRIA publication C681) suggests that approximately 10 per cent of all munitions deployed failed to function as designed. ERW are therefore, still commonly encountered, especially whist undertaking construction and civil engineering groundwork.

Furthermore, in exceptional circumstances, UXO is discovered unexpectedly and without apparent rational explanation. There are several ways this might occur:

- When *Luftwaffe* aircraft wished to swiftly escape e.g. from an aerial attack, they would jettison some or all of their bombs and flee. This is commonly referred to as *tip and run* and it has resulted in bombs being found in unexpected locations;
- Transportation of aggregate containing munitions to an area that was previously free of UXO, usually related to construction activities employing material dredged from a contaminated offshore borrow site;
- Poor precision during targeting (due to high altitude night bombing and/or poor visibility) resulted in bombs landing off target, but within the surrounding area.
- *British* decoy sites were also constructed to deliberately cause incorrect targeting. For obvious reasons, such sites were often built in remote and uninhabited areas.

Site History

From an analysis of the CS and OS historical mapping associated with the Site, the following Site history can be deduced:

Year	On-Site	Vicinity
1890 CS Map	The Study Site consisted of a shipbuilding yard in the western sector, an engine house in the central southern sector and *Graving Docks* in the eastern sector.	The Site was situated within a developed dockland.
1908 CS Map	The shipbuilding yard was demolished on-site and the structural footprint of *Brunswick Dock* was altered on-site.	The docklands area to the north-west was altered.
1927 CS Map	A large structure was built in the eastern sector of the Study Site. In addition, a smaller structure was built in the central southern sector.	Changes were not recorded in the vicinity.
1938 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
1953 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.
1974 OS Map	The small structure in the central southern sector was demolished and another small structure was built in the eastern sector.	Changes were not recorded in the vicinity.
1990 OS Map	The large structure on-site was labelled as the *Brunswick Enterprise Centre* and a carpark was developed in the western sector.	Works were demolished north-west of the Study Site and new structures were developed.
2006 OS Map	Changes were not recorded at the Study Site.	Additional structures were developed to the north-west of the Study Site.
2009 Aerial Photography	The large structure and the smaller structure in the eastern sector was demolished. A small structure still remains in the south-eastern sector.	Changes were not recorded in the vicinity.
2018 OS Map	Changes were not recorded at the Study Site.	Changes were not recorded in the vicinity.

WWII Bombing of *Liverpool*

During WWII, *Liverpool* was a strategic bombing target for the *Luftwaffe* due to its port facilities and industry. It is estimated that approximately 90 percent of all war materials brought to *Great Britain* passed through the *Mersey Docks*.

The first major air raid to impact the city occurred on the 28th August 1940 and continued to be subjected to further bombing raids throughout 1940 (*The Christmas Blitz*) and 1941, with the peak of the bombing occurring from 1st to the 7th May 1941 (*The May Blitz*). These raids involved 681 *Luftwaffe* bombers, which delivered 2,315 HE bombs as well as other ordnance. The last recorded *Luftwaffe* air raid occurred on 10th January 1942.

Multiple properties (both industry and residential) were destroyed along with many dead and injured throughout the course of the war.

WWII Luftwaffe Bombing Targets (*Figure 4A & 4B)*

Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial facilities for attack, in the event of war. In addition, logistics infrastructure and public services, such as railways, canals, power stations, reservoirs, water and gas works were also considered viable bombing targets.

Luftwaffe aerial reconnaissance photography associated with the Site identified a dock (located on-site, 310m to the north and 450m to the north) and a gas works (located 360m to the south-west) as primary bombing targets. In addition, a dock (located 175m to the north-west), a warehouse (located 205m to the north-east) and a mill and timber yard (located 320m to the east) may have been considered secondary bombing targets. Furthermore, research also identified a barrage balloon site (located 670m to the south-east) and a pillbox (located 990m to the south-east), which were likely to have been targeted in an attempt to reduce *Luftwaffe* aircraft losses.

WWII HE Bomb Strikes (*Figure 5*)

During WWII, ARP wardens compiled detailed logs of bomb strikes across their respective districts. However, ARP records associated with the Site did not note any HE bomb strikes within it. Nonetheless, seven were identified 130m to the north, 140m to the north-east, 155m to the south, 165m to the south, 250m to the north, 300m to the north-east and 325m to the north. In addition, IB's were recorded 165m to the east, 195m to the north-east and 245m to the north. Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers that accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted.

In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, the main threat came from *V* type weapons. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons. Despite this, there is no evidence to suggest that the Site (or its immediate vicinity) was subjected to rockets strikes during WWII.

The potential penetration depth of an UXB was dependent on a number of factors including but not restricted to those prior to striking the ground e.g. velocity and orientation of the UXB which in turn will be influenced on factors such as the release altitude from the aircraft and encounters with infrastructure during its fall; those encountered at the point of impact i.e. was the impact on concrete, grass, water etc and finally, the below ground level conditions which were encountered such as infrastructure e.g. services, basements, foundations, and geology e.g. made ground, clay, sand, etc. Further, as the UXB penetrated the ground, it's velocity naturally slowed where, it either came to an abrupt stop e.g. against foundations or would continue for 10's of feet along a route of least resistance which often resulted in a curving of the trajectory back towards the surface. This is known as the "J Curve" effect and often resulted in a considerable horizontal off-set from the point of entry. This is often the reason why UXBs have been discovered against or under the foundations of buildings, which were present during WWII, or many meters from the point of impact.

WWII Bomb Damage

Official bomb damage mapping was not available. However, written records identified "extensive damage" to *Brunswick Docks* and "considerable damage" from the parachute mine that fell in the river opposite the docks. In addition, photographic evidence showed considerable bomb damage to *Brunswick Docks.* Furthermore, an analysis of post-war mapping and further research of historical records did not identify any potential bomb damage on-site or in close proximity to it.

WWII HE Bomb Density (*Figure 6*)

The Study Site was located within *Liverpool County Borough,* which recorded 21 HE bombs per 100 hectares, a low level of bombing. However, given that the Site was situated within a primary bombing target during WWII, the localised bombing density may in fact have been much greater.

Abandoned Bombs

An examination of the official abandoned bomb records has not identified any abandoned bombs on-site or within 1,000m of the Site boundary.

Records of WWII UXB Disposal Tasks

An examination of the civil defence records listing UXBs dealt with in *Liverpool County Borough* did not identify any UXB disposal tasks on-site or within 1,000m.

Records of Post-WWII UXB Disposal Tasks

An examination of the post-WWII BDO tasks associated with the area has not identified any BDO operations on-site or within 1,000m of the Site boundary.

WWII Site Use

The CS mapping prior to WWII (1938), shows that the Study Site was located in a large industrial docklands area, with the Site itself being part of *Brunswick Dock* with a large structure in its eastern sector. As a result, it is possible that the docklands authorities inspected the Site for UXB entry holes following any raids. However, given that evidence suggests the Site sustained extensive bomb damage, bomb damage debris may have concealed a UXO entry hole and therefore, may have gone unnoticed.

Sources of UXO Contamination

The most likely source of UXO contamination is from *German* aerially delivered ordnance, which ranges from small IBs through to large HE bombs (the latter forms the principal threat). Additional residual contamination may be present from *British* AAA projectiles (which were used to defend the UK against *German* bombing raids).

STAGE THREE – DATA ANALYSIS

Variable	Result	Comment
Was the area considered to be a primary bombing target?	✔	Docks (located on-site) were identified as primary bombing targets.
Was the Site or the immediate area bombed during WWII?	✔	Seven bomb strikes were identified within 325m; the closest being 130m to the north.
Did the Site or the immediate area experience bomb damage?	✔	Written records identified "extensive damage" and "considerable damage" to *Brunswick Docks.*
Was the ground undeveloped during WWII?	✘	The Site was part of *Brunswick Dock* and consisted of a large structure in the eastern sector.
Would the footfall have been high in the area?	✔	Given that the Site was part of a dock, it is likely that footfall would have been high.
Would a UXB entry hole have been observed during WWII?	✘	It is possible that the dockland authorities inspected the Site for any UXB entry holes following any raids. However, given that evidence suggests the Site sustained extensive bomb damage, bomb damage debris may have concealed a UXO entry hole and therefore, may have gone unnoticed. In addition, it is likely that any UXO that fell within the dock would have gone unnoticed.
Have military personnel ever occupied the Site?	✘	No military facilities were identified within 1,000m.
Would munitions have been manufactured, stored and/or fired from the Site?	✘	There is no evidence to suggests munitions were located or fired from this Site.
Would previous intrusive works have removed the potential for UXO to be present?	✘	The Site has been subjected to some post-war redevelopment with the demolishing of structures, therefore it is likely that any shallow UXO would have been discovered and removed.
Are proposed intrusive works likely to extend into previously undisturbed ground?	✔	Shallow intrusive works are unlikely to extend into previously undisturbed ground as the dock has been infilled and structures have been demolished. However, deeper intrusive works are likely to extend into potential UXO contaminated ground.
Is there potential for an unplanned encounter with UXO to occur during proposed intrusive works?	✔	Given that the Site was a primary bombing target which sustain extensive bomb damage, an unplanned encounter with UXO is possible.
Does the probability of UXO vary across the Site?	✔	The probability of discovering shallow UXO within the Site is considered to be remote considering the post-war demolition works and the infill of the dock, however, the probability of discovering UXO within all previously undisturbed areas of the Site is extant.

STAGE FOUR – RISK ASSESSMENT

Threat Items

The most probable UXO threat items are *German* HE bombs, whilst IBs and *British* AAA projectiles pose a residual threat. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

Bomb Penetration Depth

Considering the ground conditions (highlighted in Stage 1), the average BPD for a 250kg *German* HE bomb within clays and sands is assessed to be approximately 7m below WWII ground levels, with the maximum BPD considered to be approximately 14m below WWII ground levels. Although it is possible that the *Luftwaffe* deployed larger bombs in the area, their deployment was infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.

N.B. the average BPD is assessed to be 7m below ground level during WWII, and therefore post-war infill of the dock does not pose a risk to intrusive works. If however, the intrusive works extend below the post-war infill and into the original ground/sea bed that was present during the war, then the appropriate UXO mitigations will need to be applied in this ground.

WWII *German* bombs have a greater penetration depth when compared to IBs and AAA projectiles, which are unlikely to be encountered at depths greater than 1m bgl. However, due to the "J Curve" and the potential for structures to impede the penetration into the ground, HE bombs have been discovered at much shallower depths than the average.

Risk Pathway

Given the types of UXO that might be present on-site, all types of aggressive intrusive engineering activities (i.e. investigative groundworks and shallow excavations) may generate a significant risk pathway. Whilst not all UXO encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injury to personnel, damage to equipment and project delay.

Prospective Consequences

Consequences of UXO initiation include:

1. Fatally injure personnel;
2. Severe damage to plant and equipment;
3. Deliver blast and fragmentation damage to nearby buildings;
4. Rupture and damage underground utilities/services.

Consequences of UXO discovery include:

1. Delay to the project and blight;
2. Disruption to local community/infrastructure;
3. The expenditure of additional risk mitigation resources and EOD clearance;
4. Incurring additional time and cost.

UXO RISK CALCULATION

Site Activities

Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, a number of investigative and construction methodologies have been described for analysis at this Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, *6 Alpha* has conducted separate risk rating calculations for each investigative and construction methodology that might be employed.

Risk Rating Calculation

6 Alpha's Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

UXO Risk Calculation Table – All Areas				
Activity	**Threat Item**	**Probability**	**Consequence**	**Risk Rating**
Shallow Trial Pits (<5m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Deep Trial Pits (>5m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Window Sampling (1m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Boreholes (30-40m bgl)	HE Bombs	2+3=5	3+2=5	5x5=25
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16
Cable Percussion Holes (10-15m bgl)	HE Bombs	2+3=5	3+2=5	5x5=25
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16
Shallow Excavations (<2m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Deep Excavations (>2m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Trenching (Up to 2m bgl)	HE Bombs	2+2=4	3+3=6	4x6=24
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Piling (30-40m bgl)	HE Bombs	2+3=5	3+2=5	5x5=25
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16

Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES

Do the ground conditions support a geophysical UXO survey?

Non-Intrusive Methods of Mitigation – Magnetometer results may be affected by ferro-magnetic contamination due to previous construction activities and made ground within the Site.

Intrusive Methods of Mitigation – Intrusive magnetometry may be effective on this Site, prior to boreholing and piling especially. However, any ferrous metal/red brick contamination in made ground/old foundations may affect the detection capability of the UXB survey equipment, as it passes through the contaminated layer especially. Nonetheless, beyond the contaminated strata such a survey should prove effective.

Mitigation Measures to Reduce Risk to 'ALARP'

Activity	Risk Mitigation Measures	Final Risk Rating
All Activities in All Areas	**1. Operational UXO Emergency Response Plan;** appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery (this plan can be supplied by *6 Alpha*); **2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety awareness briefing is an essential part of the *Health & Safety Plan* for the Site and helps to evidence conformity with the principles laid down in the *CDM* regulations 2015 (this brief can be delivered directly, or in some cases remotely, by *6 Alpha*).	**ALARP**
Trial Pits, Window Sampling, Excavations and Trenching in All Previously Undisturbed Areas	**3. Non-intrusive UXO Survey and/or EOD Banksman Support;** Where 'open' intrusive works into previously undisturbed ground are proposed and where the extent is considered to be within the capabilities of non-intrusive UXO survey equipment and implementation of this is assessed as likely to prove effective, a non-intrusive geophysical UXO survey should be trialed and, if it proves successful, should be employed to survey site-wide, or in specific areas where 'open' intrusive works are to be implemented to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. If the survey proves partially or wholly ineffective, an EOD Engineer should be present in the UXO Banksman role to monitor ongoing 'open' intrusive works to identify any suspicious items that may be UXB or UXO related (this service can be provided by *6 Alpha*).	
Piling and Boreholing in All Areas	**4. Intrusive UXO Survey;** Where 'blind' intrusive works into previously undisturbed ground are proposed, an intrusive UXO survey (employing down-hole magnetometer or MagCone techniques) is strongly recommended. Such a survey should extend to the *assessed average bomb penetration depth* or to the maximum depth of the works, whichever is encountered first, or until geology is encountered through which it is assessed a UXB would not penetrate, to identify for signs of sub-surface anomalies which may model as the target UXO in advance of said works. (this service can be provided by *6 Alpha*).	

This assessment has been conducted based on the information provided by the Client, should the proposed works change then *6 Alpha* should be re-engaged to refine this risk assessment

Report Figures

Figure One - Site Location

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

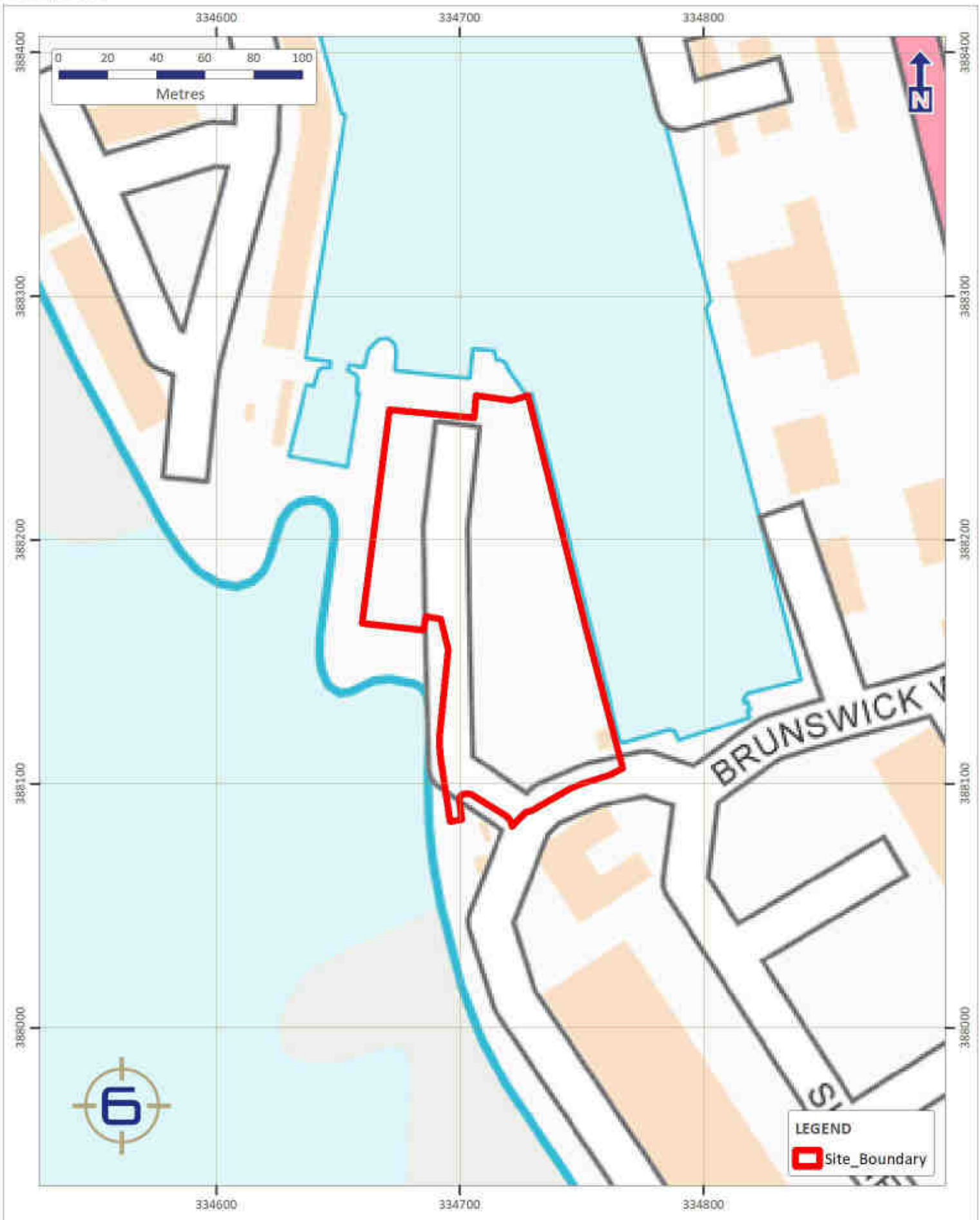
Site Location

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
P6474	1	RG	CC	27 February 2018

Figure Two - Site Boundary

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

Site Boundary



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
P6474	2	RG	CC	27 February 2018

Figure Three - Aerial Photography (Current)

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

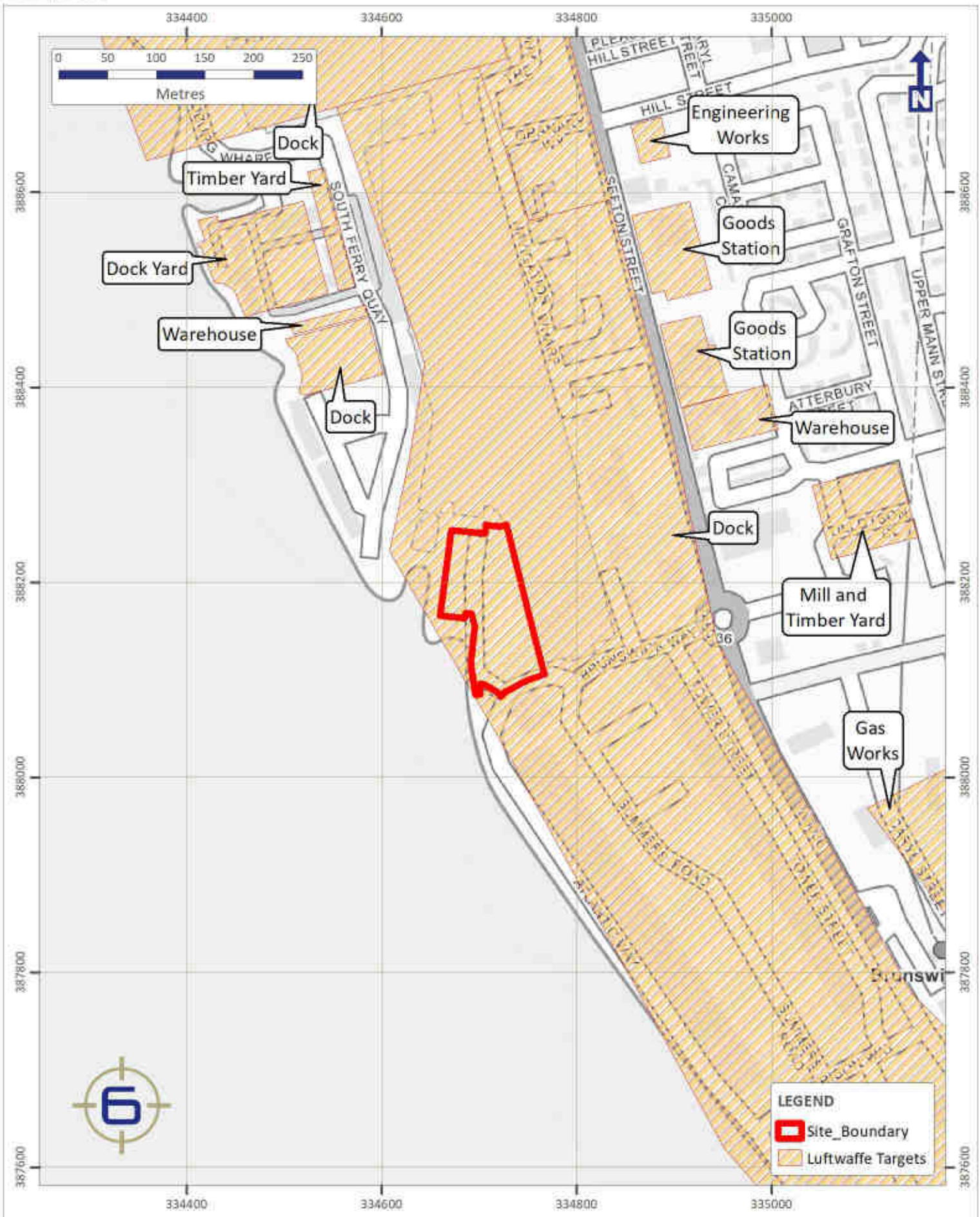
Aerial Photography (Current)

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
P6474	3	RG	CC	27 February 2018	Map data: Google	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

Figure Four A - WWII Luftwaffe Bombing Targets

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

WWII Luftwaffe Bombing Targets



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE			
P6474	4A	RG	CC	27 February 2018	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.	alpha ASSOCIATES

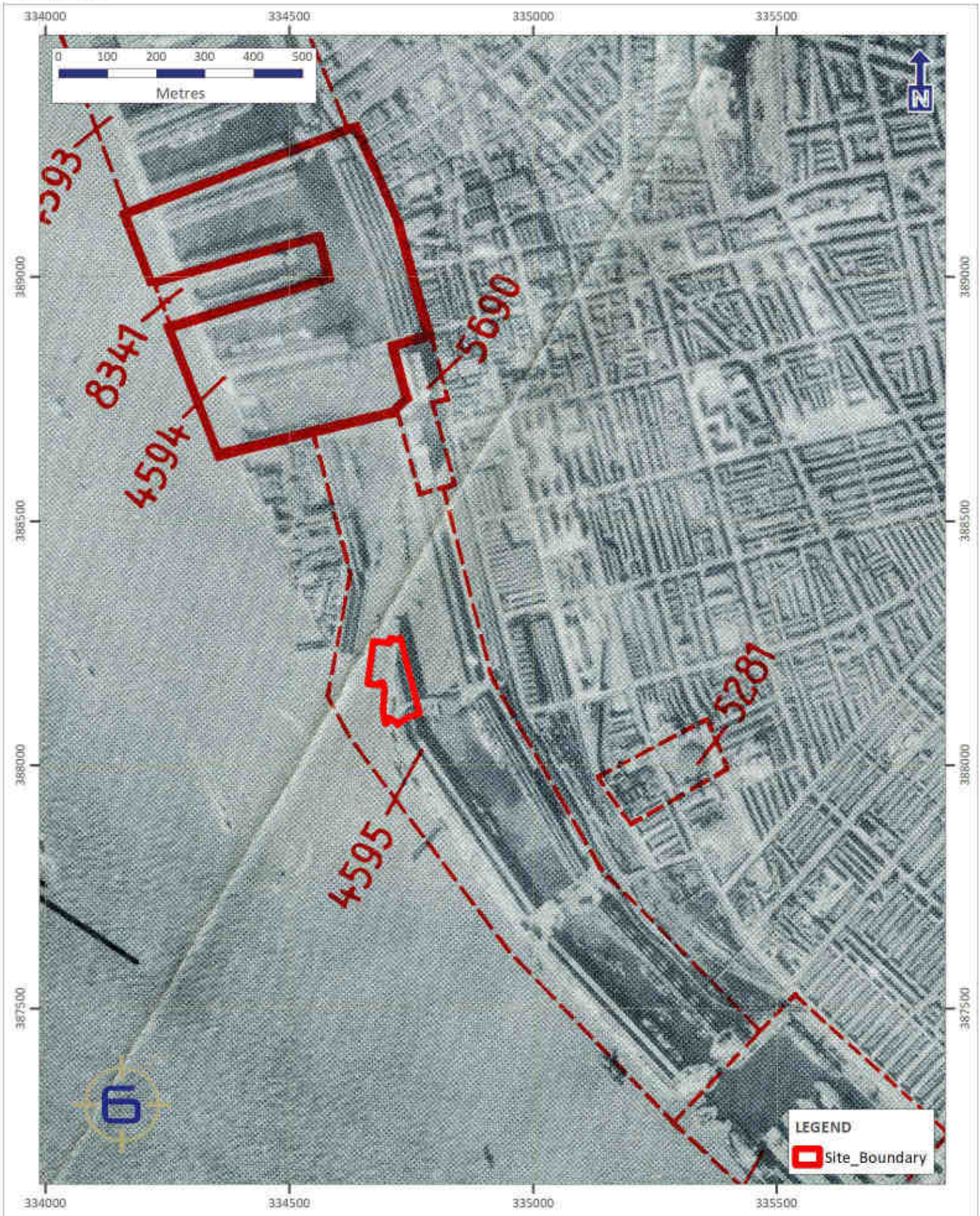
Figure Four B - WWII Luftwaffe Aerial Photography

BRITISH NATIONAL GRID

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

WWII Luftwaffe Aerial Photography

BOMB SEARCH
WWW.6ALPHA.COM



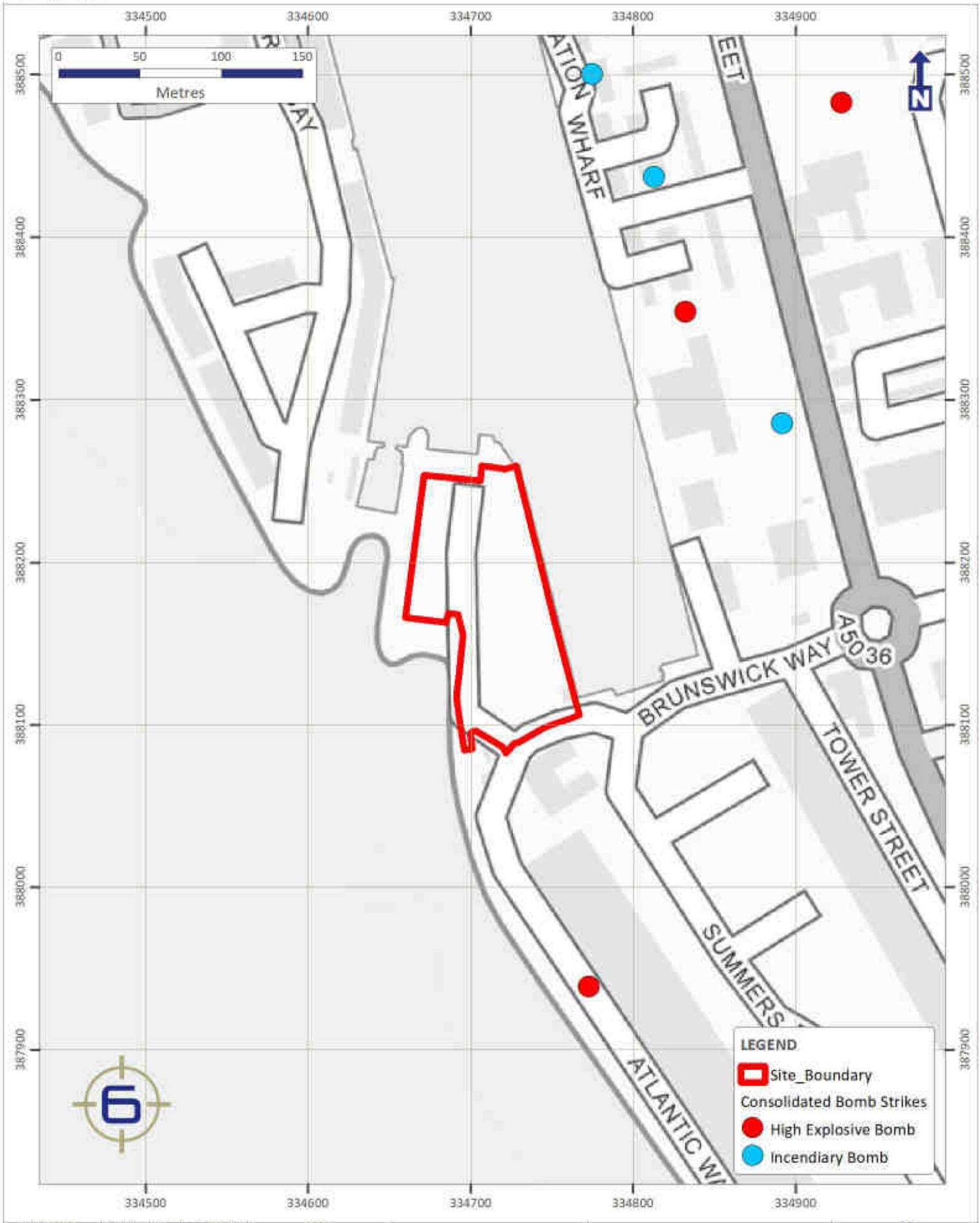
PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
P6474	4B	RG	CC	27 February 2018	Map data: NARA	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES

Figure Five - WWII High Explosive Bomb Strikes

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

WWII Consolidated Bomb Strikes



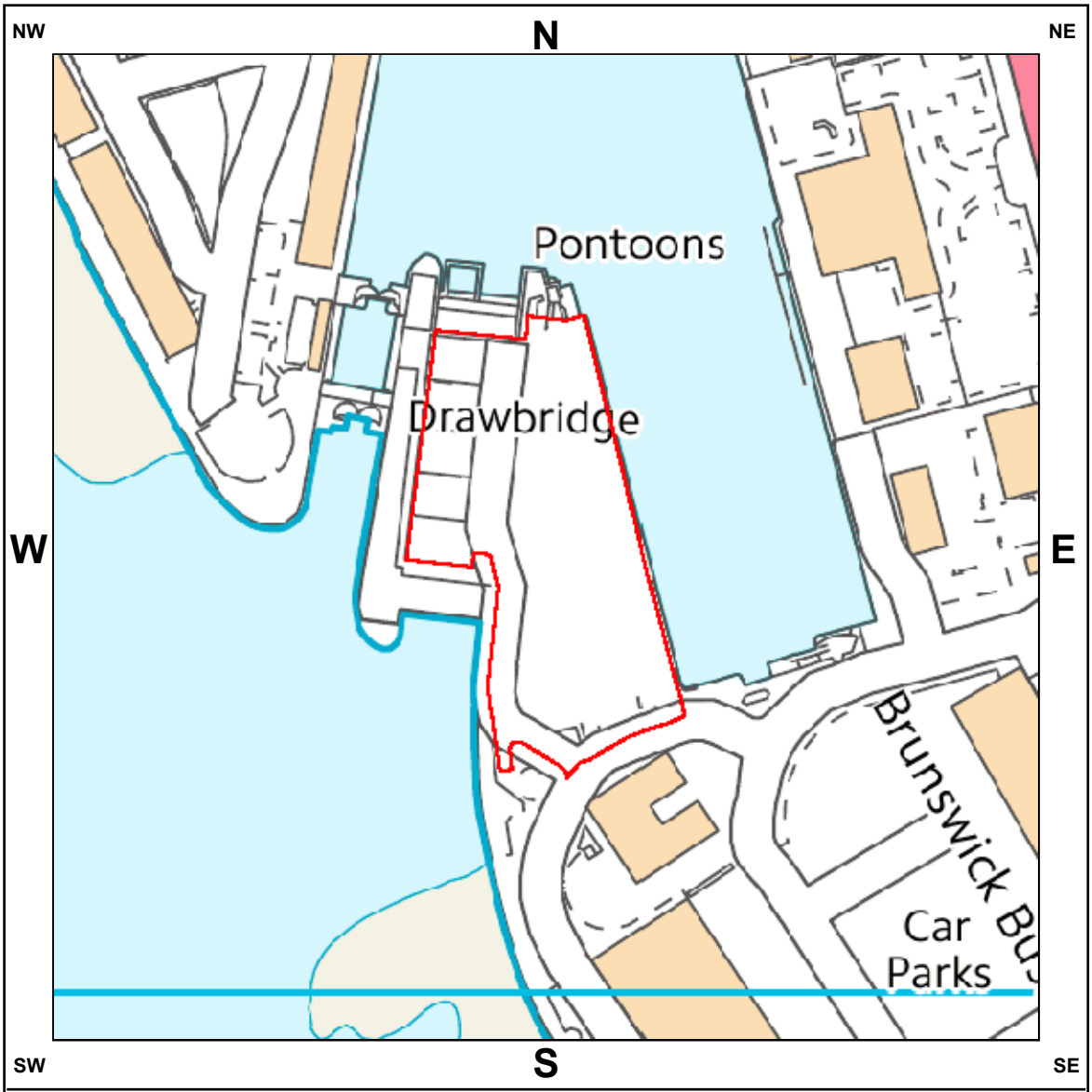
PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
P6474	5	RG	CC	27 February 2018

Figure Six - WWII High Explosive Bomb Density

BRUNSWICK QUAY, LIVERPOOL, MERSEYSIDE

WWII High Explosive Bomb Density

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
P6474	6	RG	CC	27 February 2018



Map Legend

Site Boundary

Business Use Only

Map data

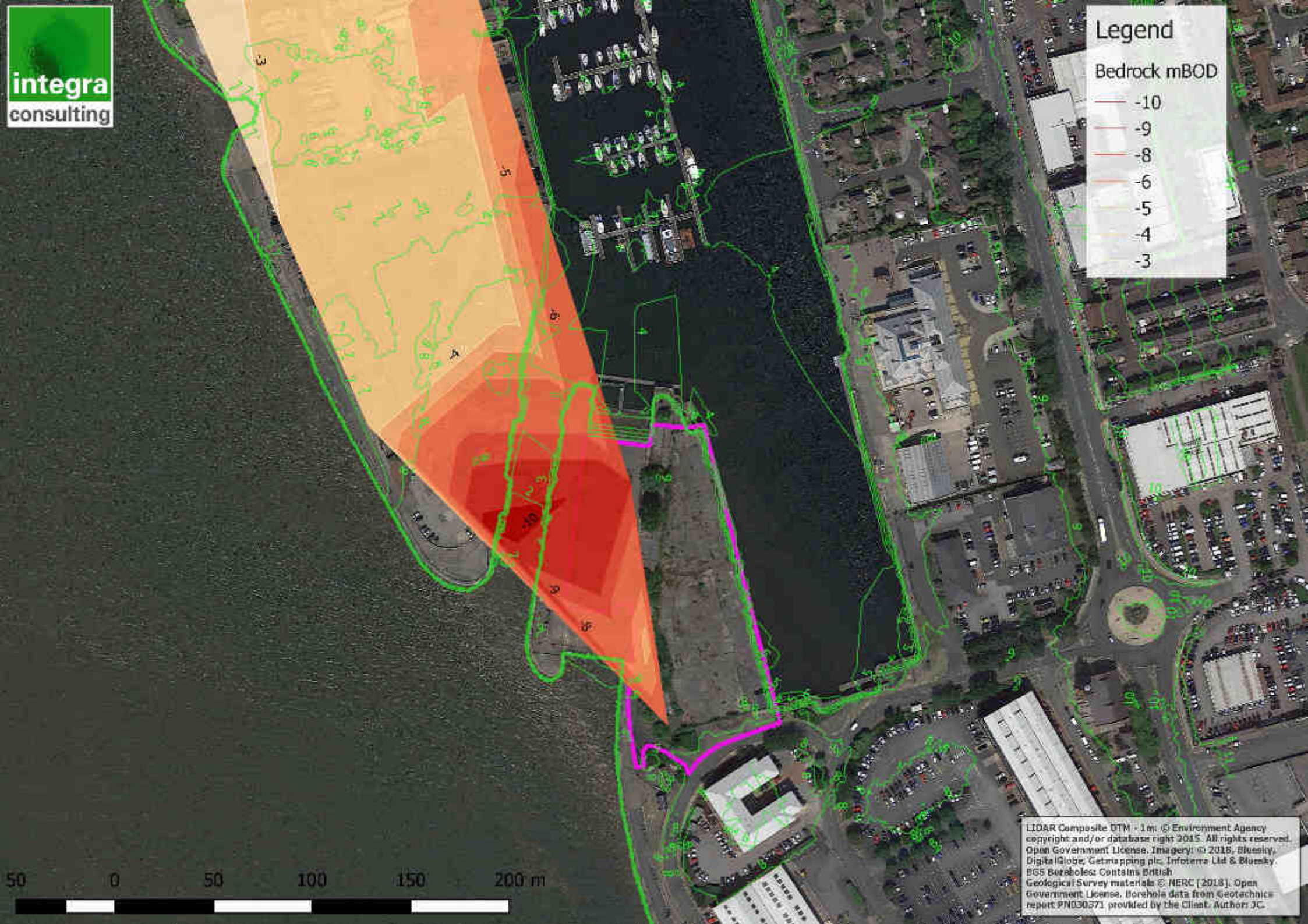
Search Details

Order Number: 157908433_1

Date of Report: 26 February 2018

APPENDIX 15

INDICATIVE BEDROCK CONTOUR PLAN


integra
consulting
Legend
Bedrock mBOD
-10
-9
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-6
-5
-4
-3
50
0
50
100
150
200 m
LIDAR Composite DTM - 1m. © Environment Agency copyright and/or database right 2015. All rights reserved. Open Government License. Imagery: © 2018, Bluesky, DigitalGlobe, Getmapping plc, Infoterra Ltd & Bluesky.
BGS Boreholes: Contains British Geological Survey materials © NERC [2018]. Open Government License. Borehole data from Geotechnics report PN030571 provided by the Client. Author: JC.

APPENDIX 11

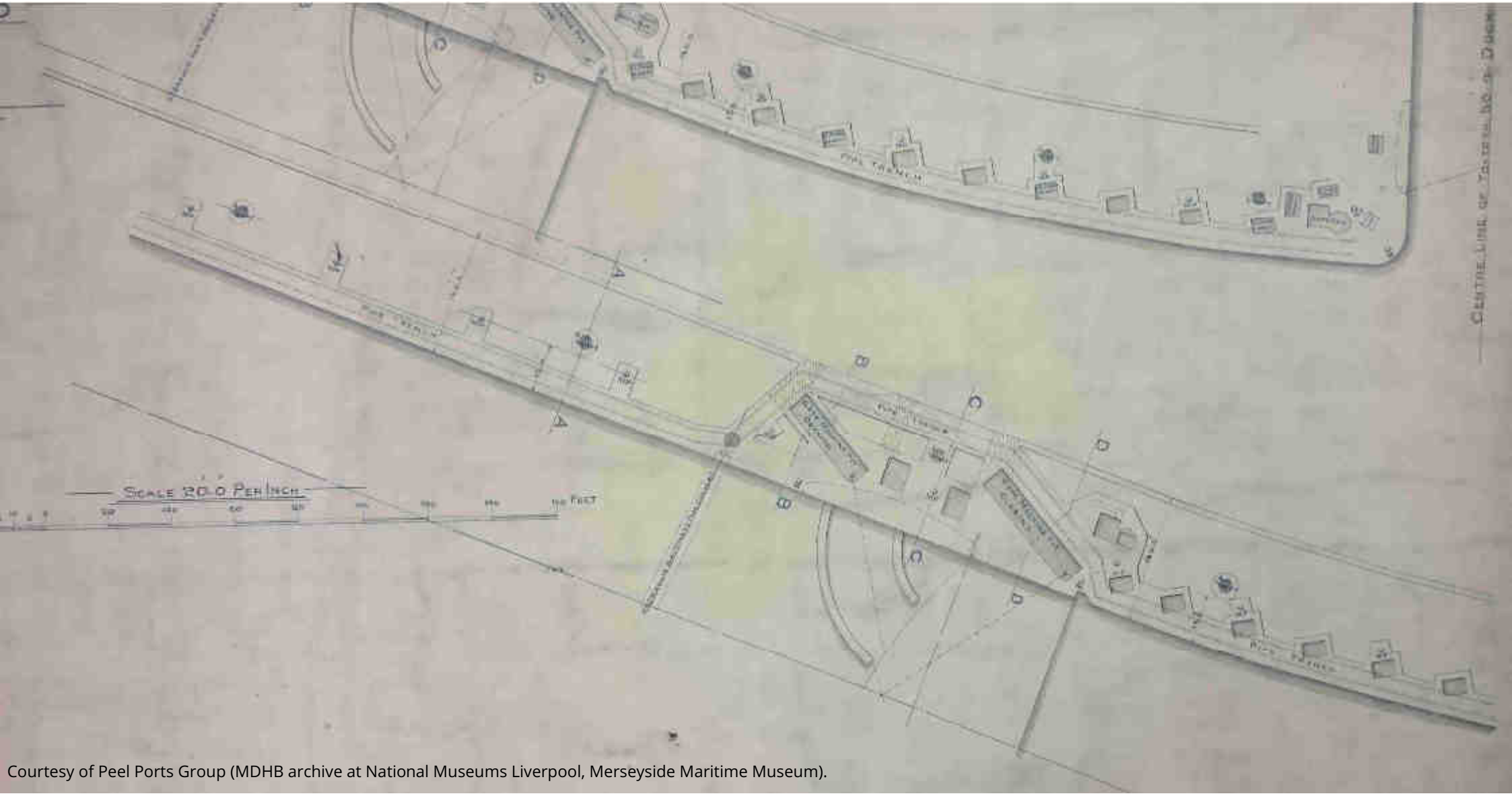
LIVERPOOL MARITIME ARCHIVE RESOURCES

Resource 1

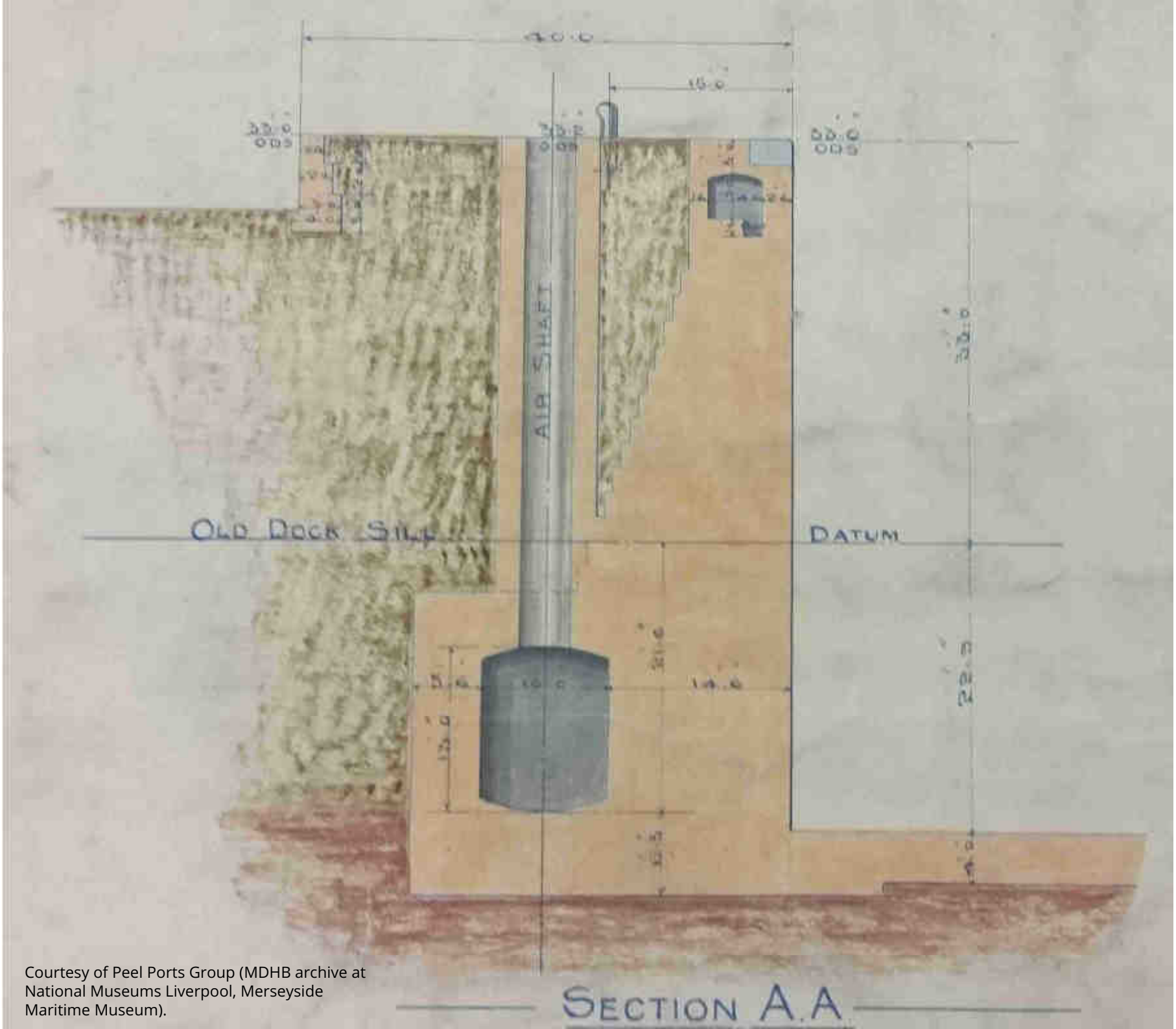
Plan and sections through air shaft, gate opening machine pit, lock gates and gate closing machine pit.

Plan shows plan view of east wall of 100ft lock and 4 No. sections through wall. All sections show extents of concrete (present in significant thickness), location of shallow pipe trench and deep culvert. Section AA shows section through air shaft showing depth and connection to underground culvert. Section BB shows section through gate opening machine pit (2.82m depth x 1.98m width). Section CC shows section through lock gate and top of wall overhang. Also shows ‘old raily [railway] metal’ at approx. 1.5m centres between ground level and 0.91m depth. Section DD shows section through gate closing machine pit (2.82m depth x 1.98m width).

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



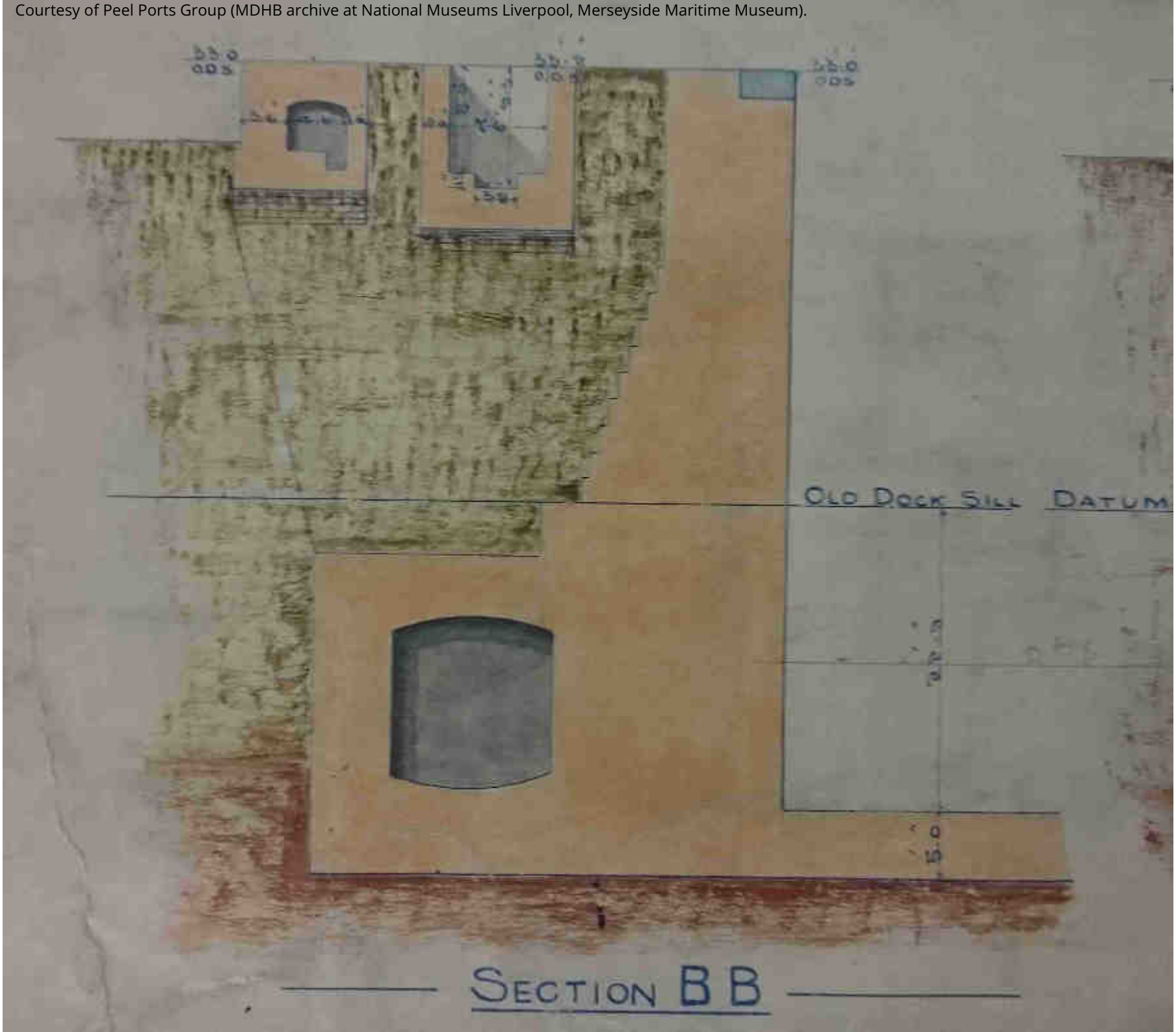
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

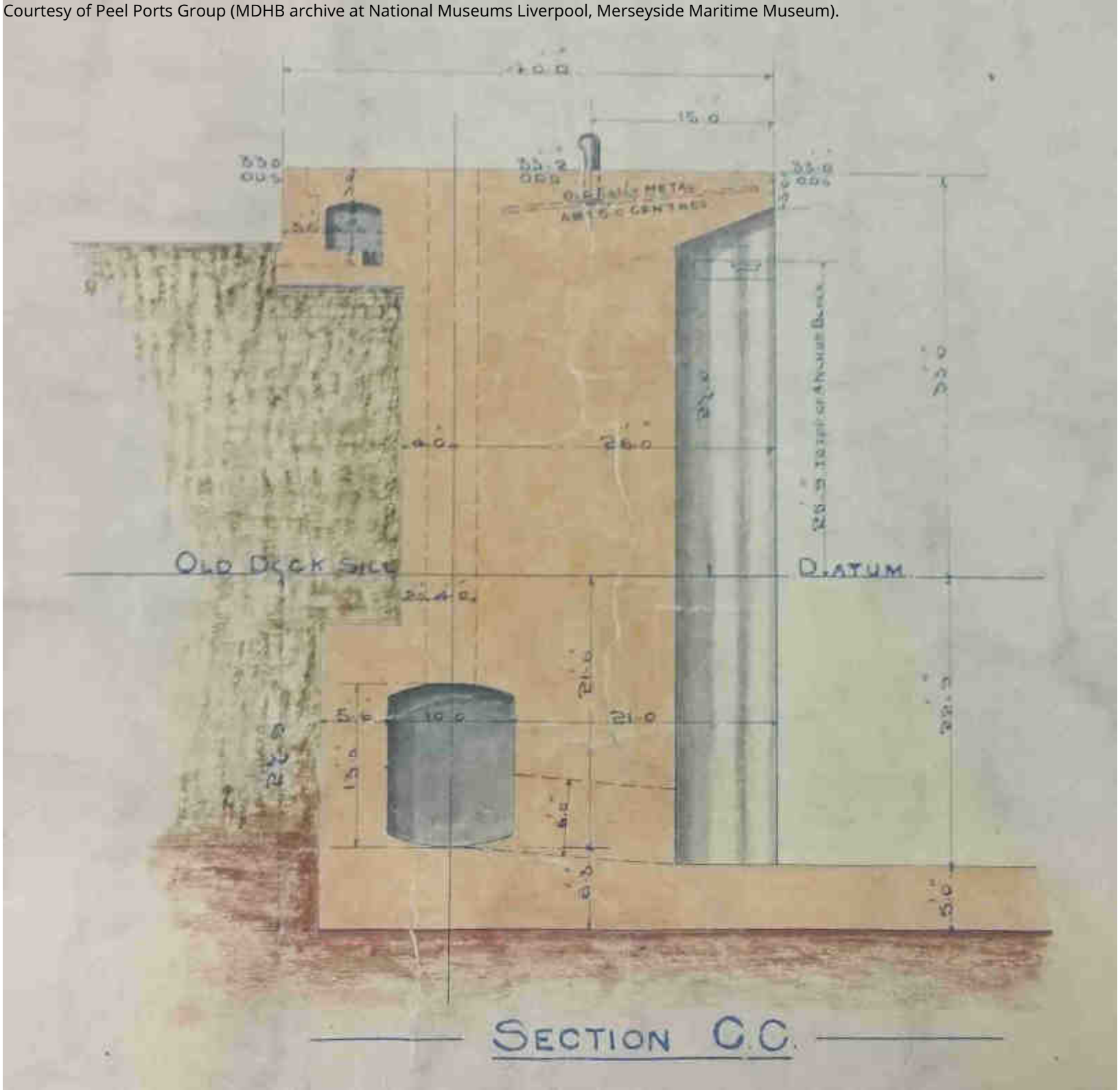
SECTION A.A

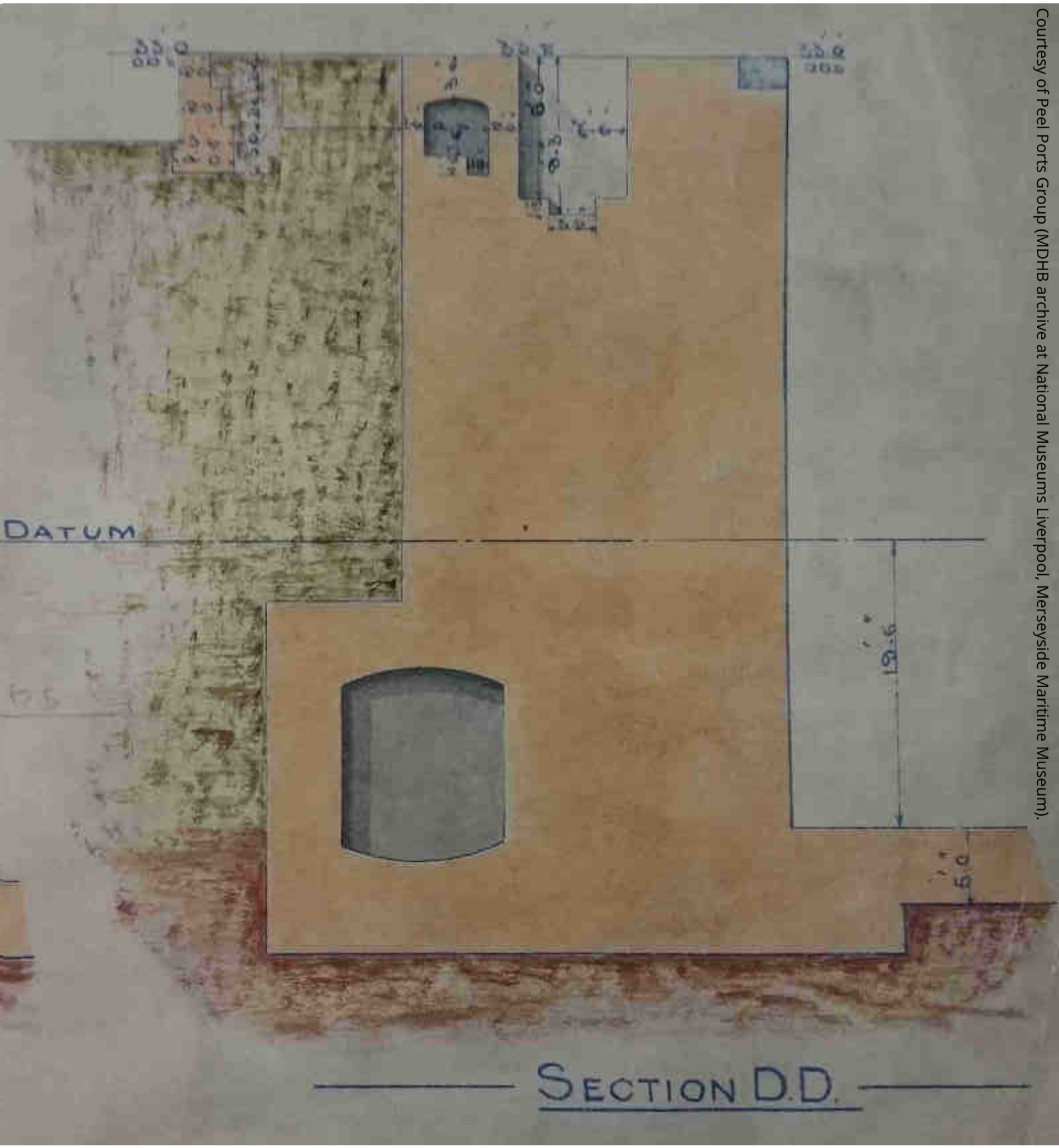
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



SECTION B B

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



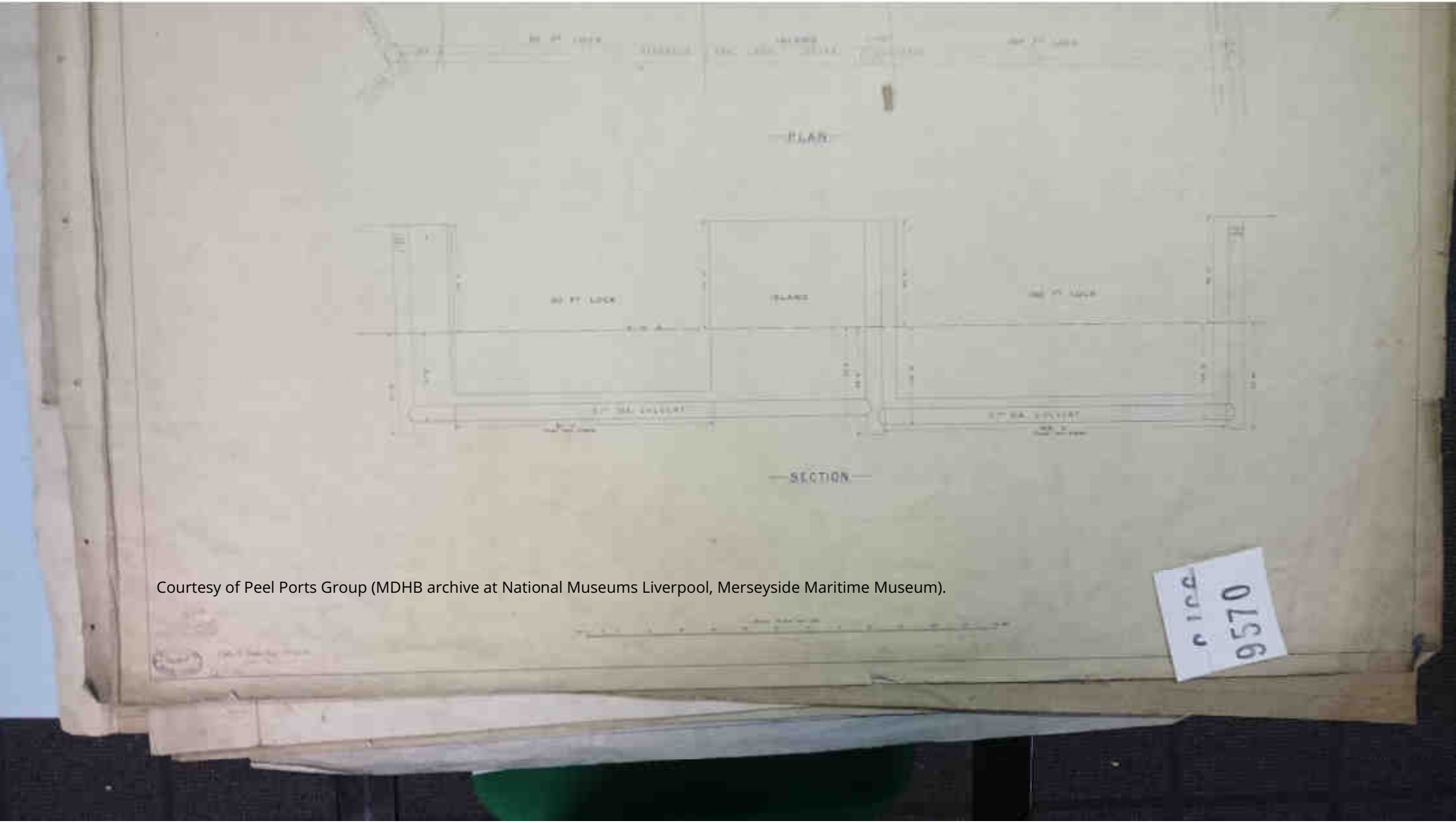


Resource 3

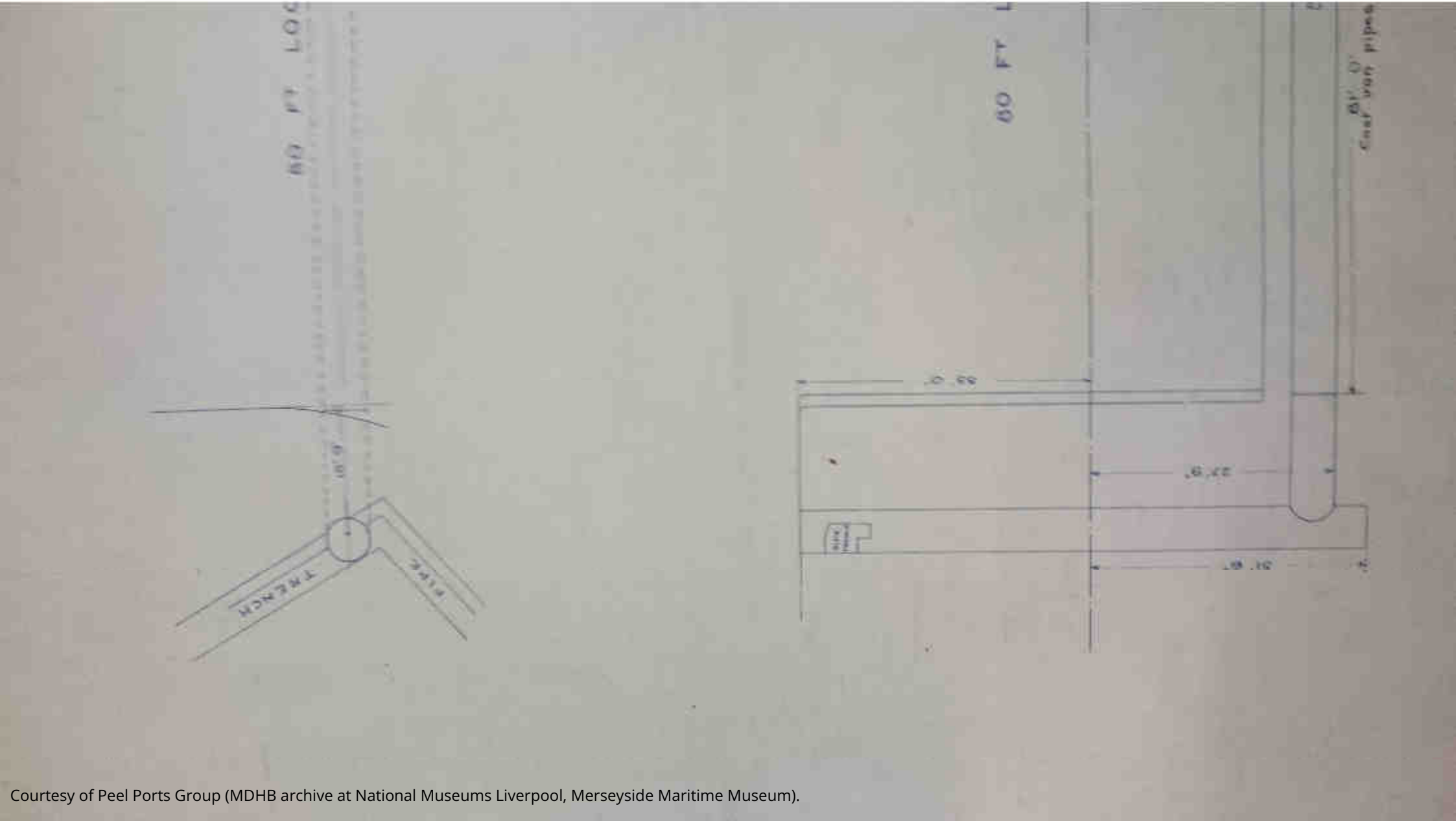
‘Plan And Section Of Hydraulic, Gas & Water Culvert’

Plan view shows location of a 1.52m diameter cast iron culvert passing from west side of 80ft lock to east side of 100ft lock and 3 No. connections to surface: 1 in the western wall of the 80ft lock, 1 in the central island and 1 in the east wall of the 100ft lock. Cross section shows depths of culvert beneath locks and approximate locations of connections to surface from lock walls where they intersect with the shallow pipe trench.

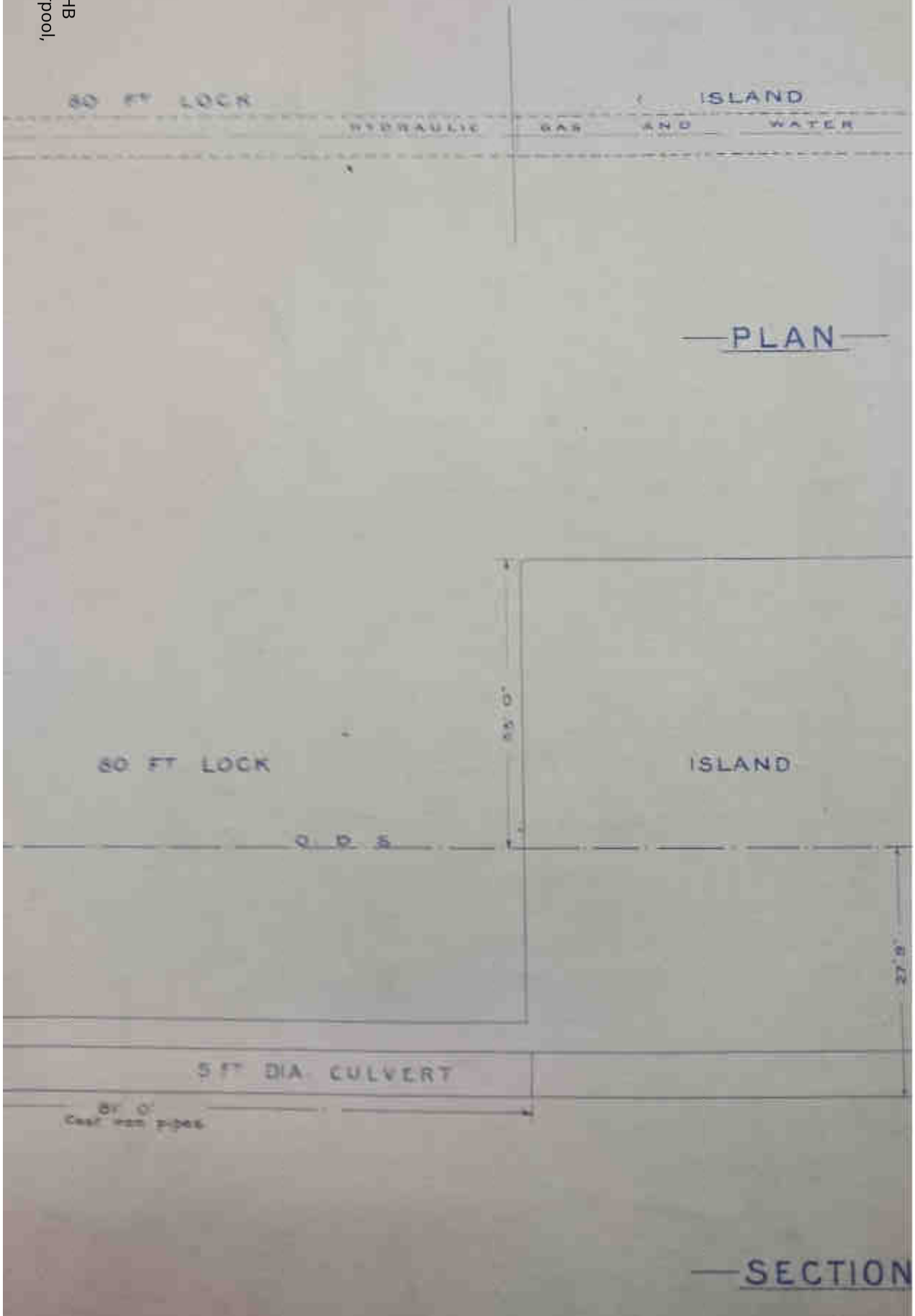
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

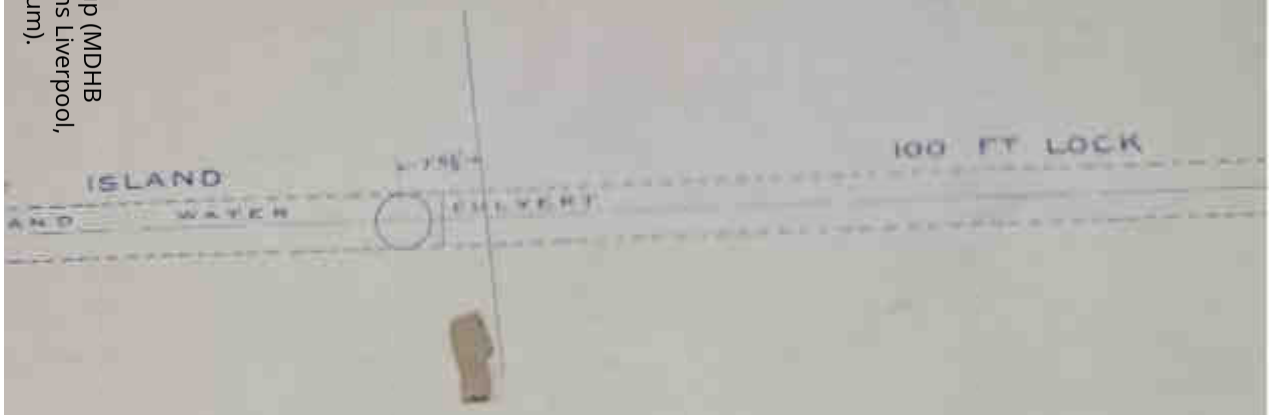


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

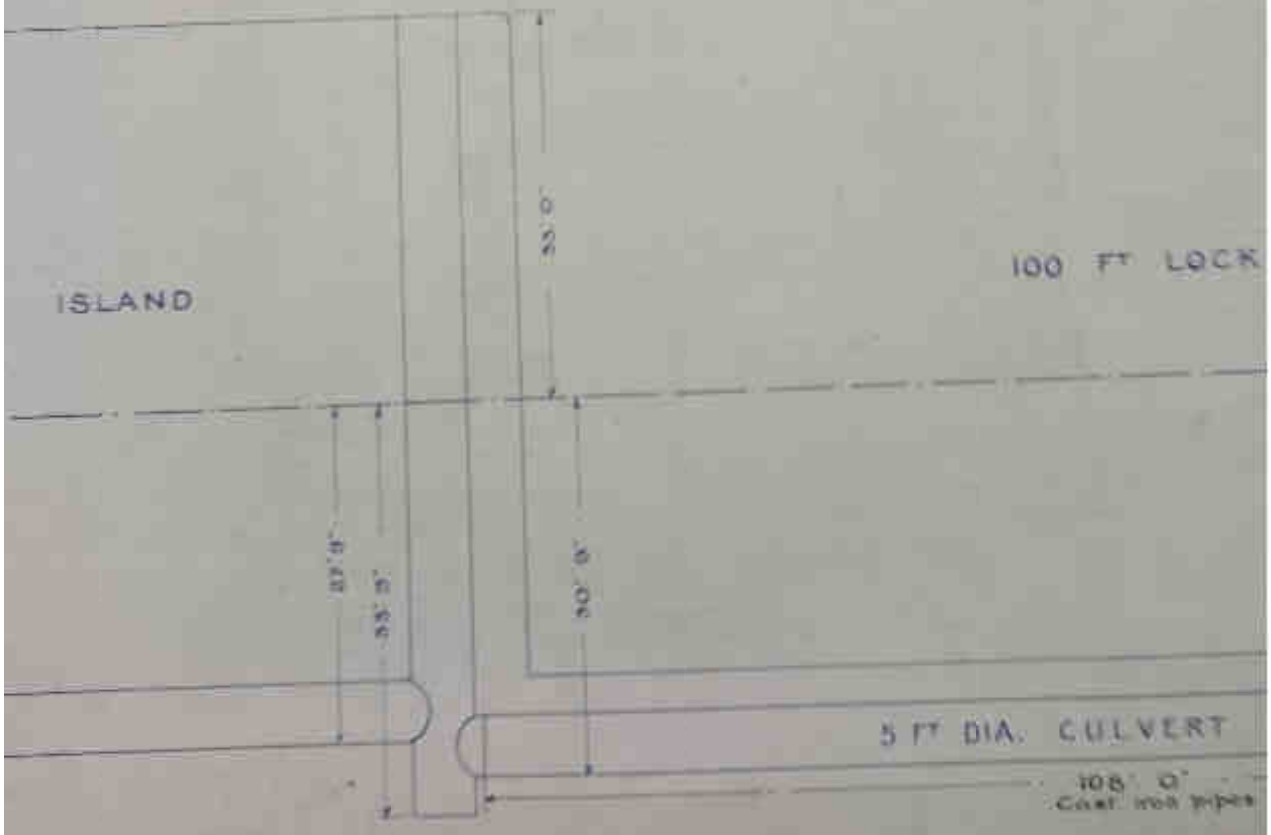


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



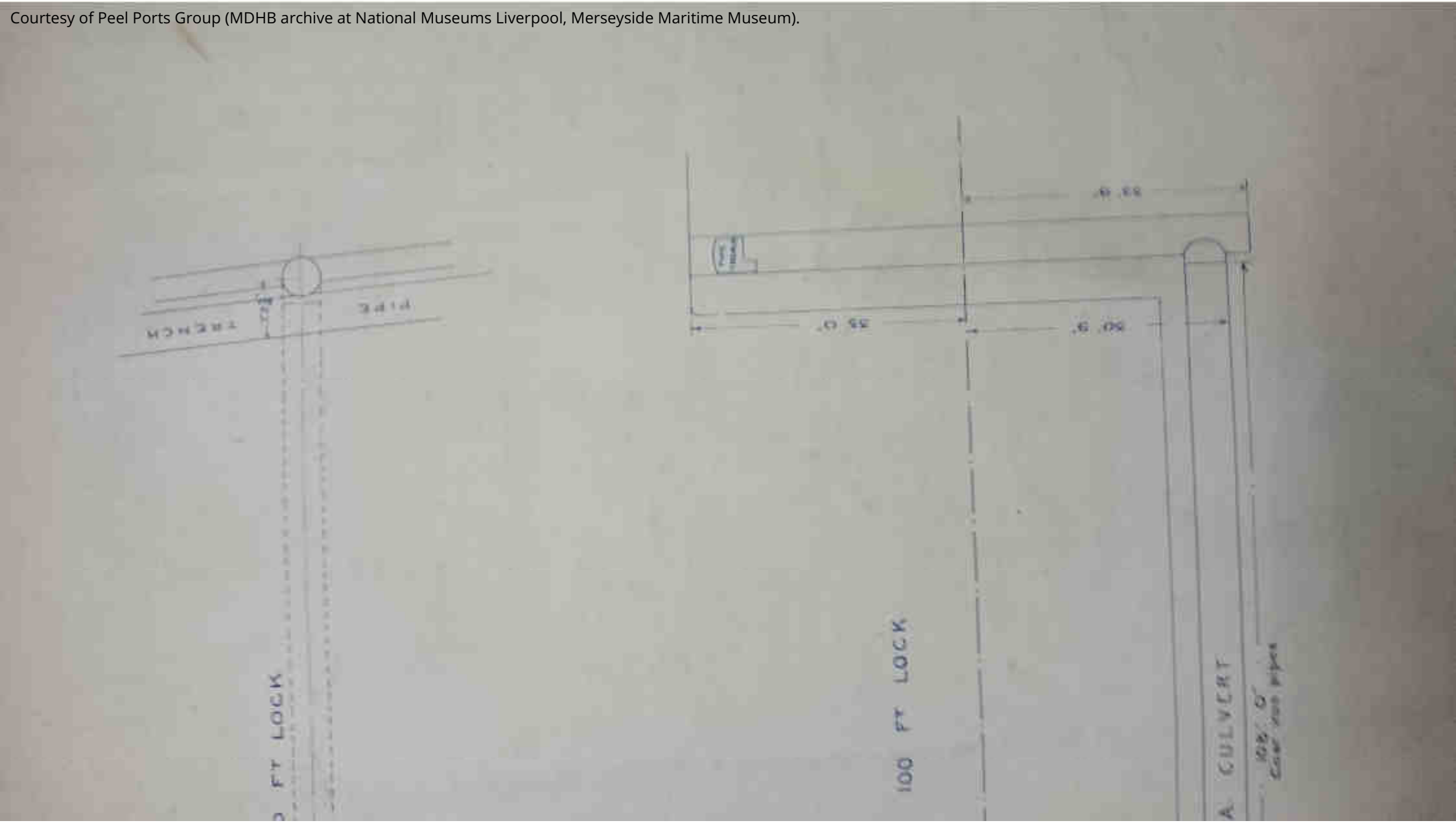


PLAN



SECTION

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

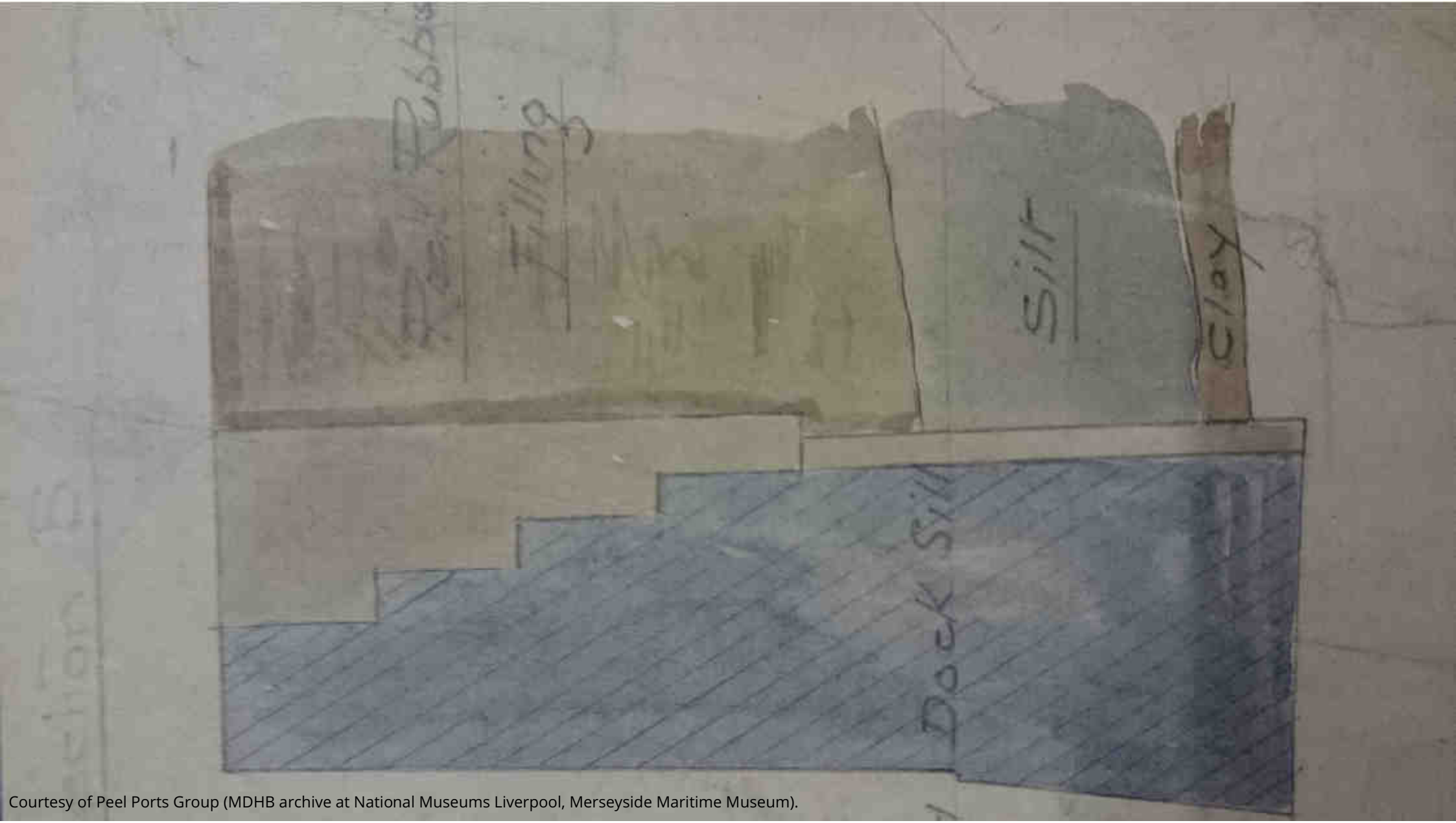


Resource 5

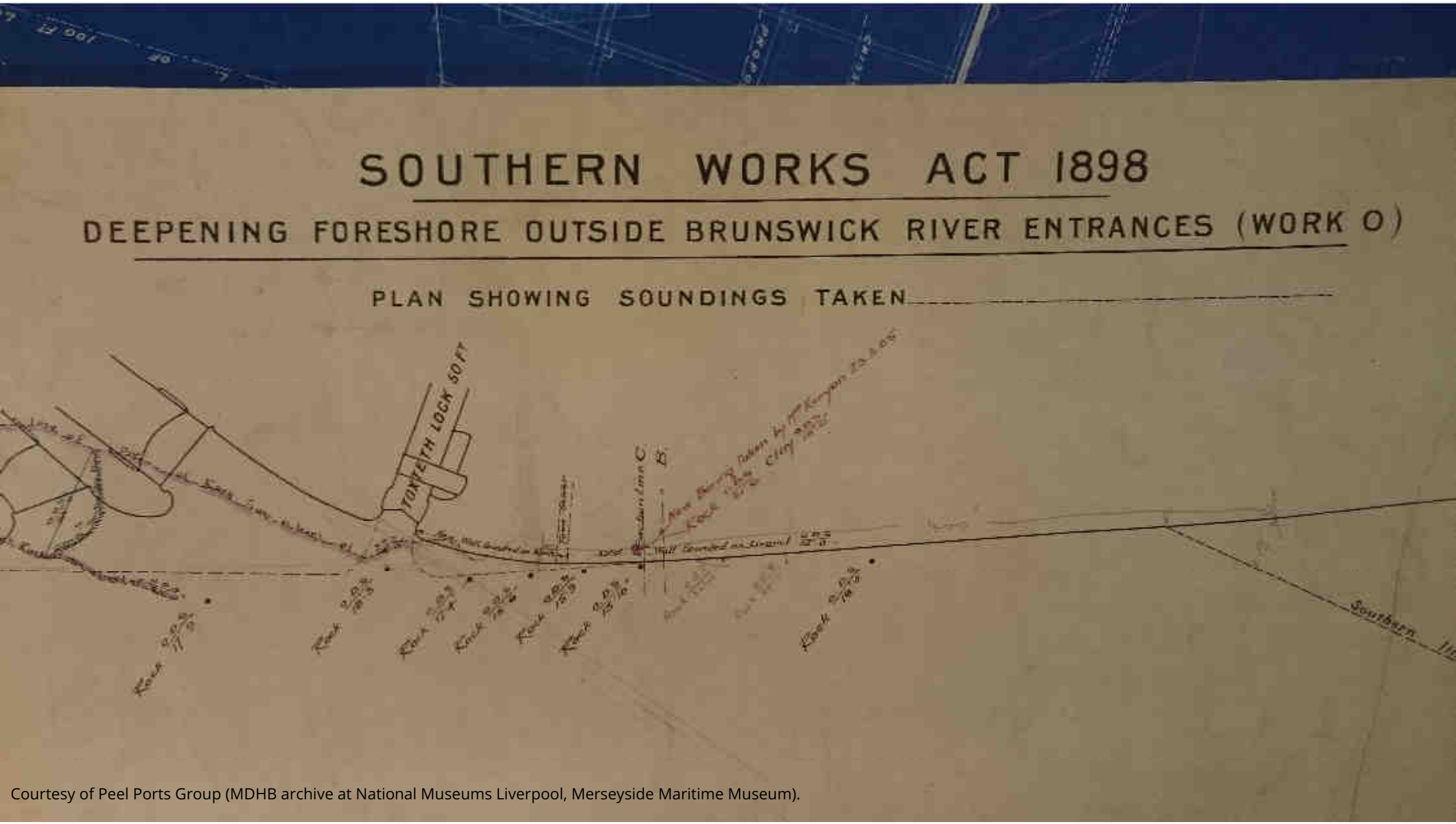
Section B through wall to the south of historic Toxteth Lock

Toxteth Lock was located approximately 21m south of the site. The River Wall to the south of this is shown on a cross sectional sketch. The (presumably concrete) wall widens towards the top. Behind it is ‘rock rubble filling’ almost to old dock sill (ODS = 10.06m bgl). This is underlain by ‘silt’, underlain by a relatively thin layer of ‘clay’, underlain by ‘rock’ at roughly 14.6m bgl.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 6

‘Brunswick New River Entrances’ plan

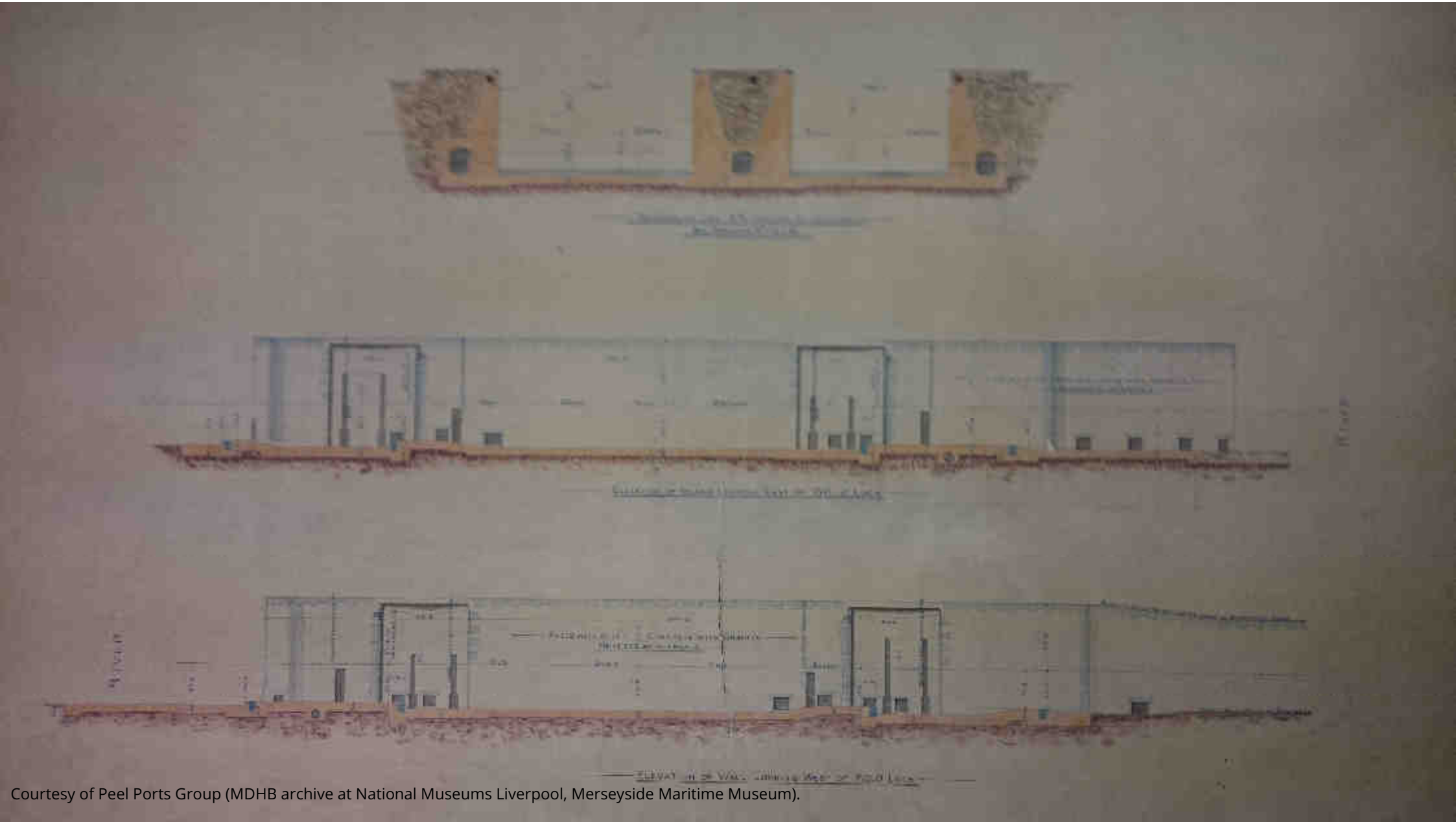
Cross sectional plan shows 100ft and 80ft locks. Old Dock Sill (ODS = 10.06m bgl) is used as a datum. Cross section includes many depths and measurements and shows locations of deep culverts and shallow pipe trenches. Dock walls appear to be constructed of concrete (orange on drawing) which widens towards the base. The space between the walls appears to be filled with gravel (brown mottling on drawing). The base of the locks appear to be covered in a layer of concrete approximately 1m thick, underlain by possibly more concrete (1.22m thick), underlain by rock (red mottling on drawing).

Cross sectional plans show elevation of island between locks looking east of the 80ft lock and elevation of wall looking west of 80ft lock. Cross sections show wall construction, locations of chain pipes, gate mechanisms, the hydraulic, gas & water culvert and other unlabelled features. A note on the drawing states that the wall is ‘faced with 6 to 1 concrete with granite’.

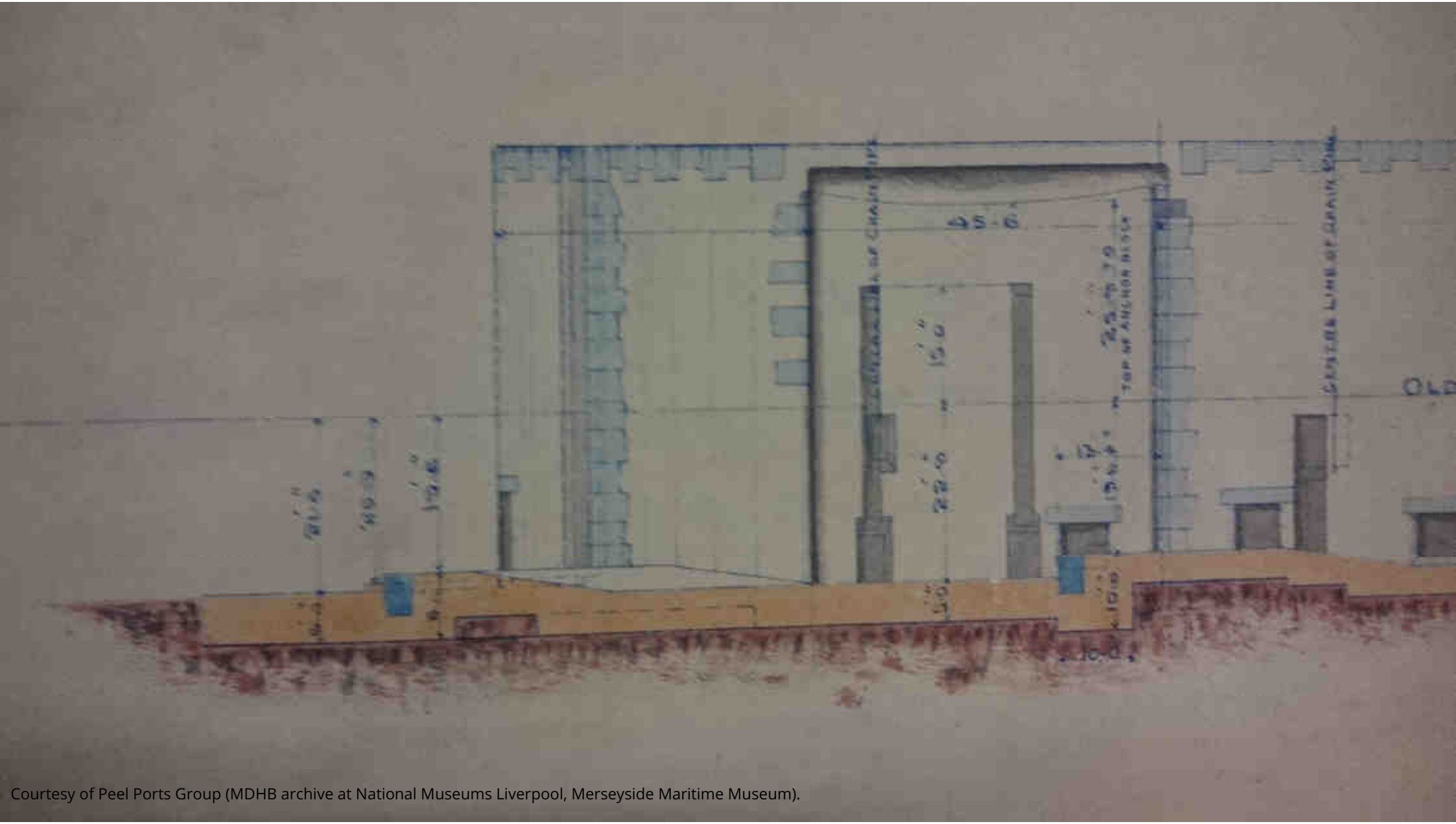
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

BRUNSWICK NEW RIVER ENTRANCES
SOUTHERN WORKS ACT 1898
WORK.O.

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

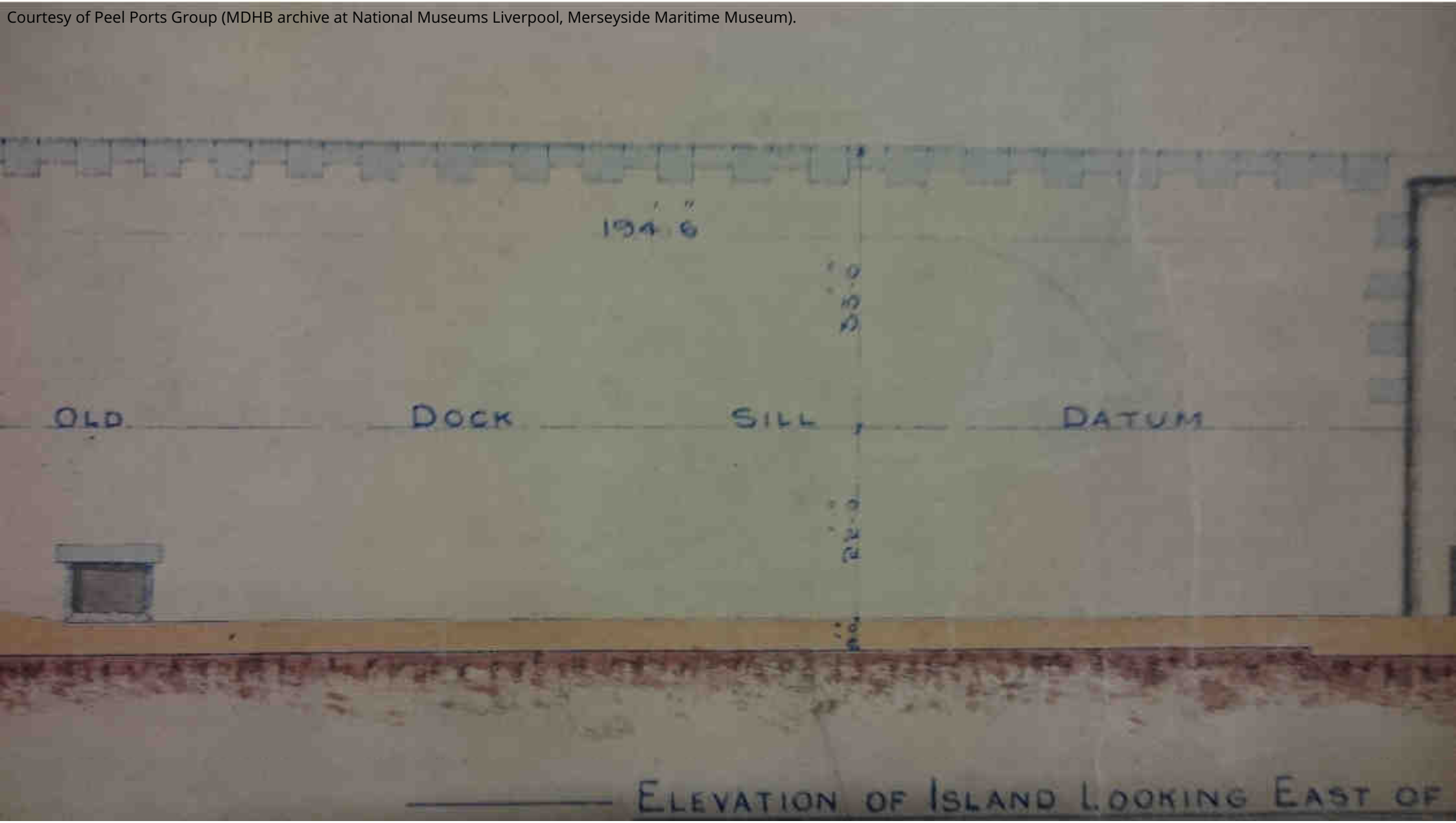


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

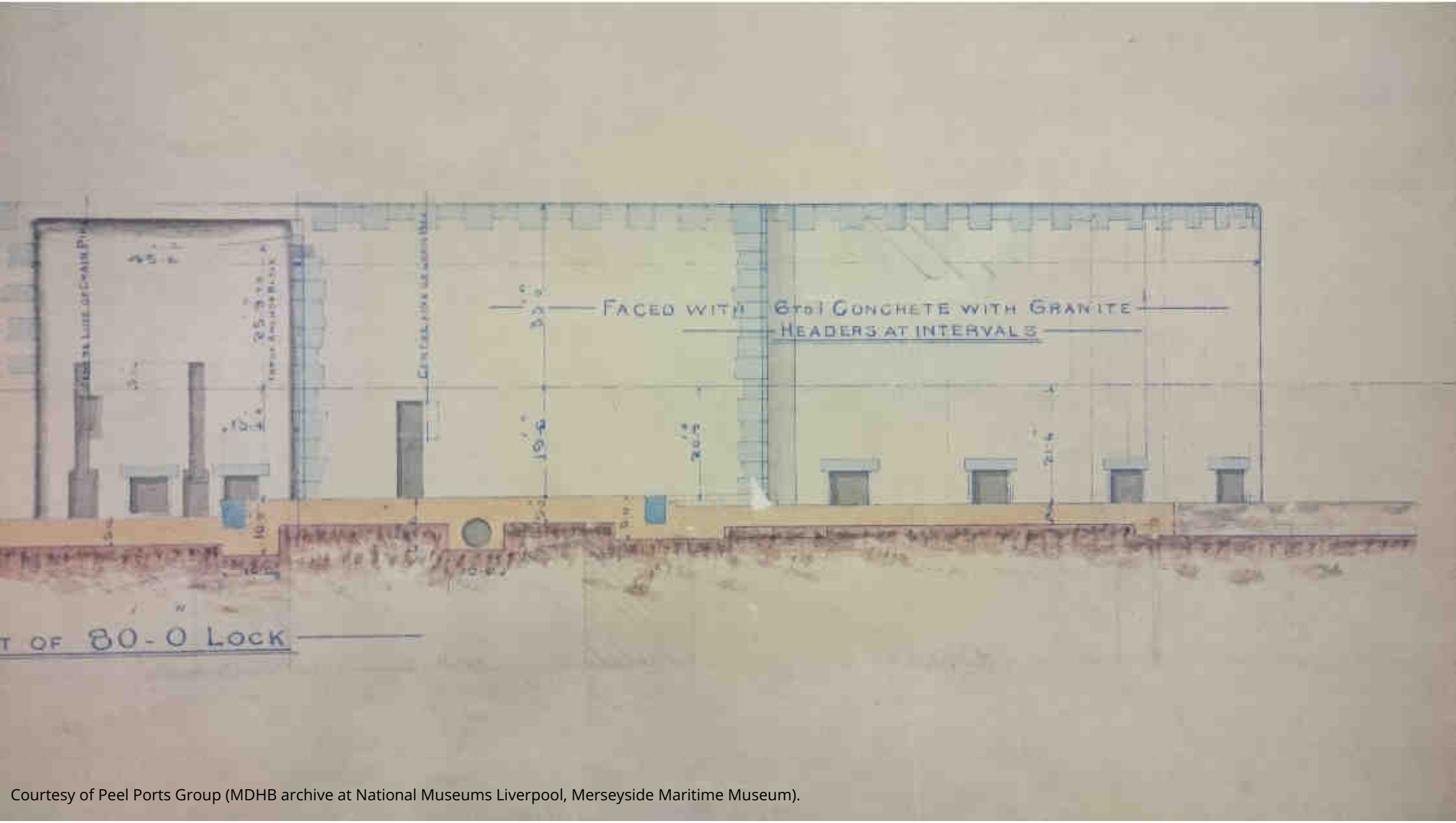


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

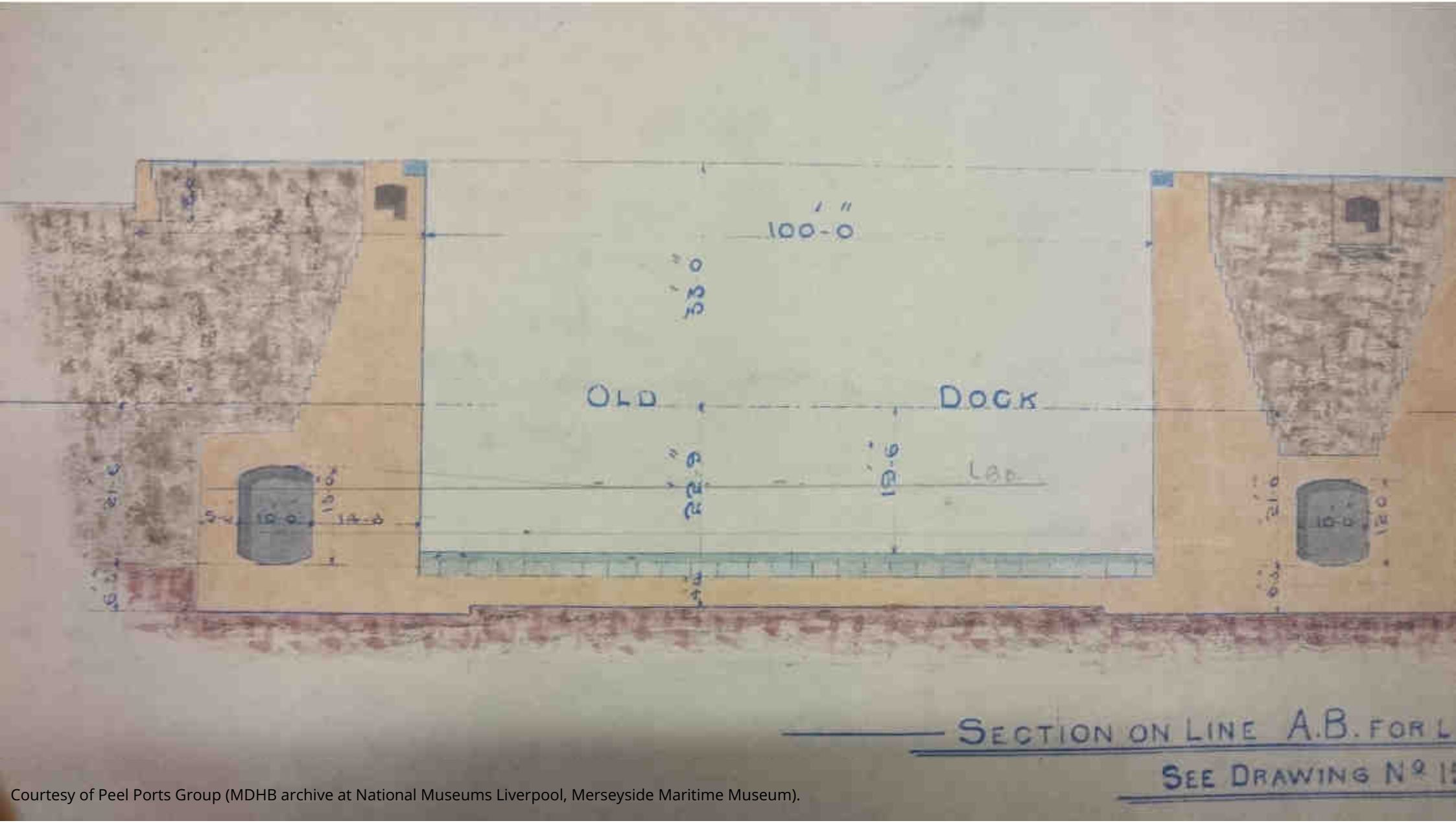
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



ELEVATION OF ISLAND LOOKING EAST OF



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



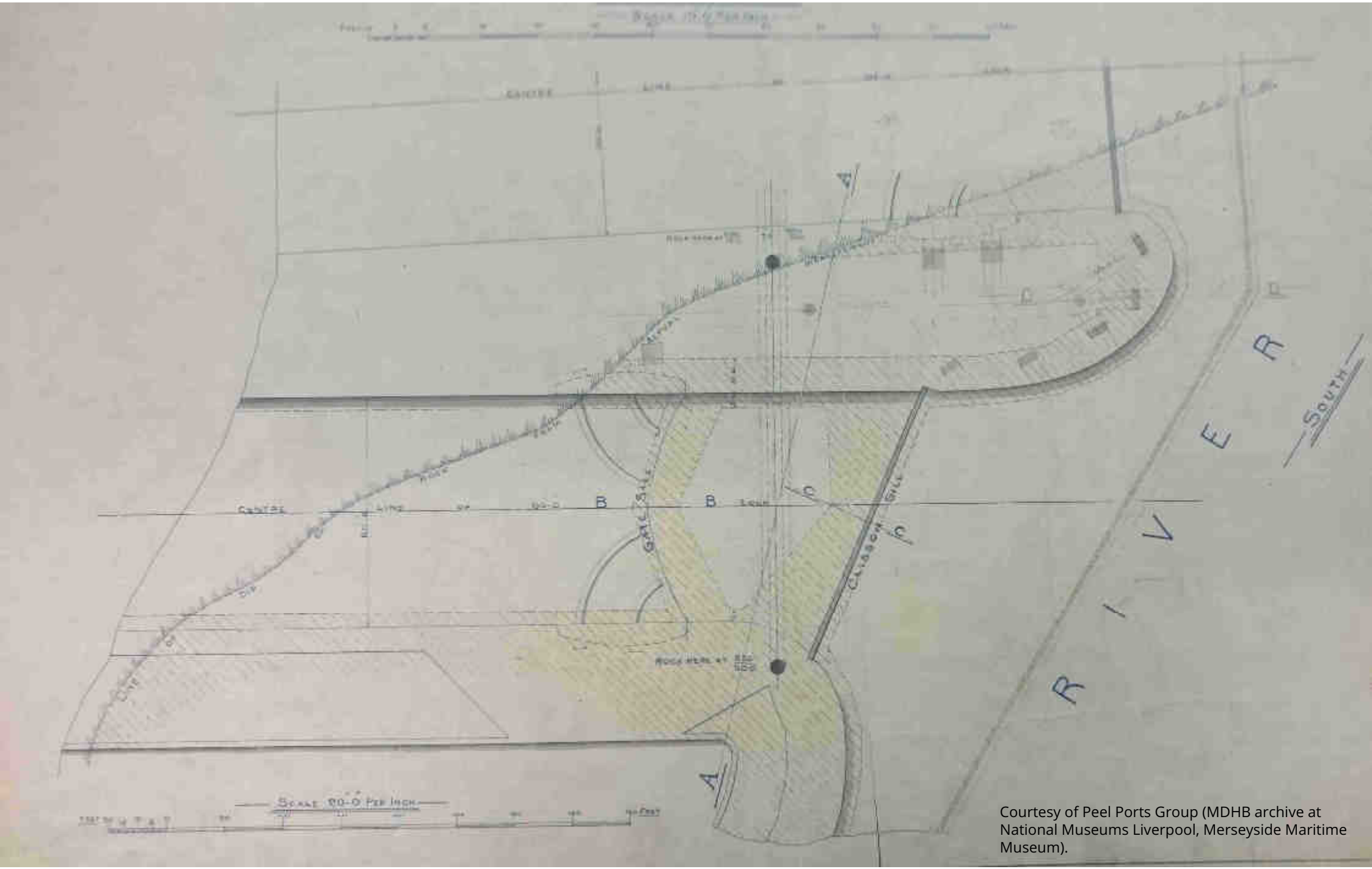
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 7

‘Foundations for Outer gate and Caisson Sill for 80’0’’ Entrance’ plan and cross sections

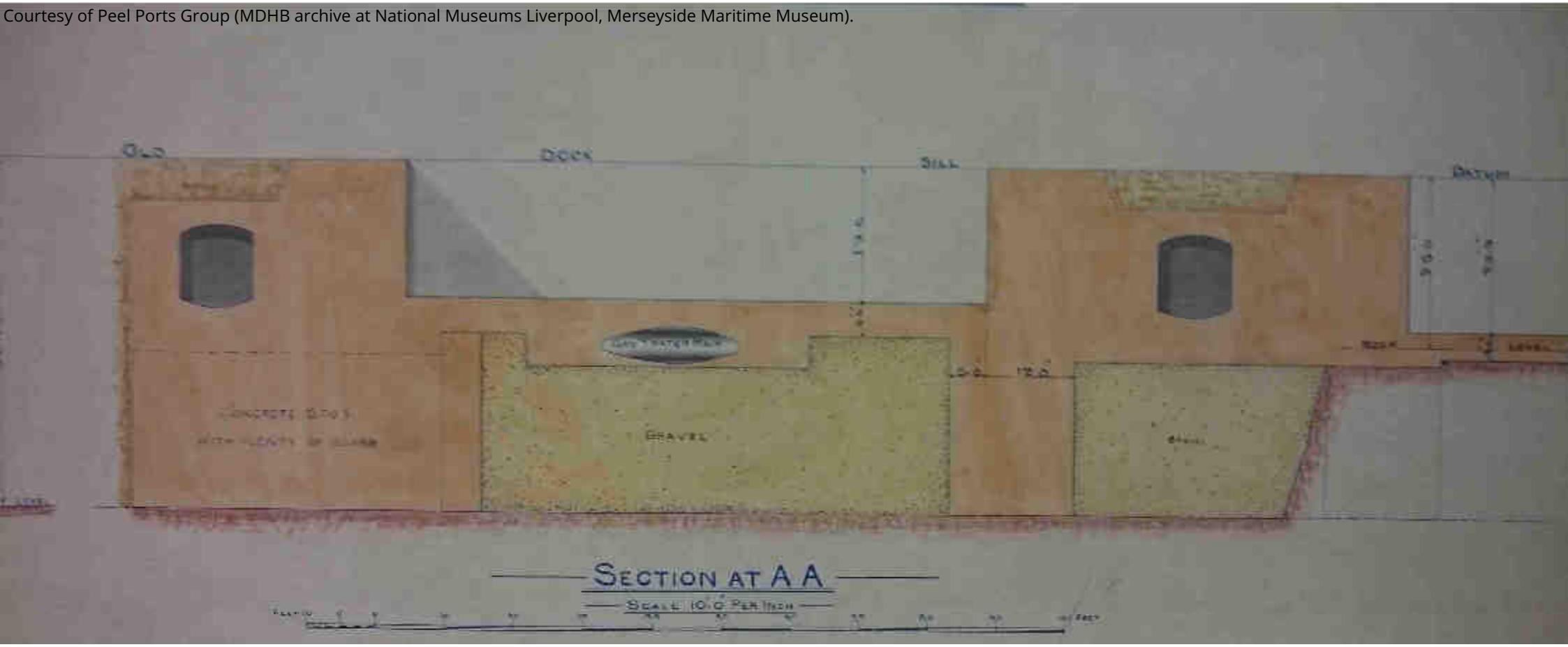
Plan view shows 80ft lock and half of 100ft lock and rock levels at end of cast iron culvert where it crosses 80ft lock. Also shows the underwater section which extends into the river to the south of the locks and the location of the timber piles which secure it. Section AA shows cross sectional view across 80ft lock and apparent rock cut beneath it to include the gas and water main, with lock construction materials including gravel and ‘8 to 1 concrete with plenty of burrs’. Section BB shows a cross section through the gate sill with rock level and base construction. Section CC shows a cross section through the caisson sill with rock level and base construction. Section DD shows a cross section through the river-facing end of the island between the locks. This shows the concrete extending past the end of the island beneath the water, which is secured to rock with 0.30m x 0.30m timber piles. Also shows culver outlet and wall construction including ‘8 to 1 concrete with plenty of burrs’.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



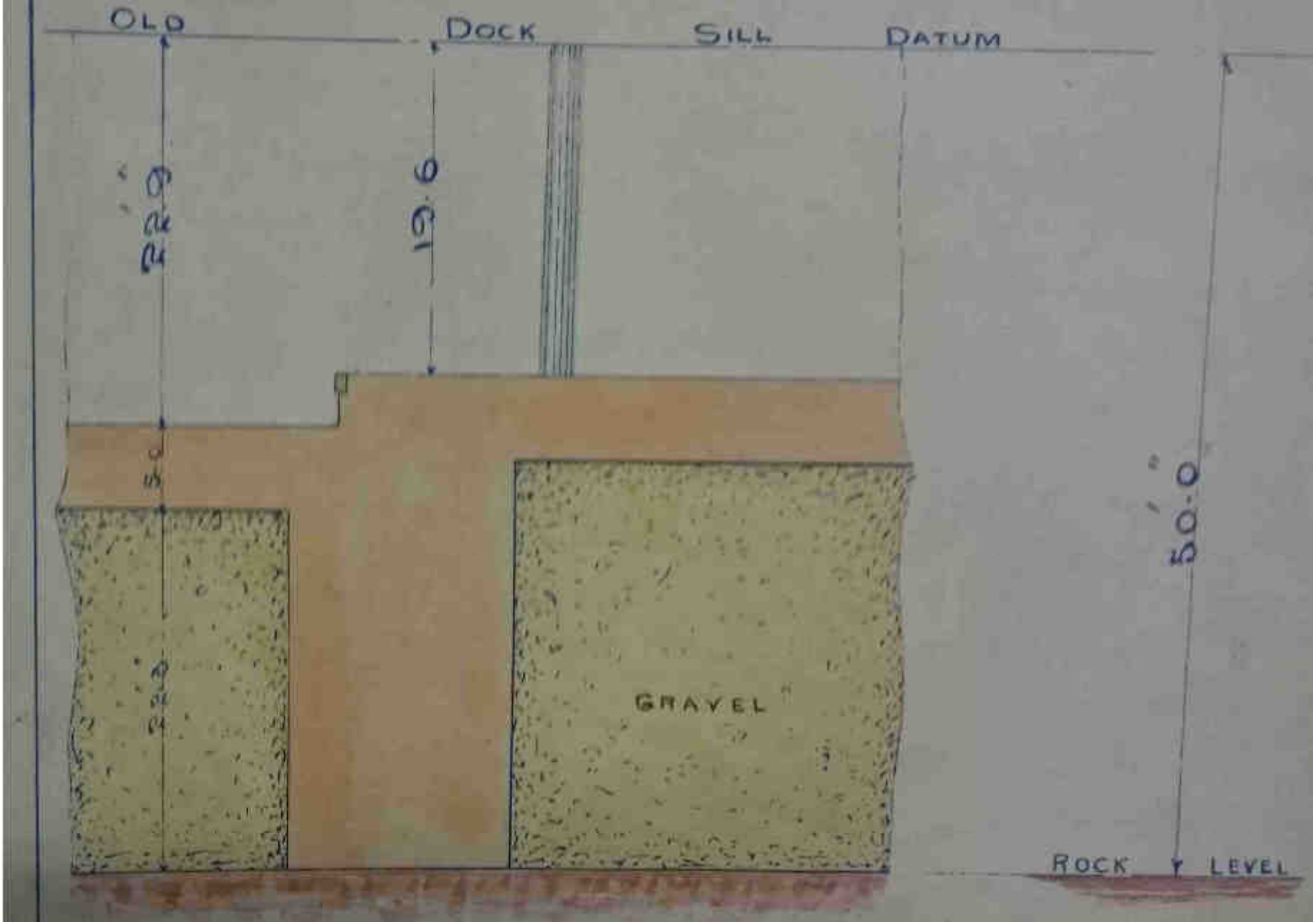
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



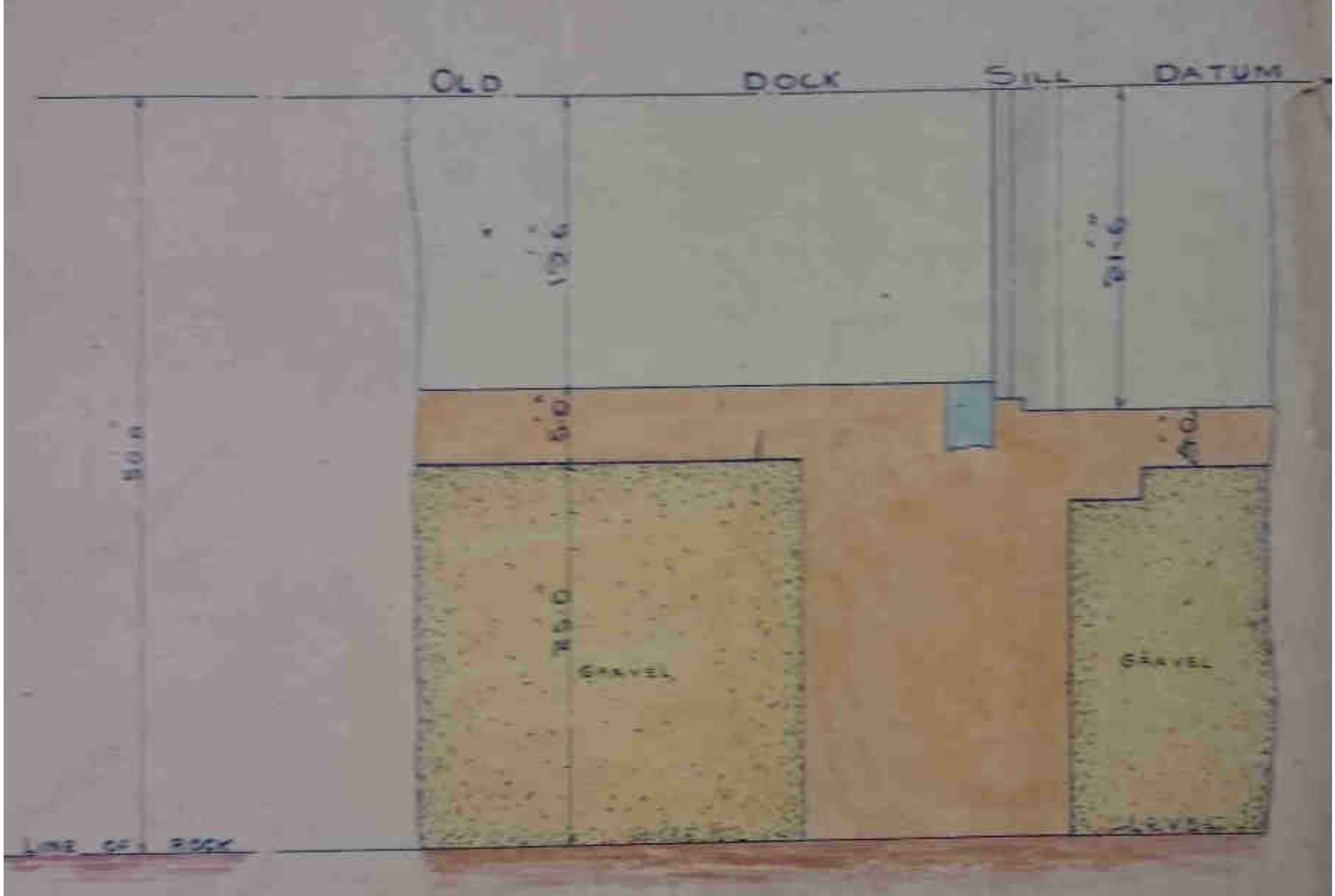
SECTION AT A A

SCALE 10.0 PER INCH



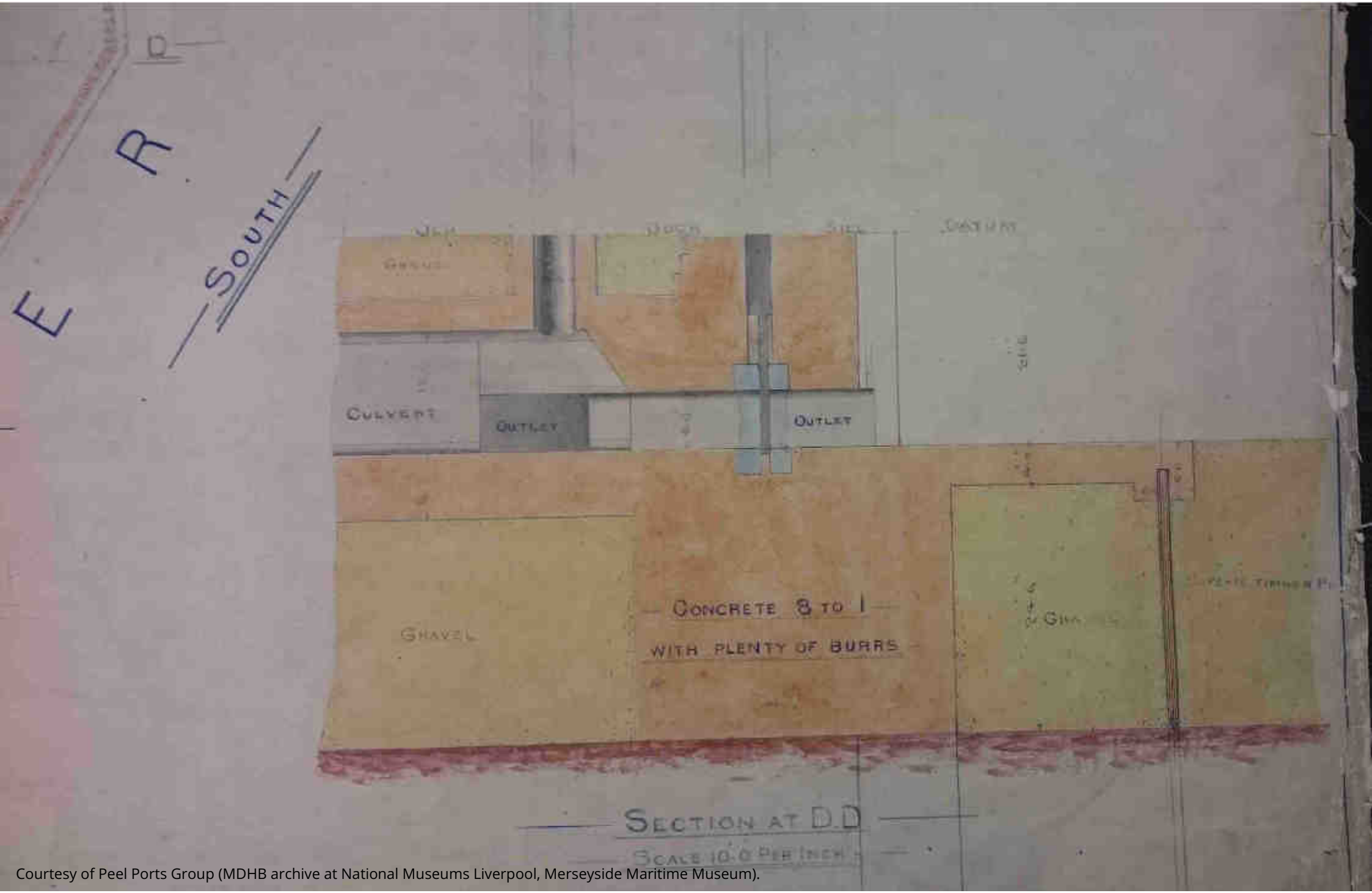
SECTION AT B B

GATE SILL



SECTION AT OC
CAISSON SILL

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Resource 8

‘Plan, Elevation & Section of Intended River Entrances Into Brunswick Dock’

Note: *this plan is an **intended** layout and as such, the final construction detail may have deviated from this.*

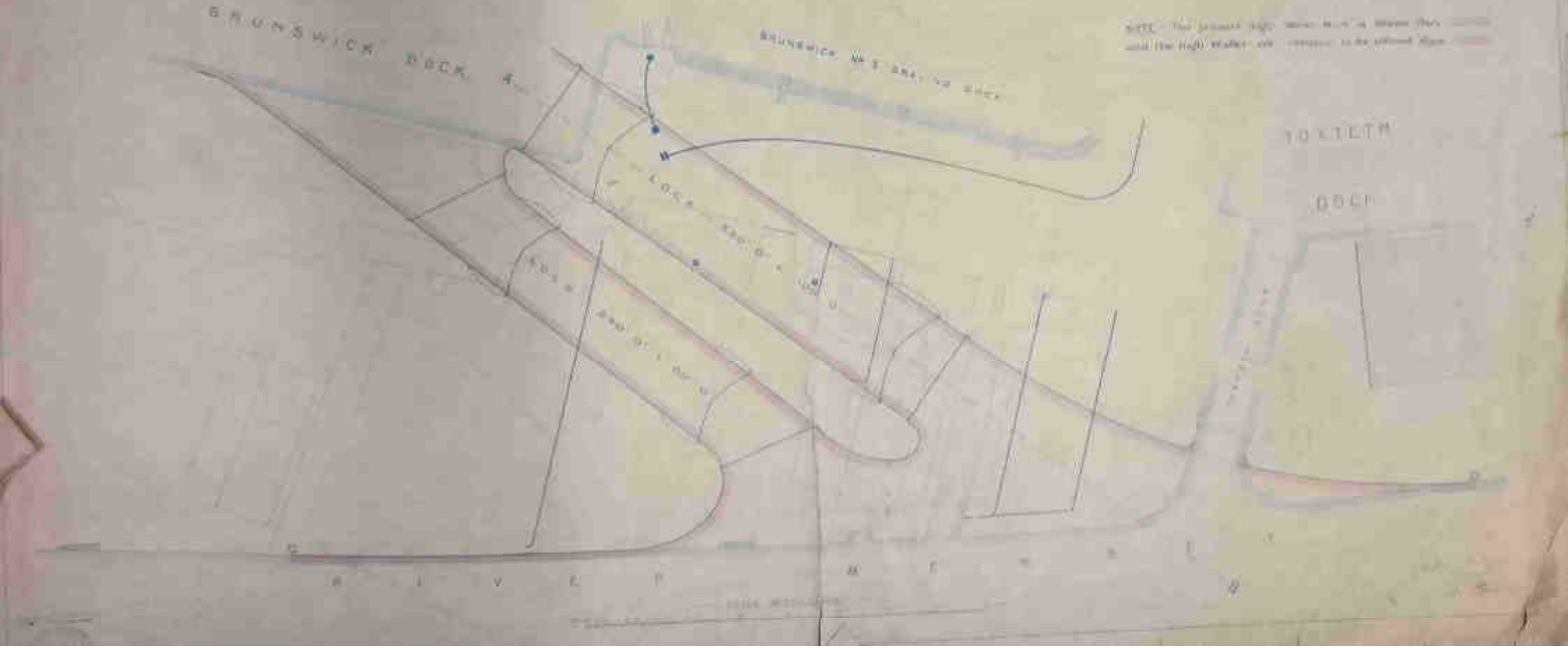
Plan shows Brunswick Locks and Brunswick No. 2 Graving Dock. Section AB shows the eastern wall of the 100ft lock and river wall, along to Toxteth Lock to the south. Indented layouts and the mean tide level is given. Section CD shows a cross section of the Brunswick Locks entrances and Toxteth Lock. This section shows the approximate rock level (red shading).

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

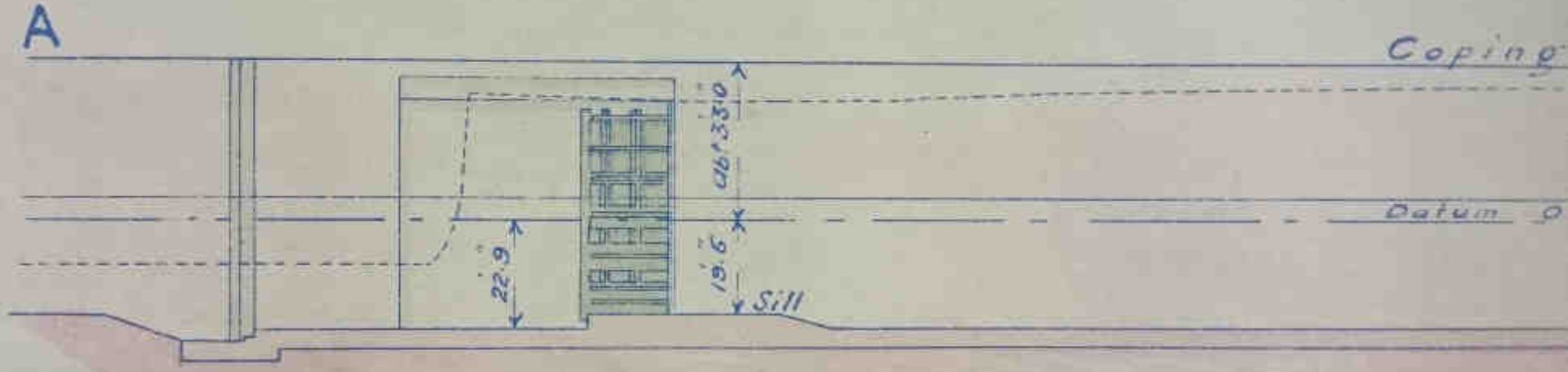
SOUTHERN WORKS – ACT 1898.

PLAN, ELEVATION & SECTION OF INTENDED RIVER ENTRANCES INTO BRUNSWICK DOCK.

WORK O



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



& SECTION OF INTEN
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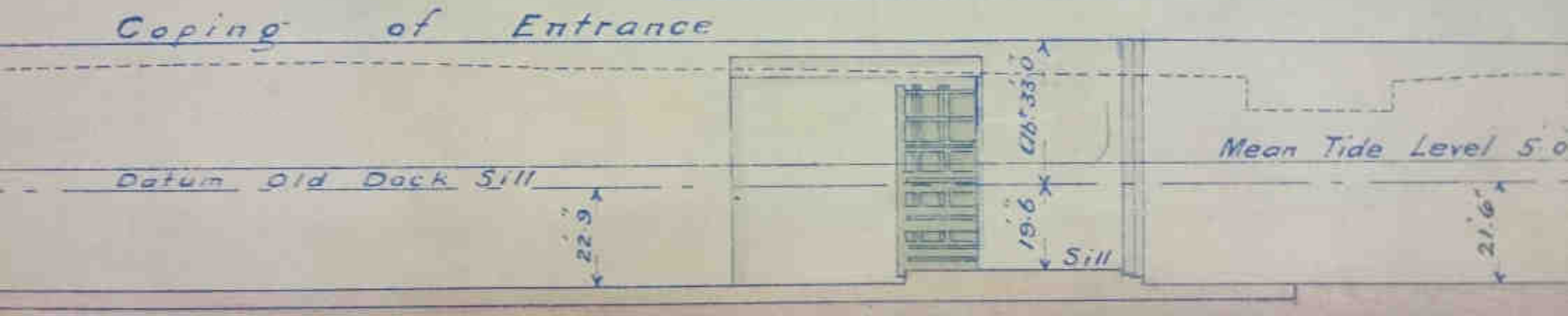
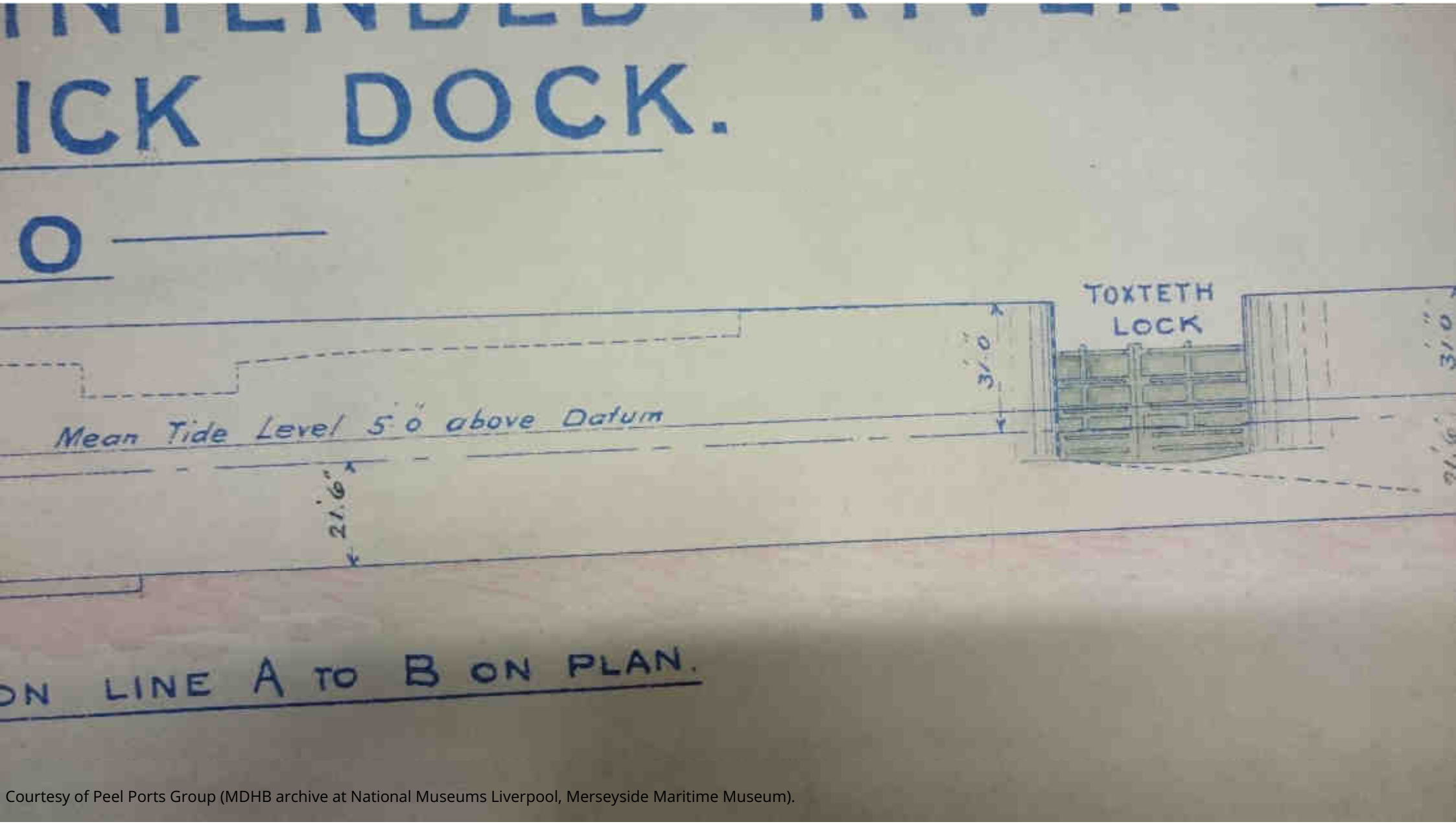


SECTIONAL ELEVATION ON LINE A TO E



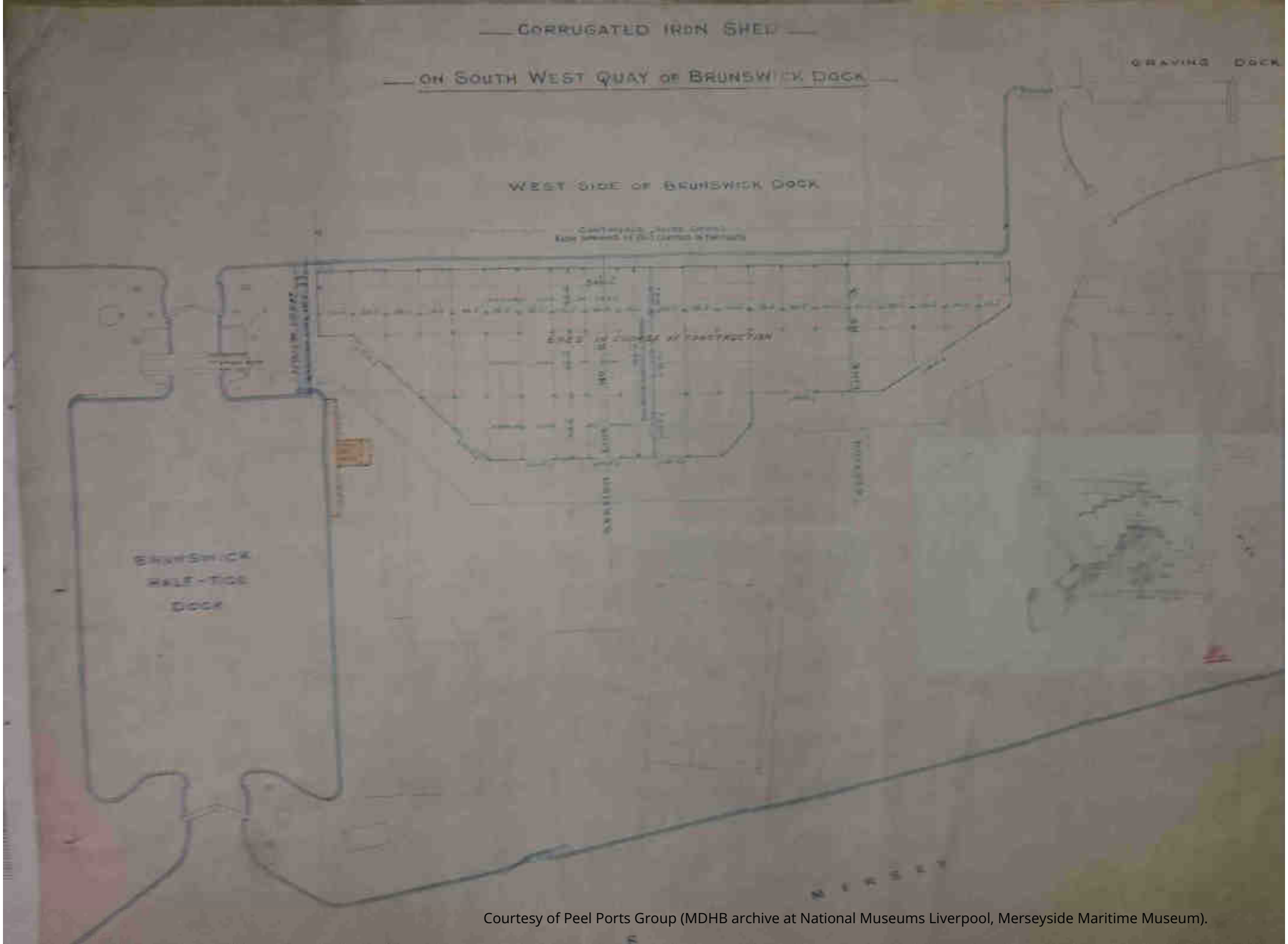
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 9

Plan of land to the west of Brunswick Dock

Plan shows the northern part of the site before the Brunswick Locks were constructed. Brunswick Half Tide Dock is included, and the industrial ‘shed’ present to the immediate north of the site.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

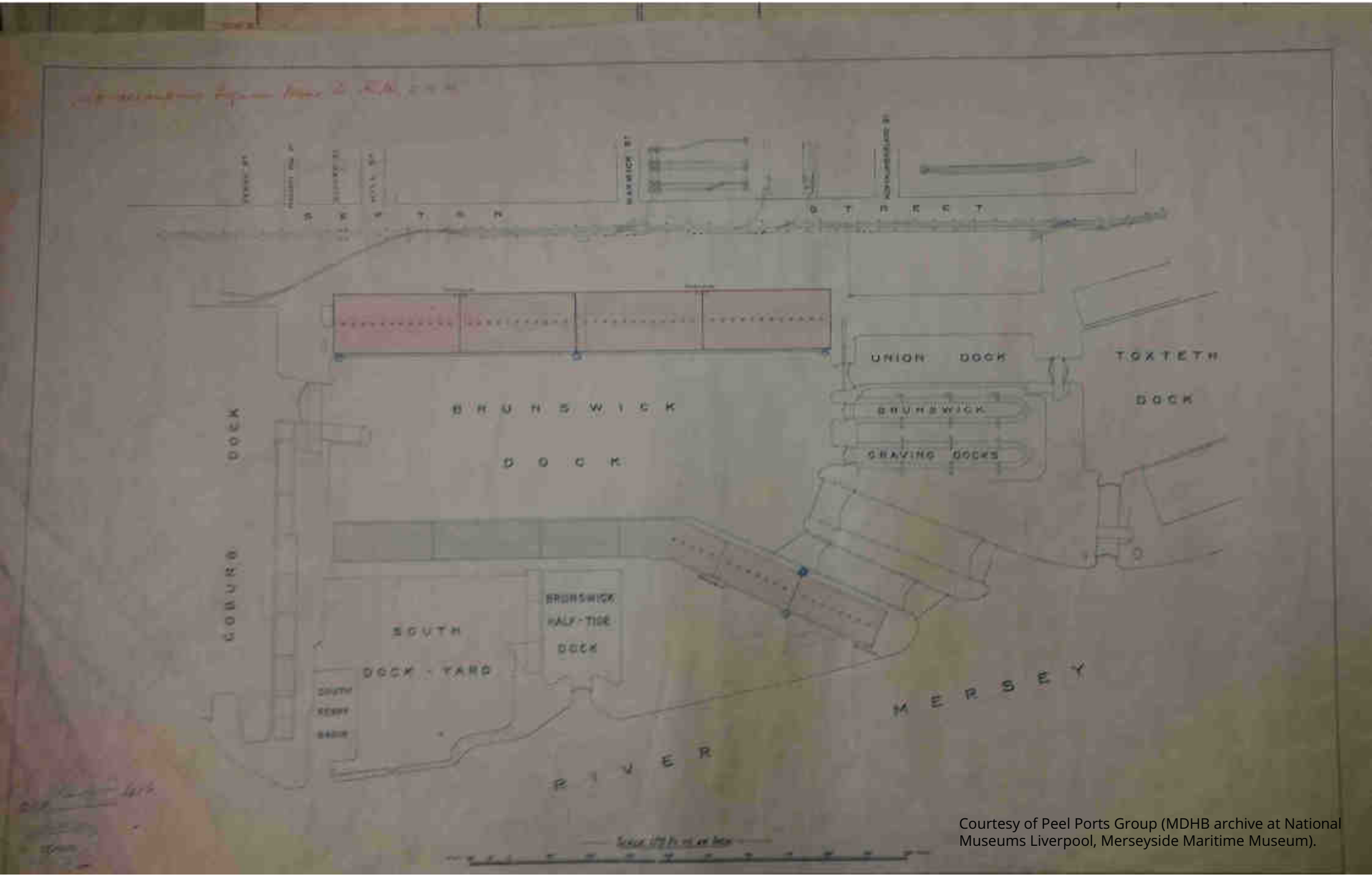


Resource 10

Plan of Brunswick Dock

Plan shows the site post-construction of the Brunswick Locks. Brunswick no. 2 Graving Dock is present on site. Brunswick Dock is surrounded by industrial warehouses to the east and west. Union dock connects Brunswick Dock to Toxteth Dock to the South. Brunswick Dock is connected directly to Coburg Dock to the north.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



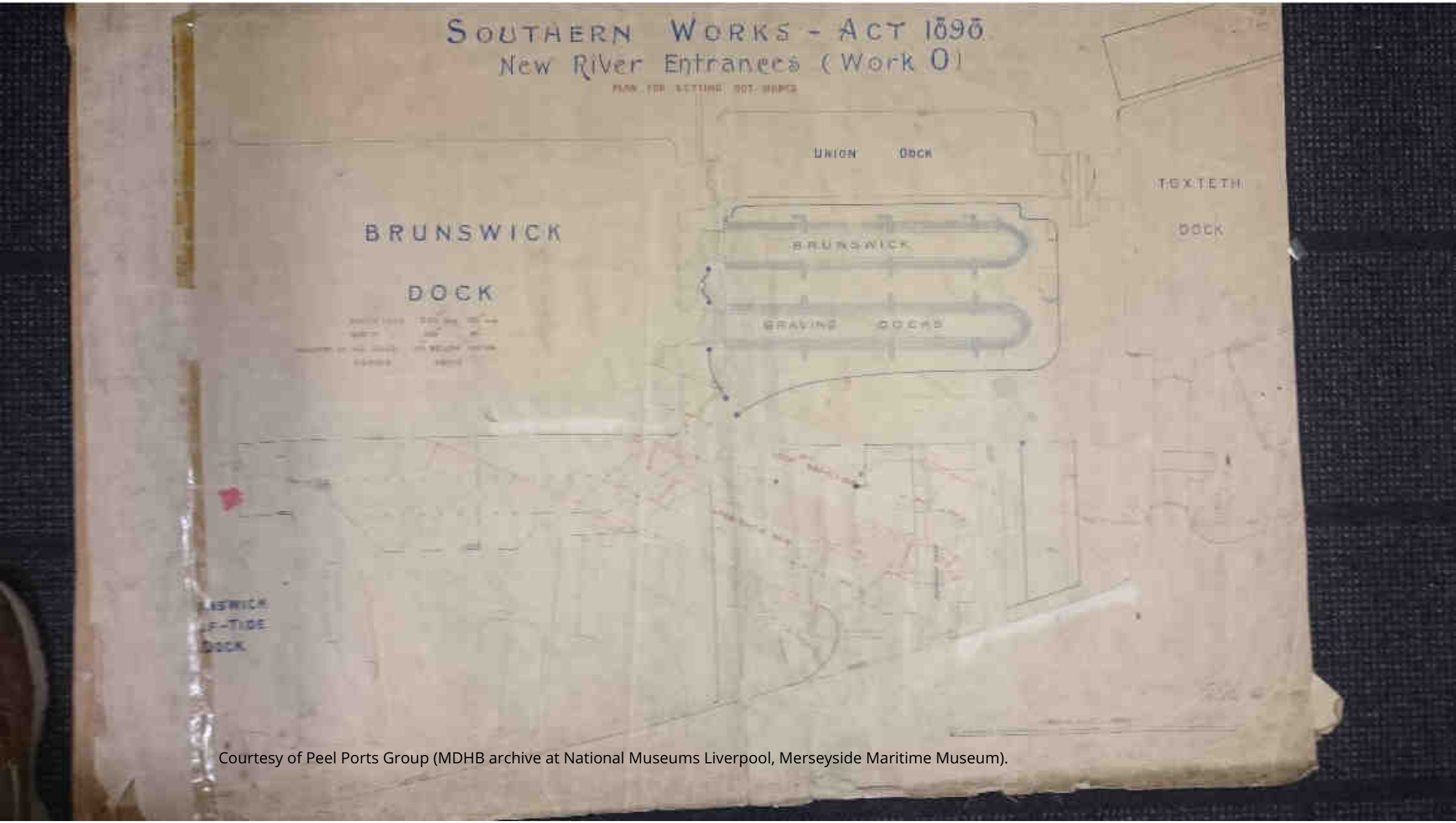
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 11

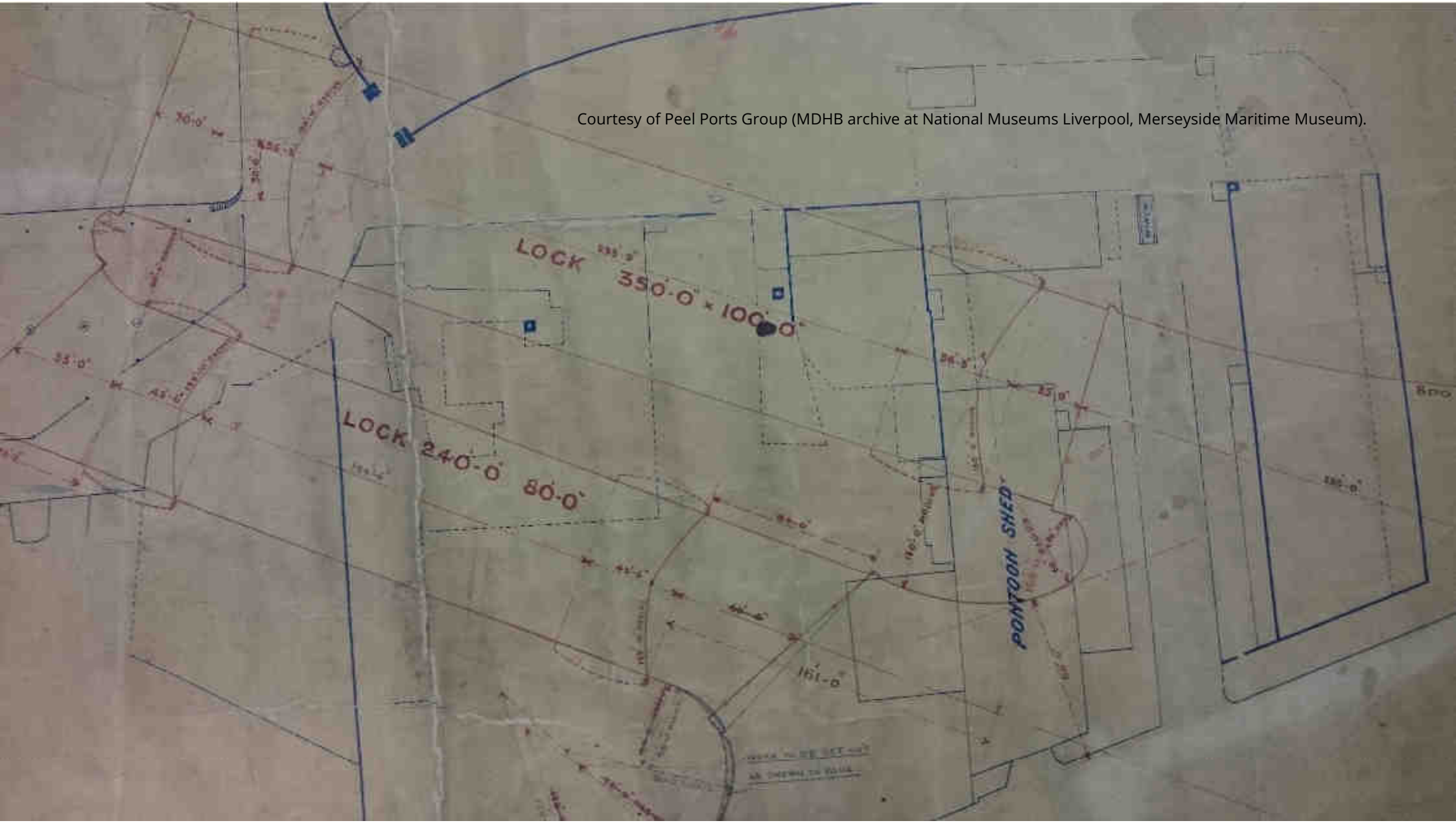
‘Plan for Setting Out Works’

Plan shows overlay of planned Brunswick Locks over land and previous buildings on which they were to be built.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



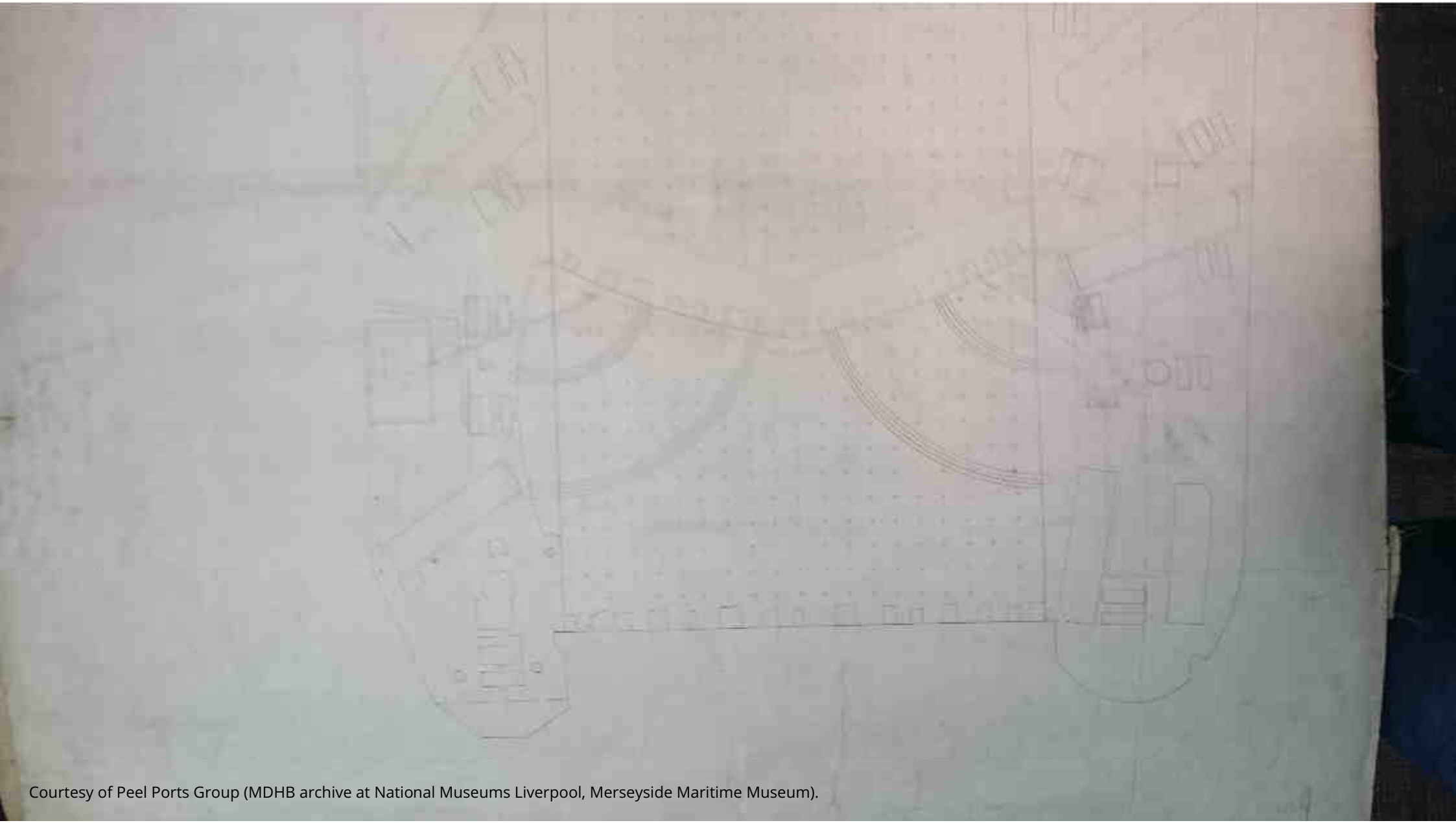
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 12

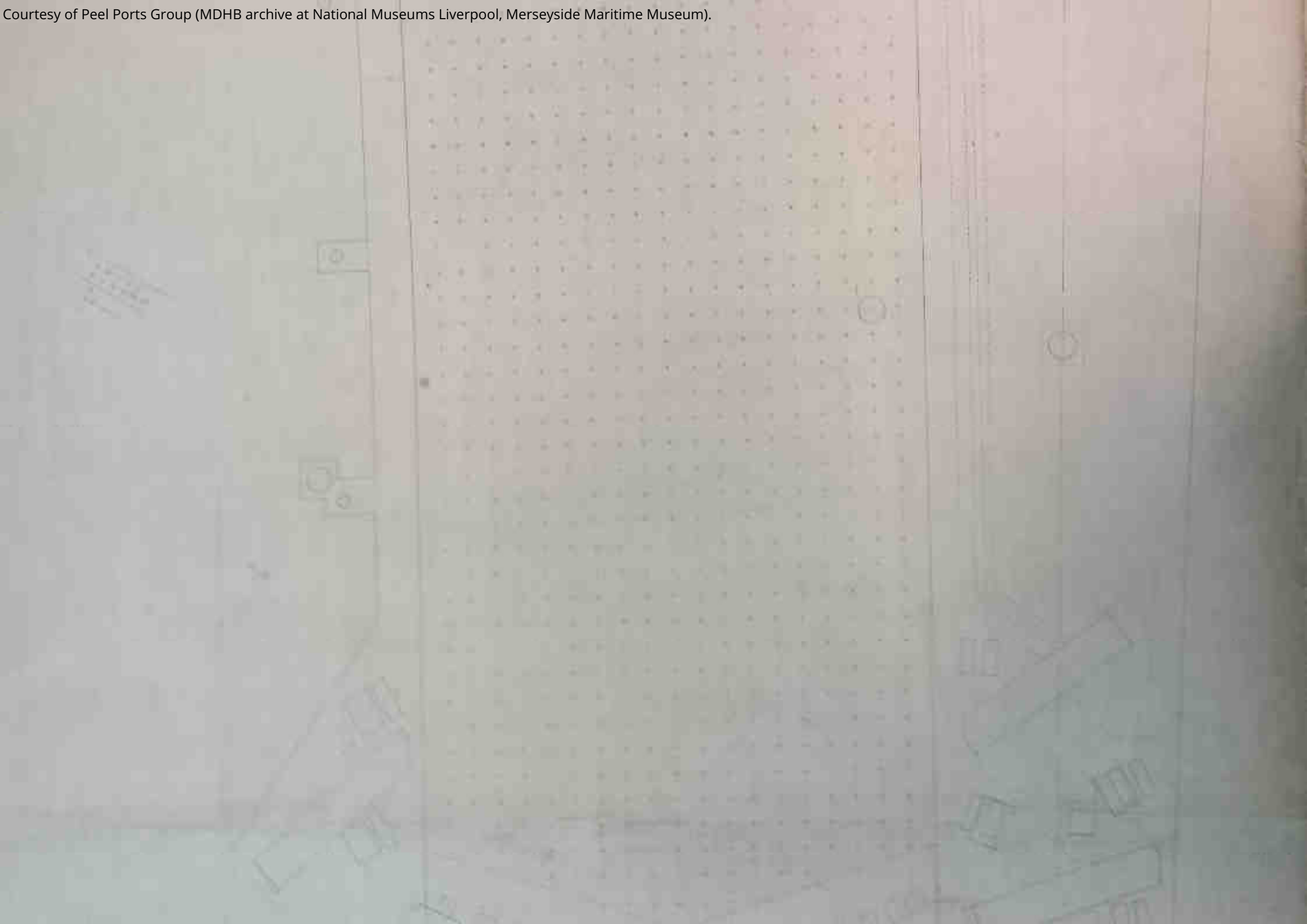
Possible foundation plan for base of 100ft lock

A long plan shows the 100ft lock in detail. Many small, evenly spaced dots are present along its length – these are conjectured to be the locations of timber piled foundations.

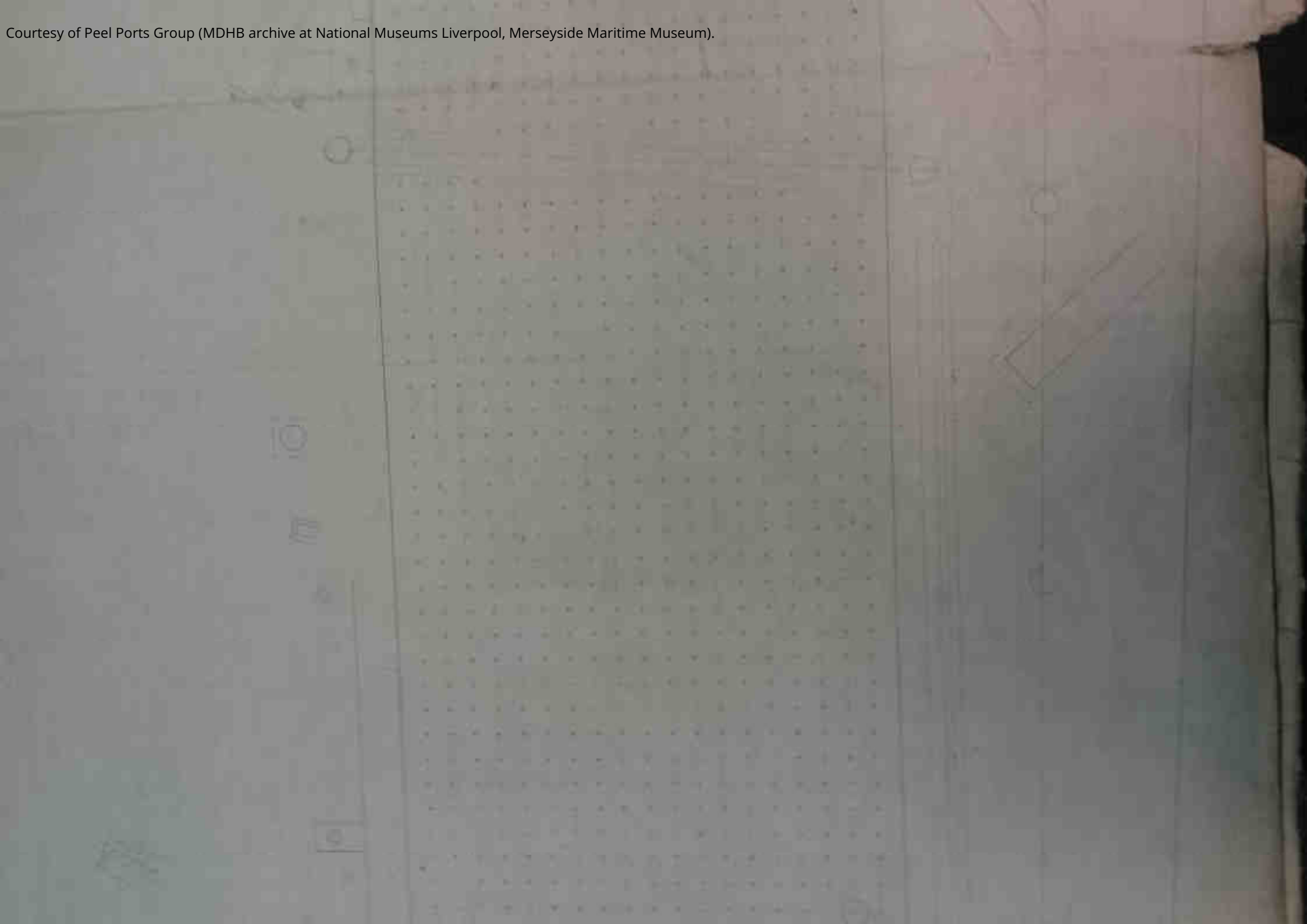
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

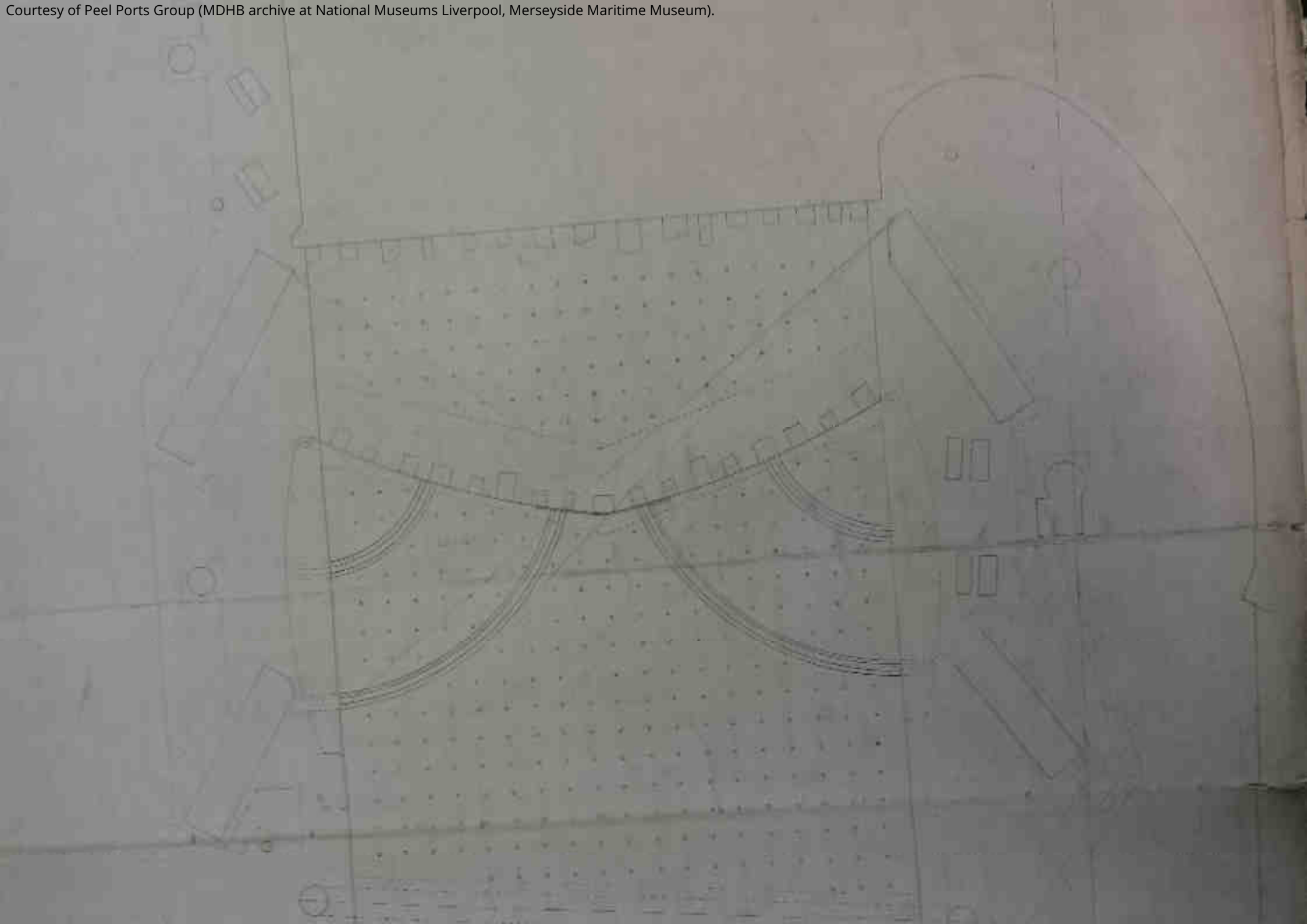


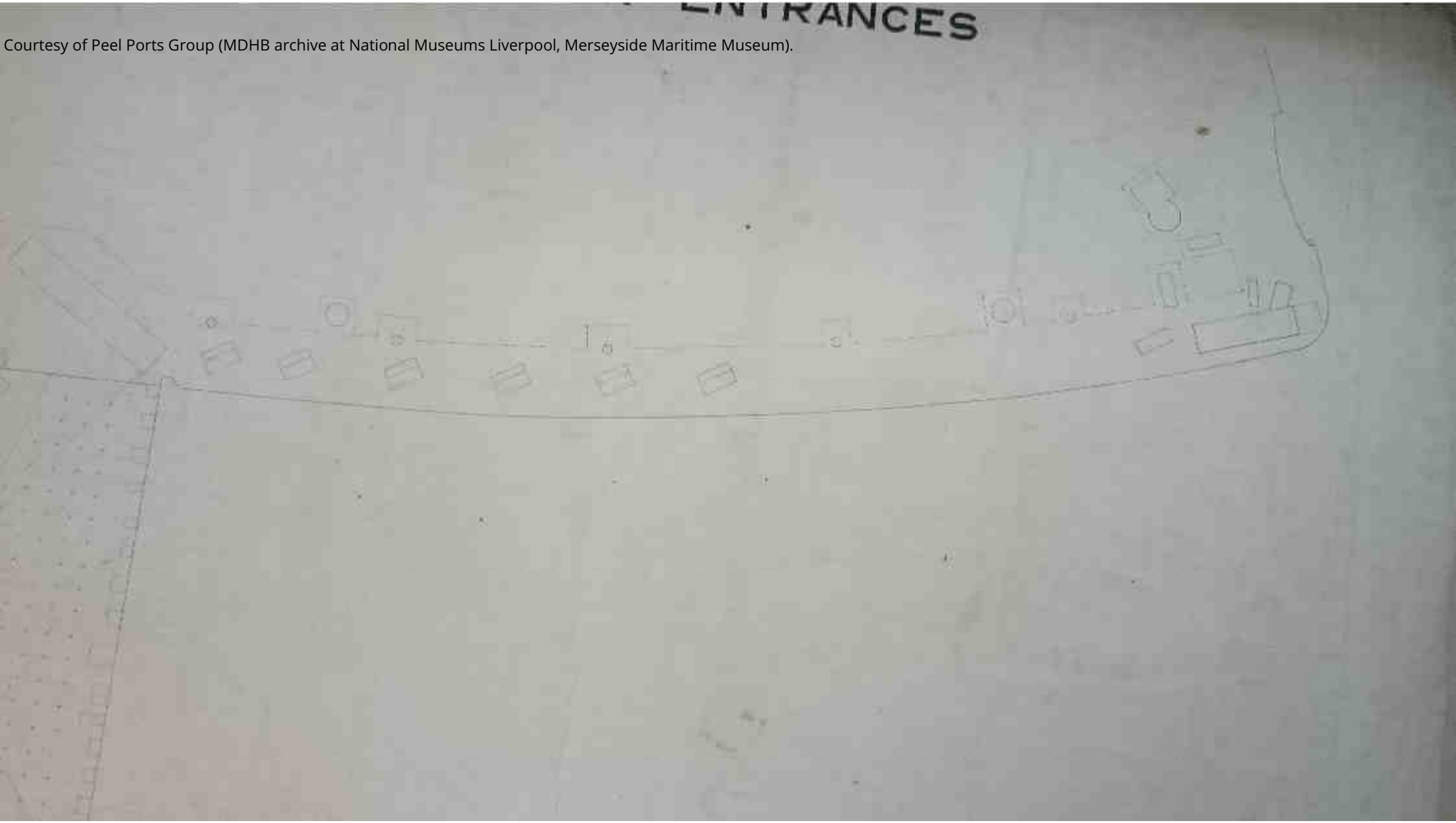
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).





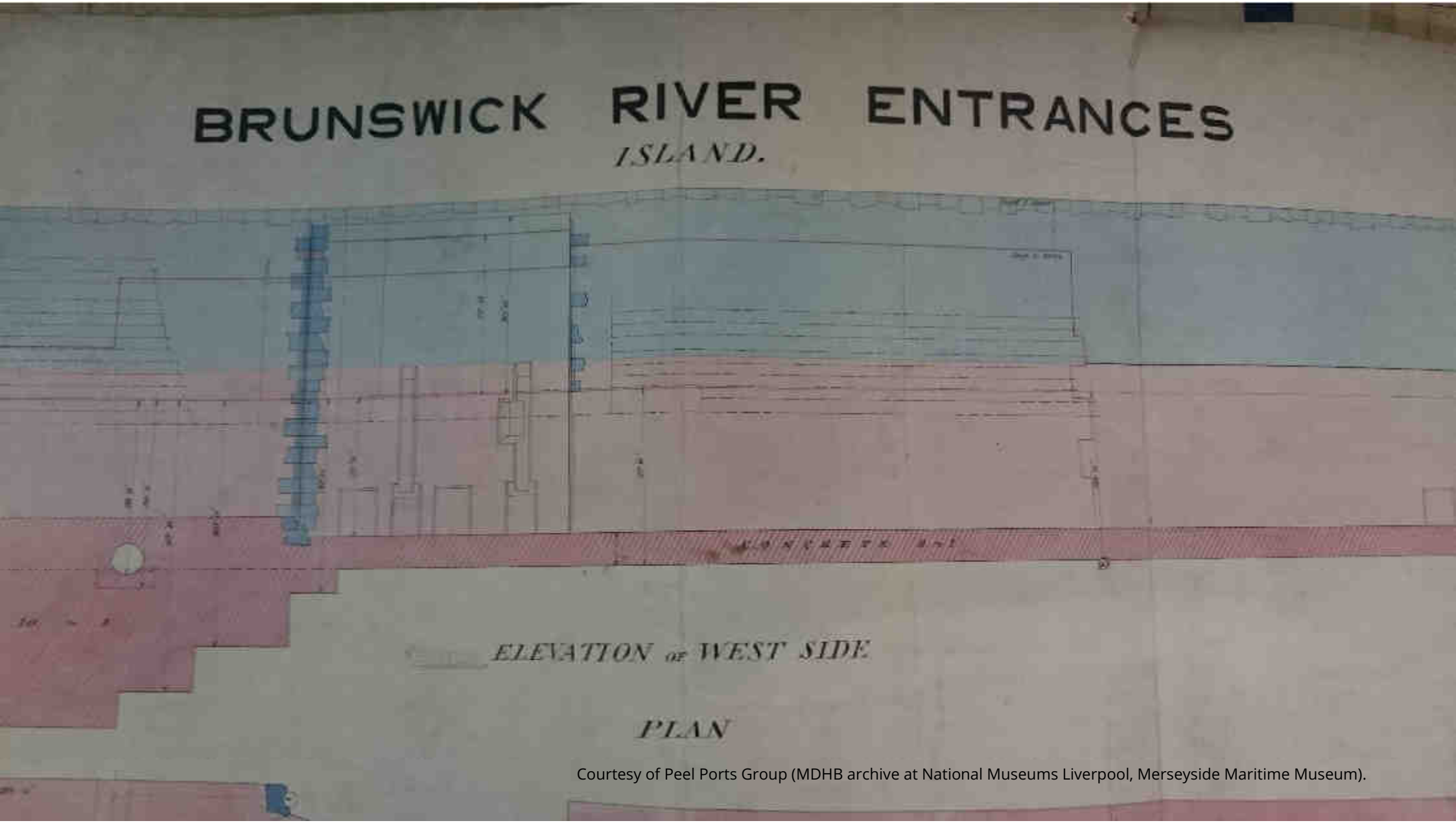
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 13

‘Brunswick River Entrances: Island’ plan and cross sections

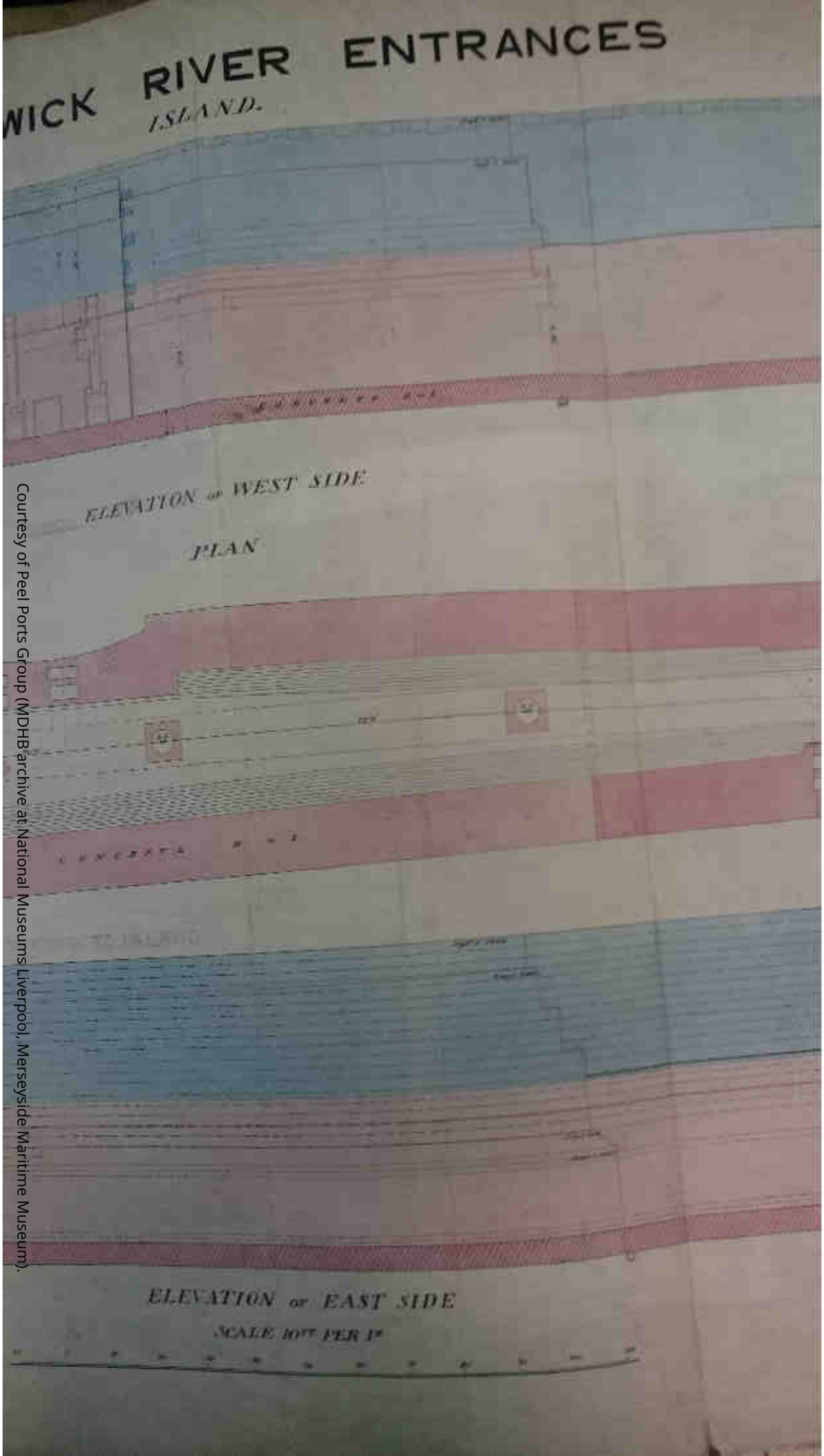
Cross sections show the west side and east side walls of the island between the Brunswick Locks. Plan view shows island construction. The river-facing end of the island has a significant thickness of concrete beneath it, presumably to act as a breaker for the head of river water. The concrete is either 10 to 1 or 8 to 1 and various sub surface features are founded upon it.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



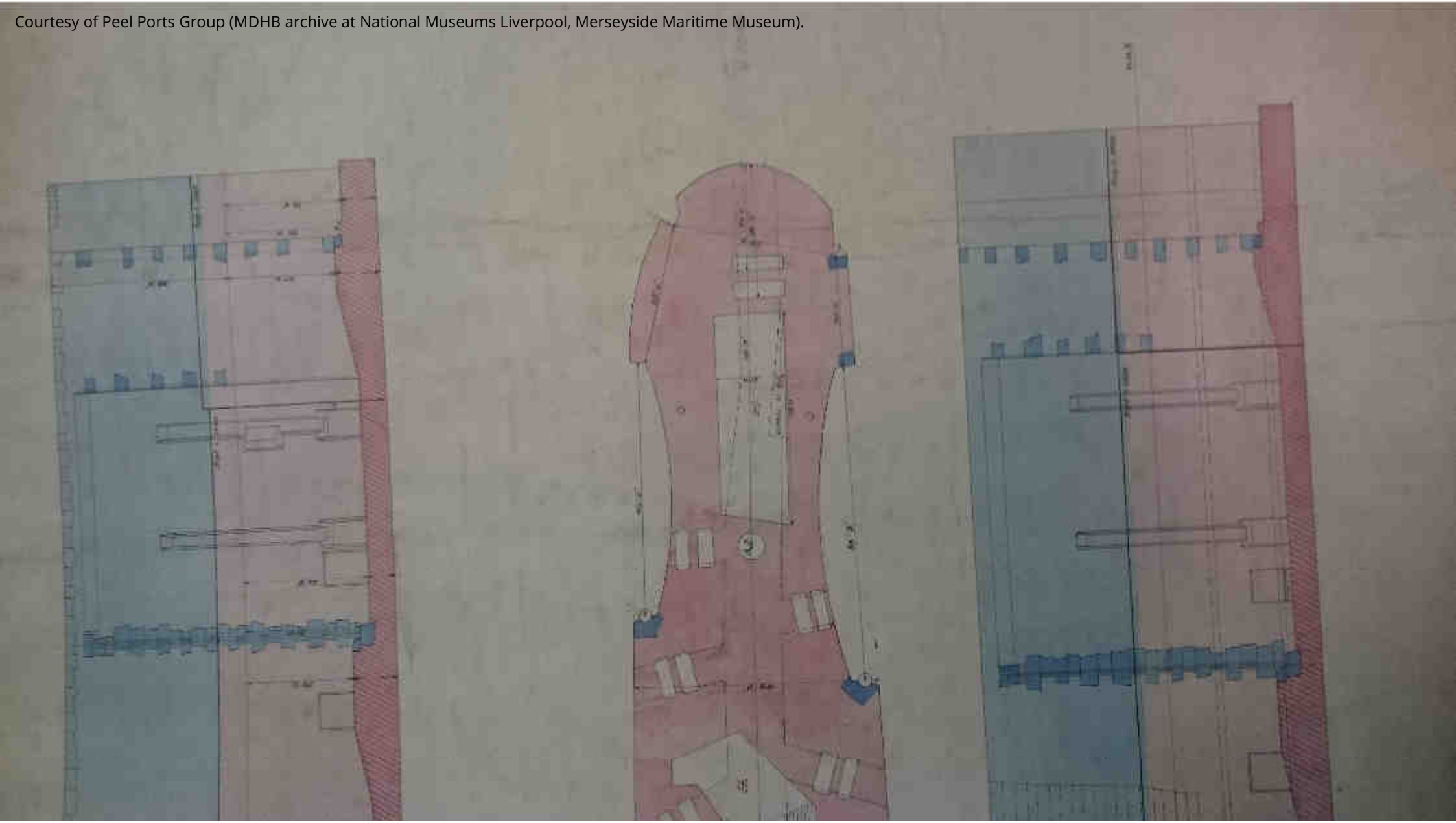
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Resource 14

‘Brunswick River Entrances Foundation Plan’

Plan view shows the depths of foundations of the 100ft lock, its walls, the 80ft lock, its walls and the island between them. The depths are given in feet below ODS (Old Dock Sill, 10.06m bgl). Most parts are formed on rock (pink), except the southern-most part of the island and roughly the southern half of the 80ft lock are founded on gravel. Some parts are labelled with the date they were constructed.

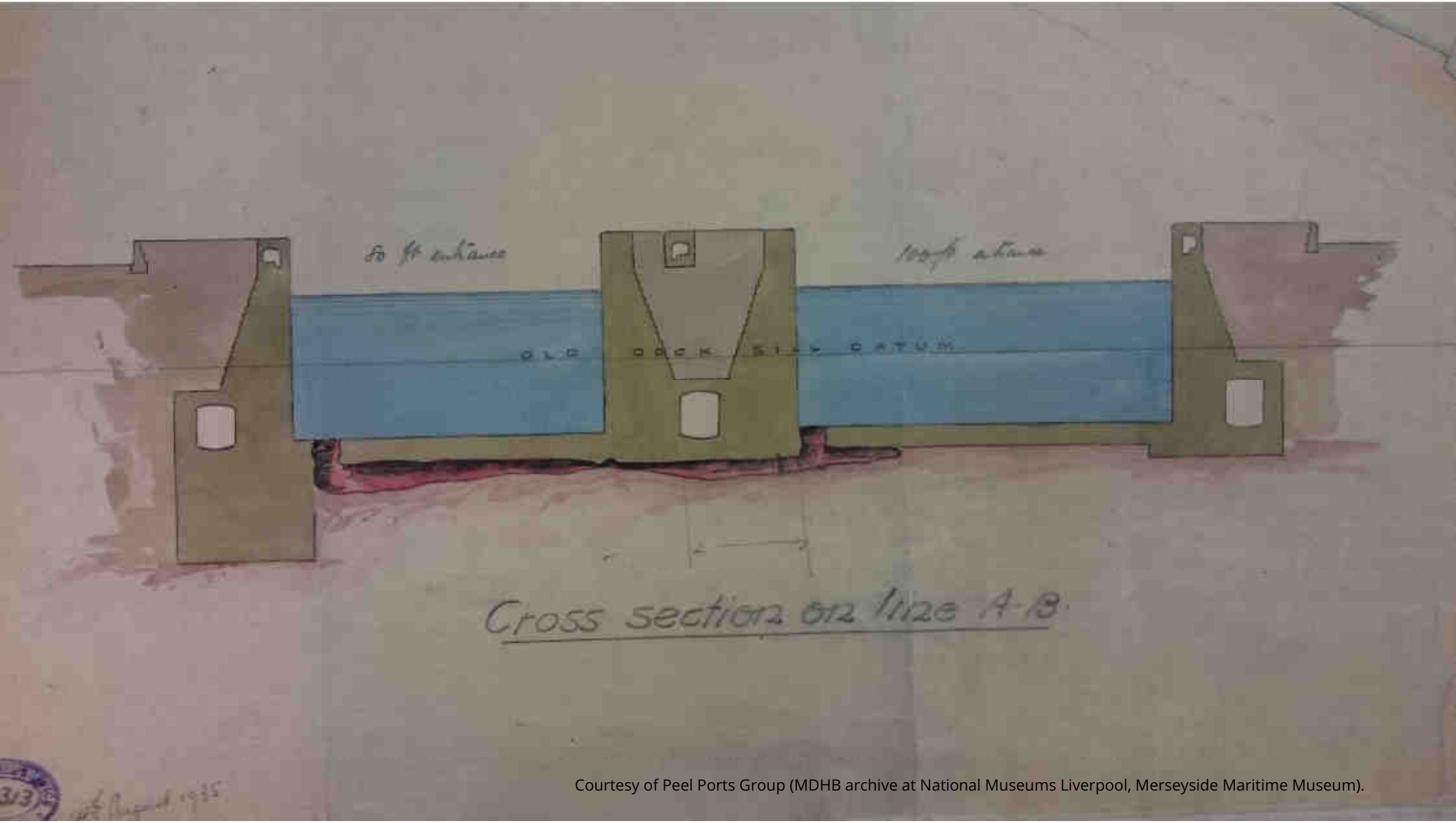
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Resource 15

‘Brunswick 100ft River Entrance: Examination of floor of lock March 1926’ plan, plan of damage to underside of 100ft and 80ft locks and section AB.

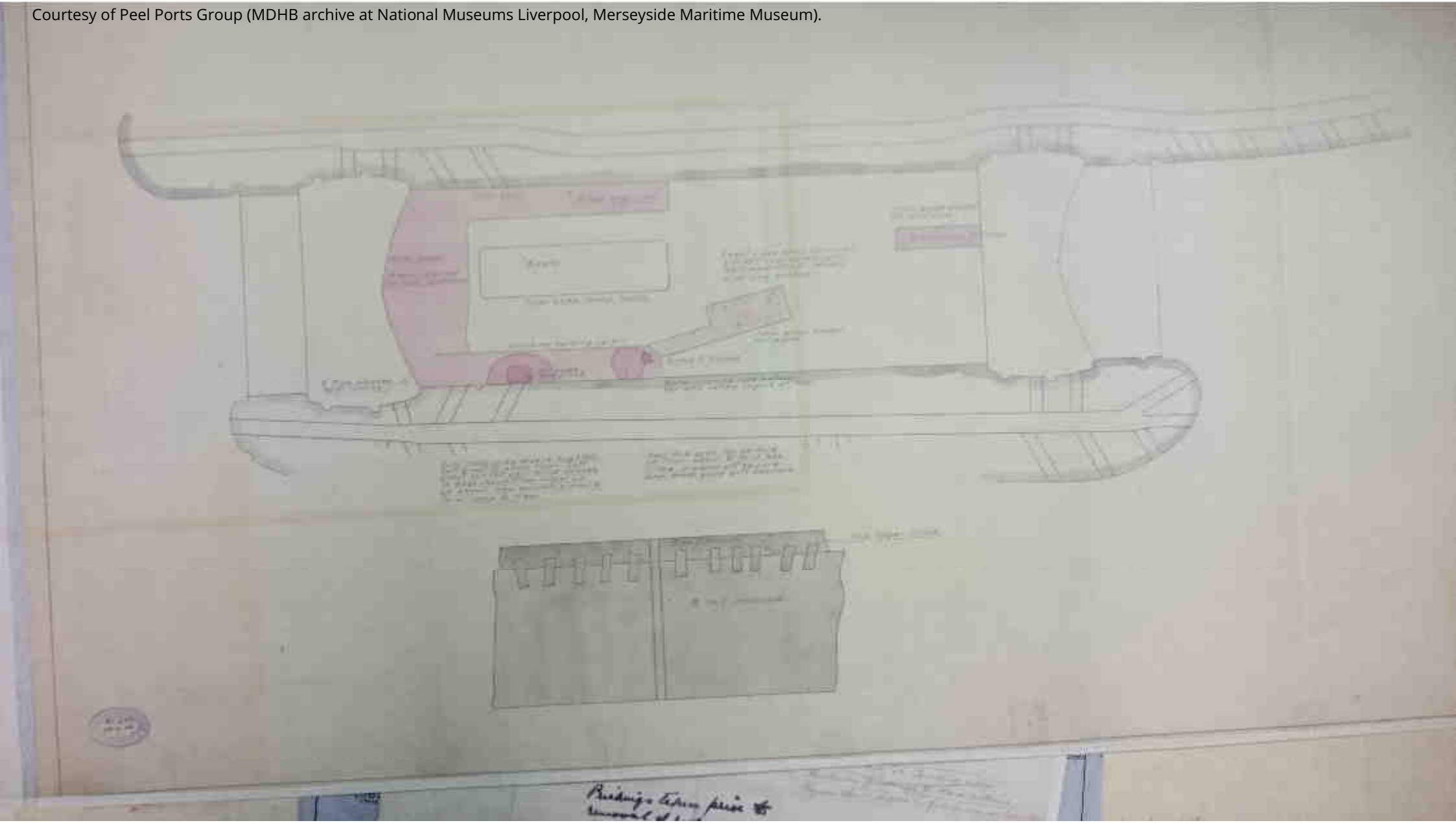
Plan details damage to lock floor as reported by divers. Some of the concrete was reported as damaged and was repaired, indicating that the thickness of the concrete lock floor may be of variable thickness and quality. Another plan shows damage to the underside of both locks; this is unlabelled but is possibly water ingress where the locks are not completely watertight. This plan is also shown in section.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Cross section on line A-B.

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

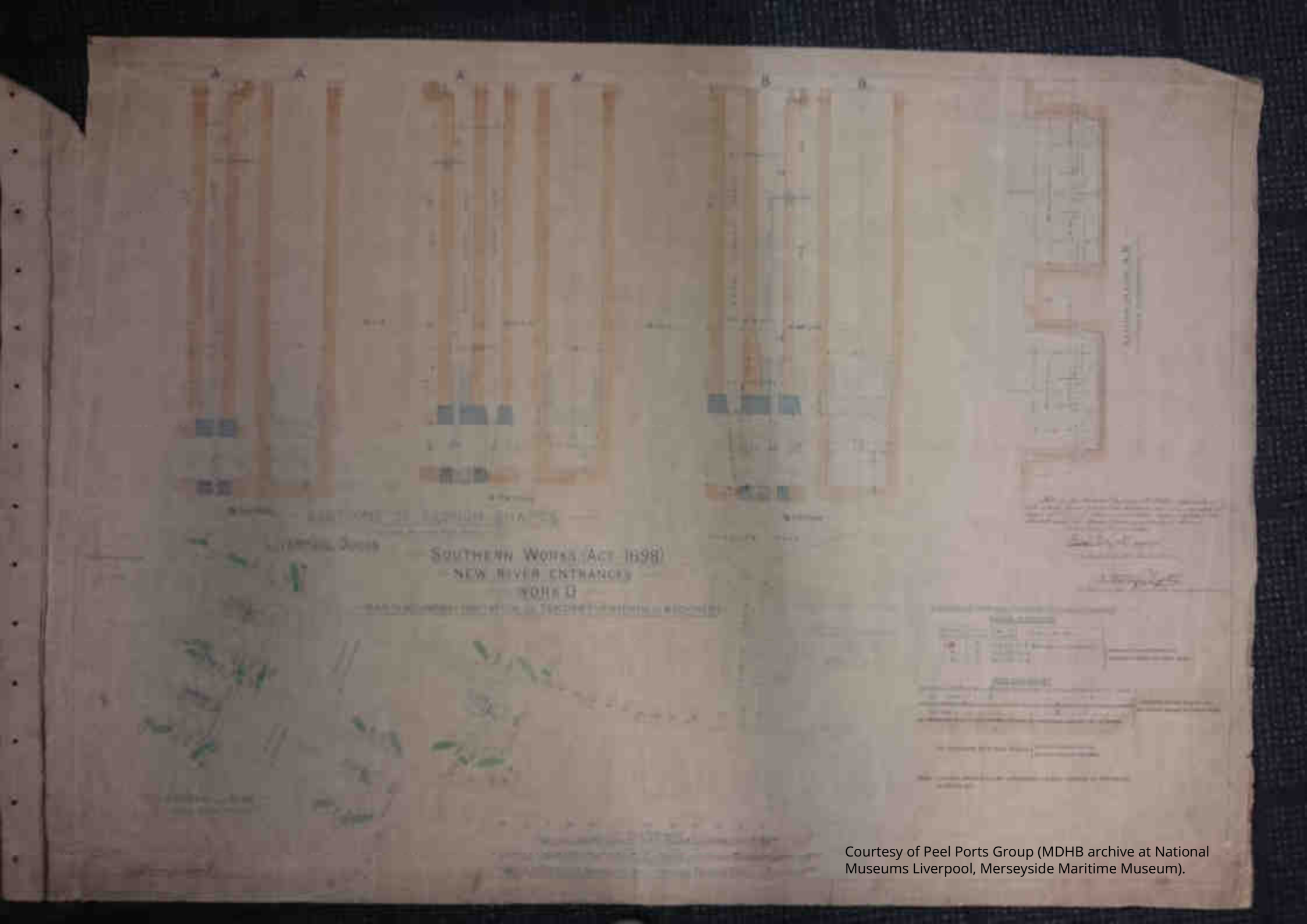


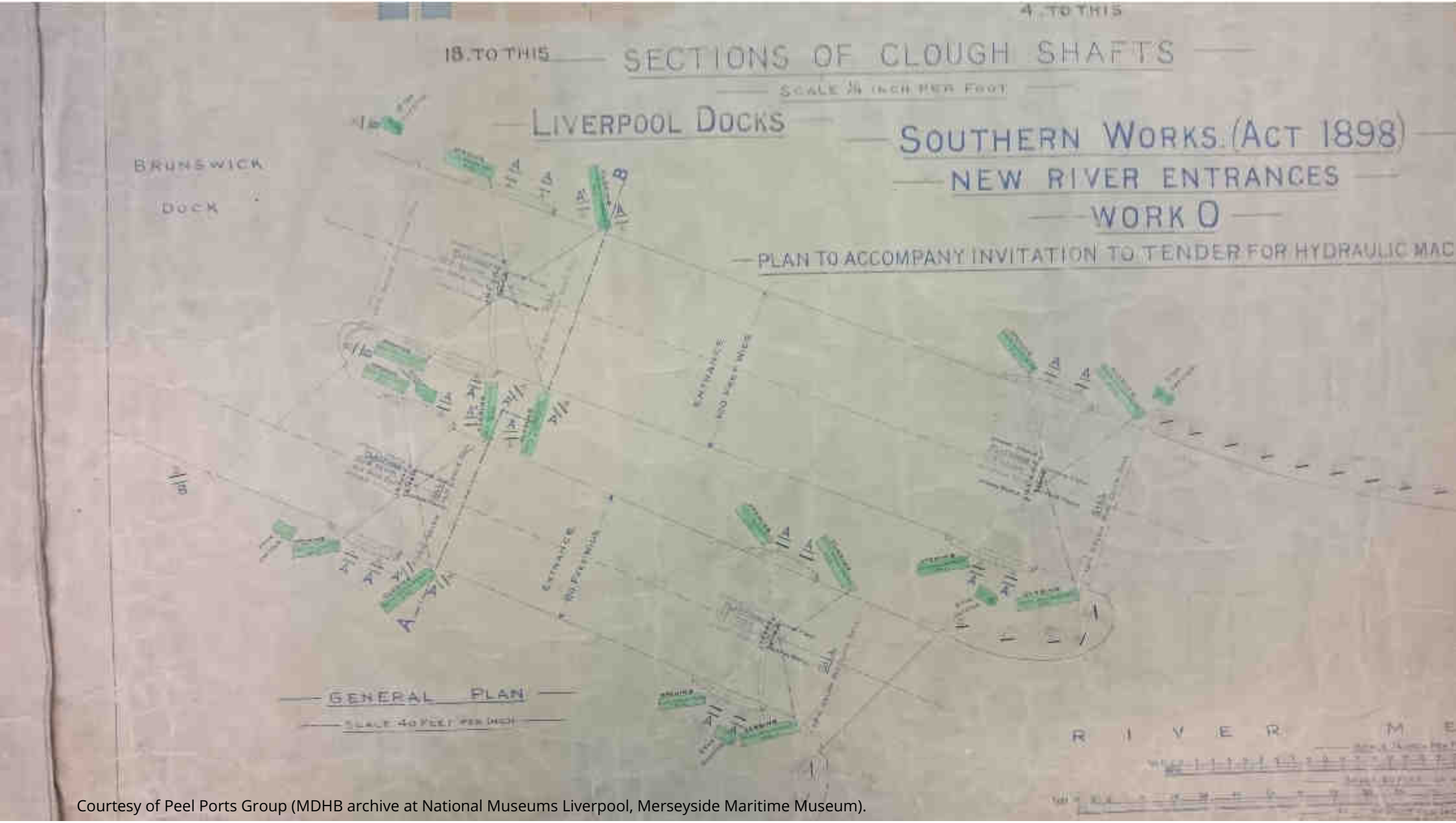
Resource 16

‘Plan to Accompany Invitation to Tender For Hydraulic Machinery’

Plan details locations of hydraulic machinery and sections show hydraulic clough shafts including construction and depth. Another section through the Brunswick Locks shows the locations and depths of opening and closing chains.

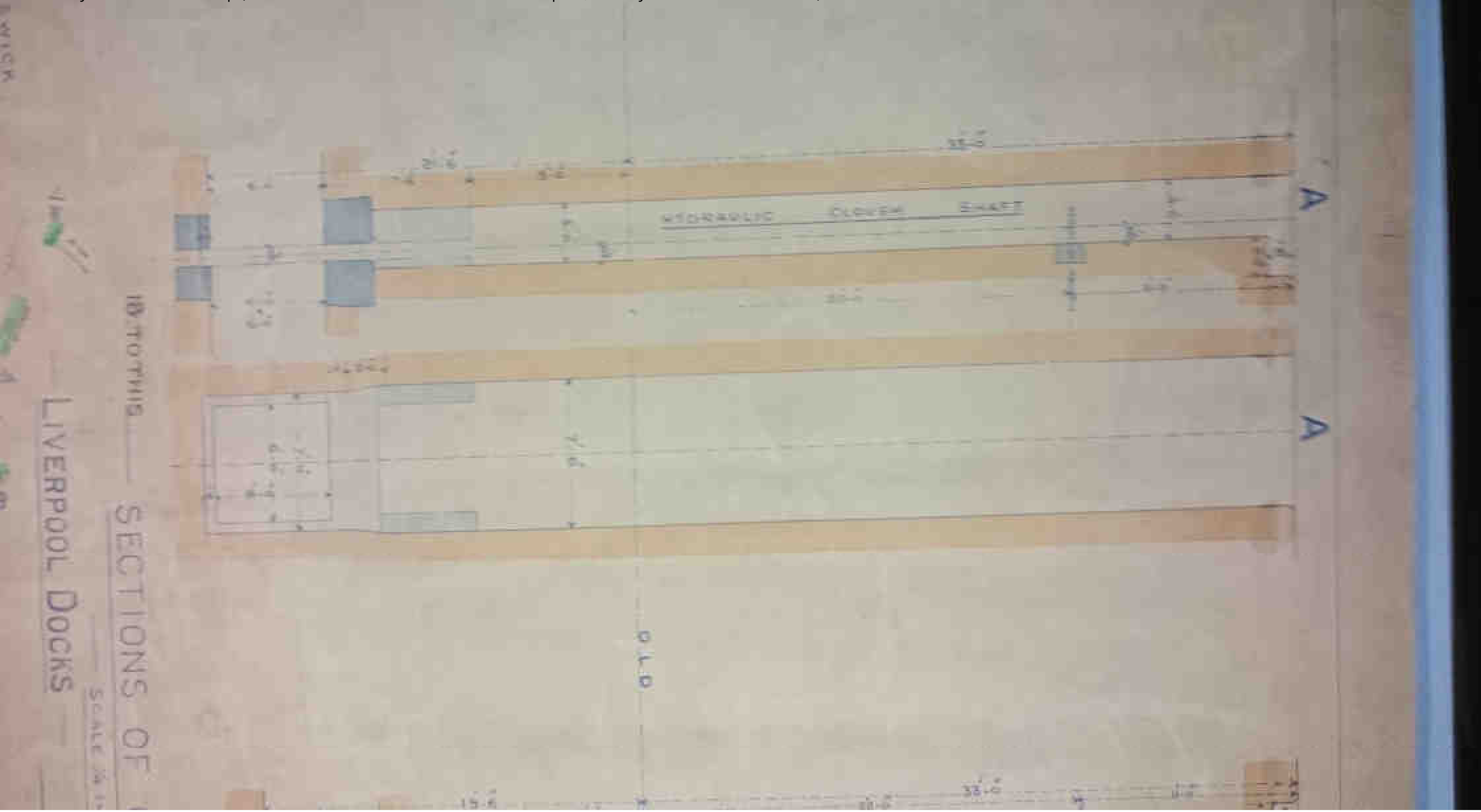
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



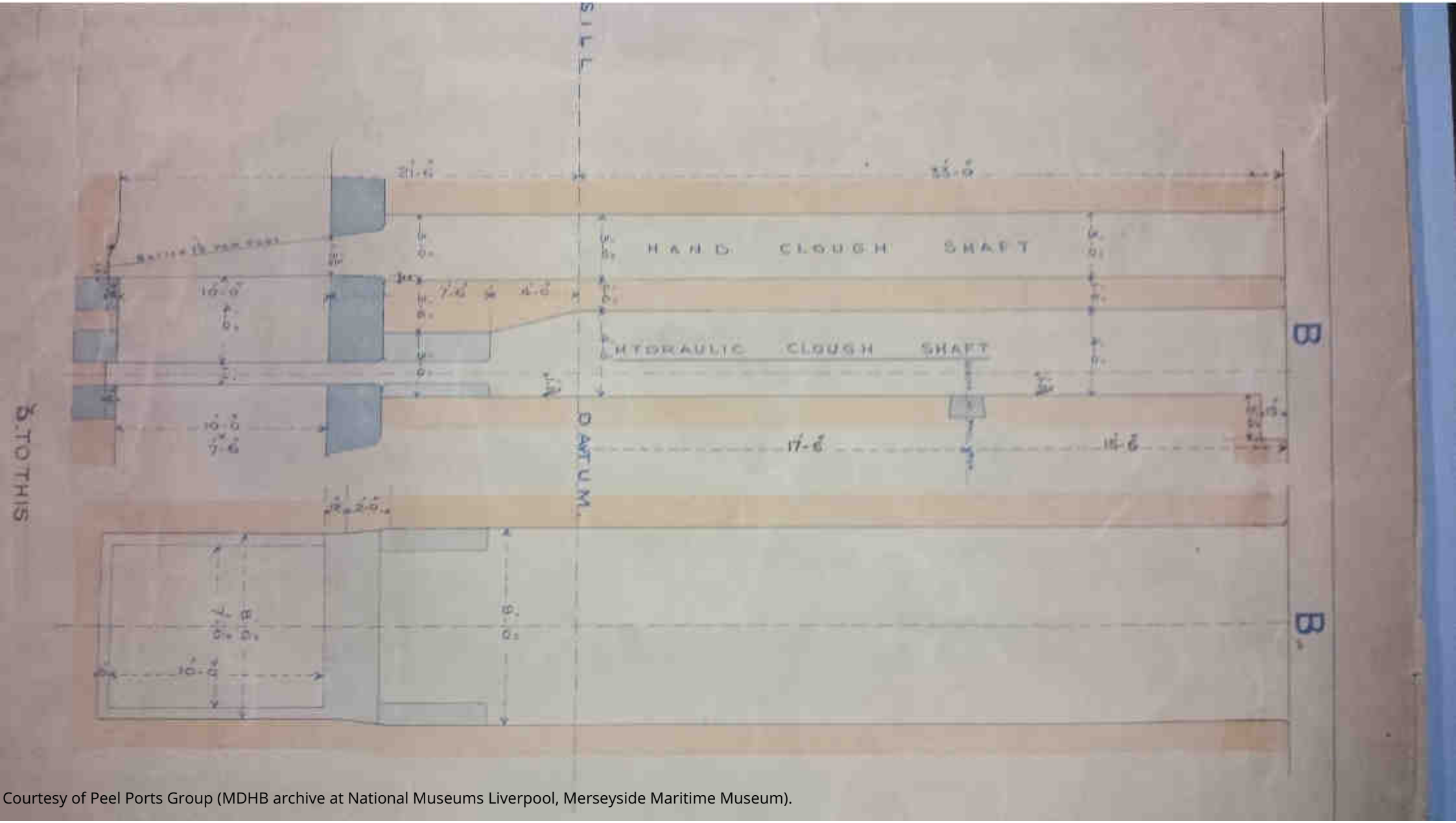


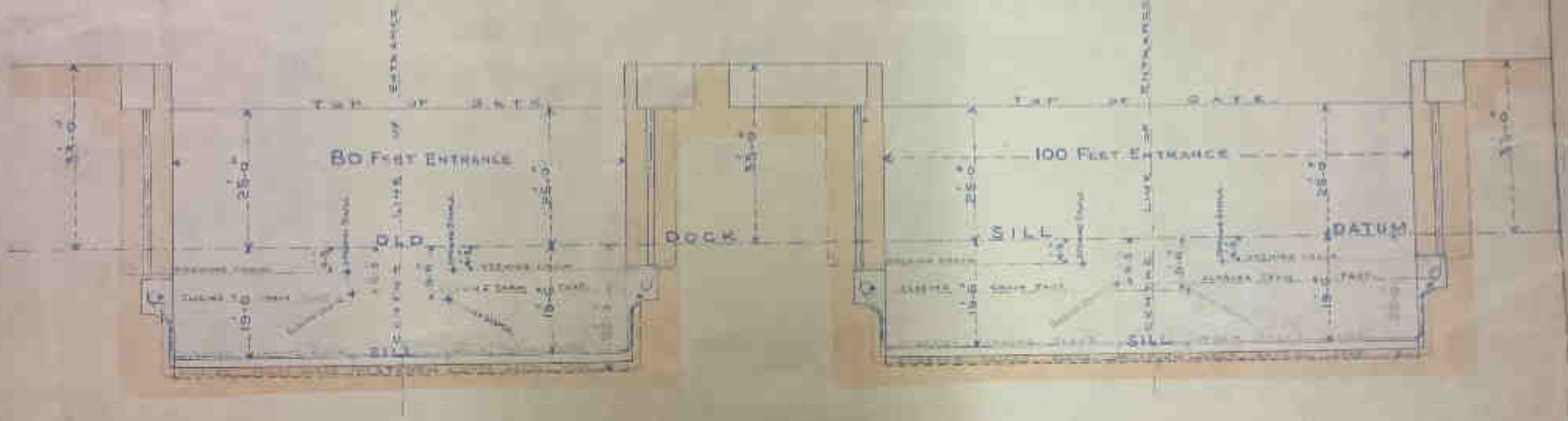
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).




A¹
A¹
DOCK
SILL
TO THIS
NS OF CLOUGH SHAFTS
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).





Section on Line A.B

Scale 20 Feet per Inch

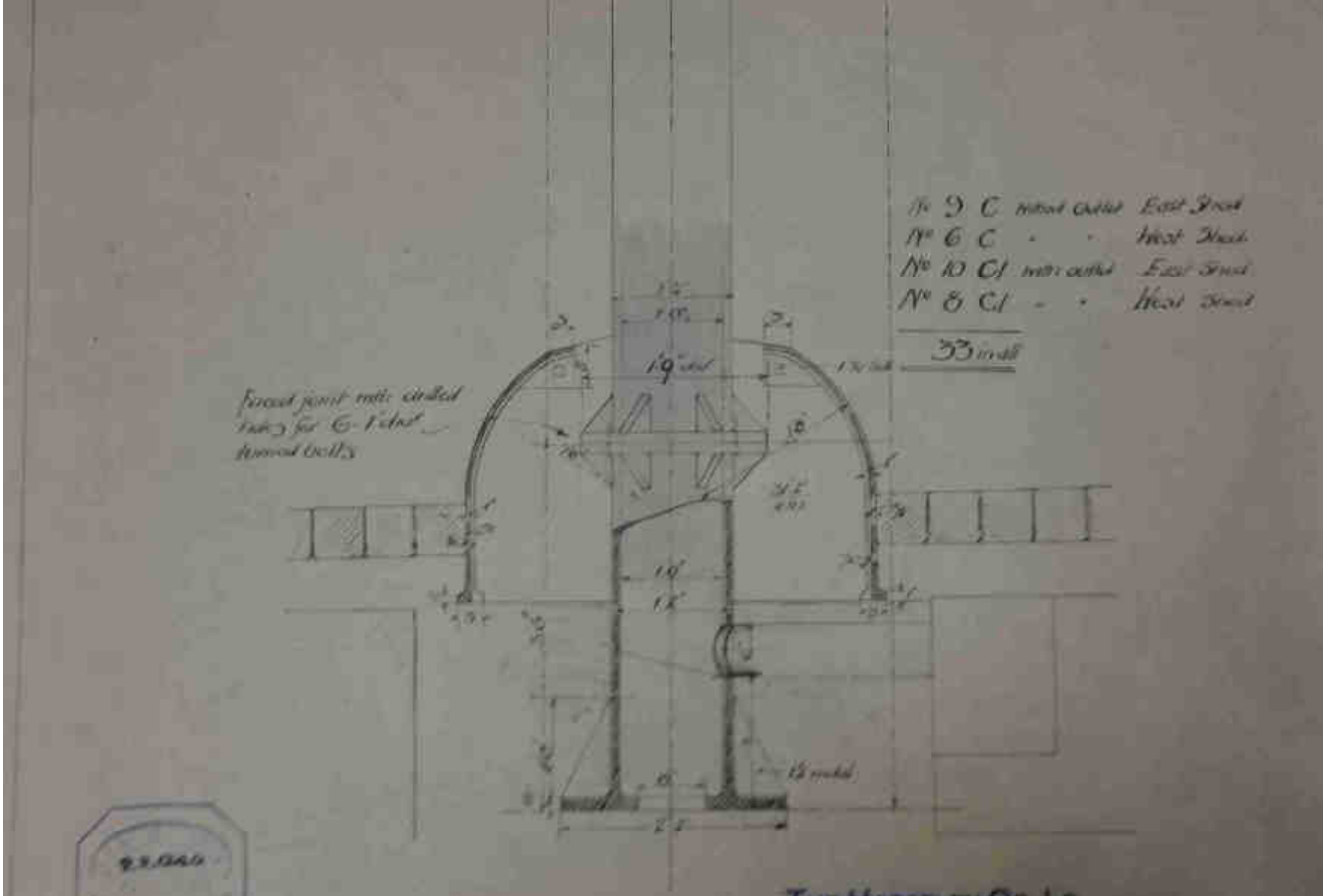
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

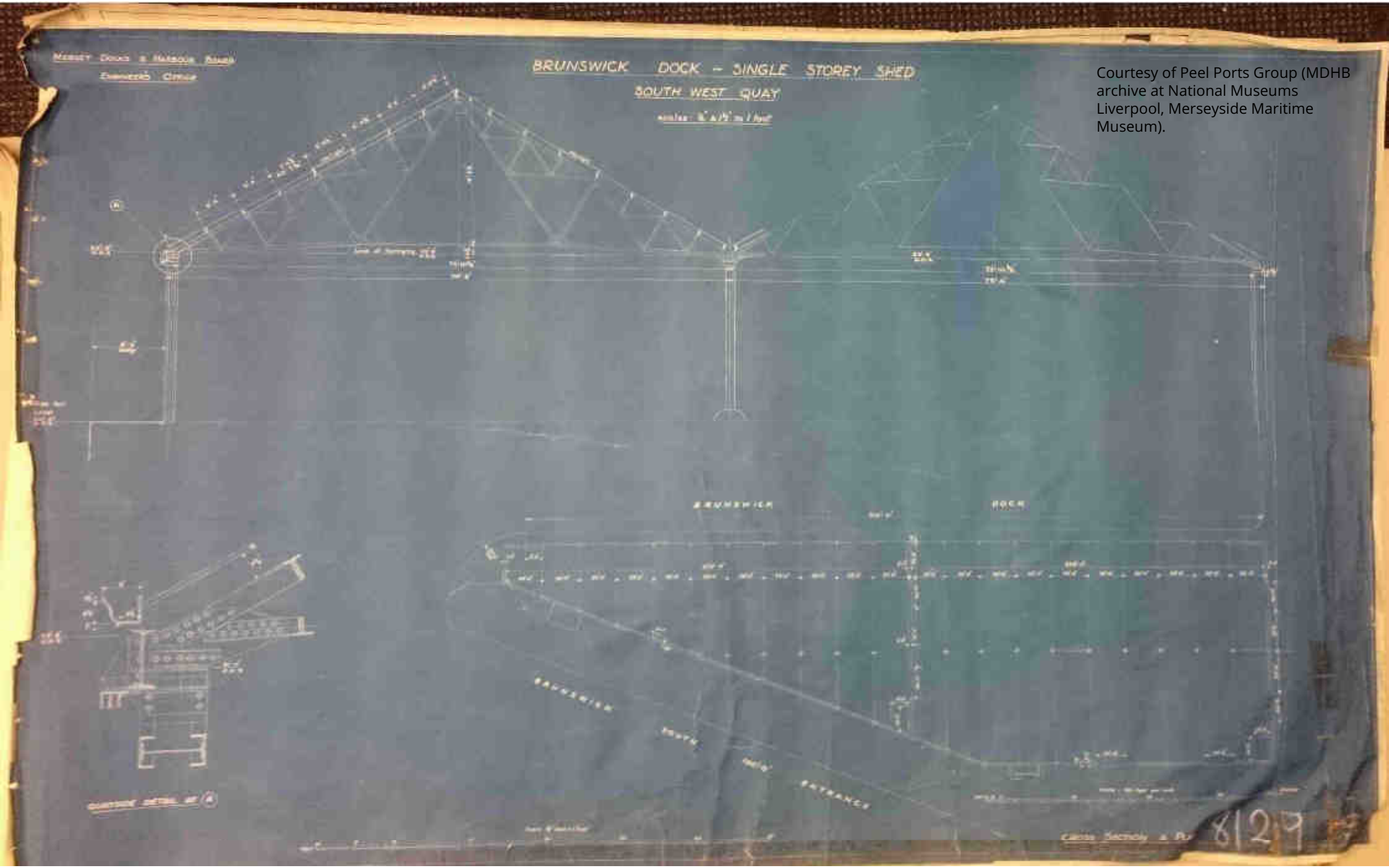
Resource 17

Historic warehouse plans

A cross section shows dimensions and construction of footings of the large historic warehouse building. A blueprint cross section though the length of the building shows the height of the building, the roofs and the width of both halves of the building. The blue print also contains a plan view which shows the locations of footings and the distance of the building from the edge of the dock. Another plan view shows the historic warehouse with dimensions and locations of footings. A close up plan view shows the locations of drains within the building. A cross sectional plan shows a view of the subsurface construction beneath the warehouse building, against the dock wall.

Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).





Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

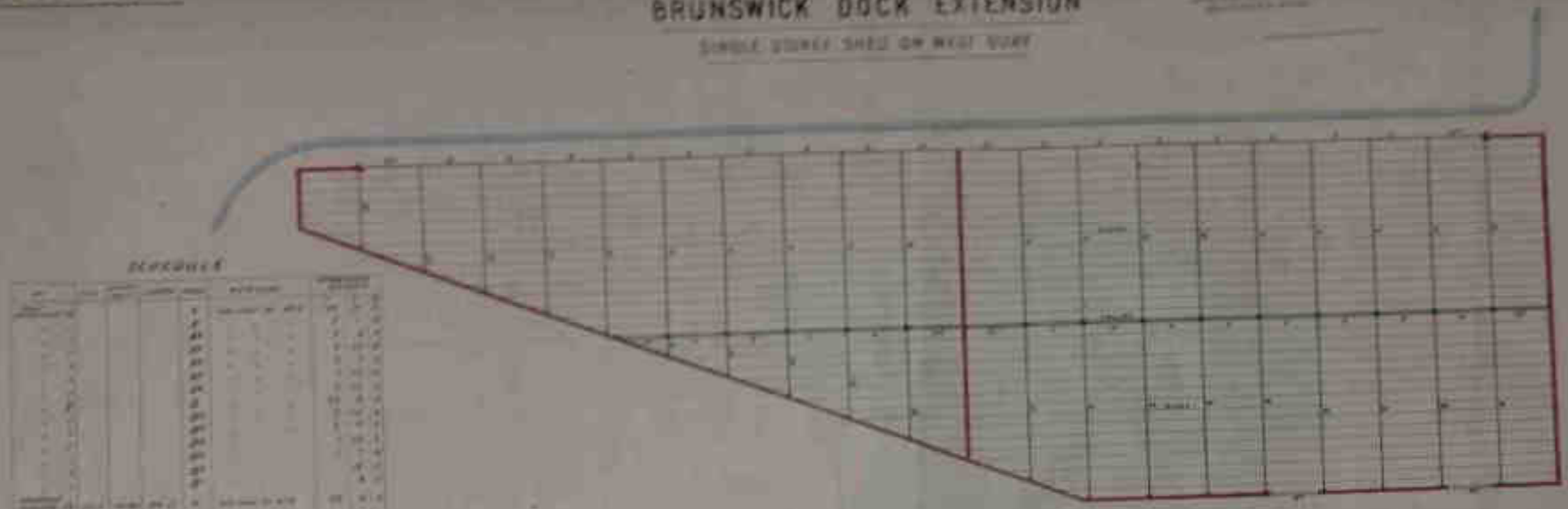
LIVERPOOL DOCKS

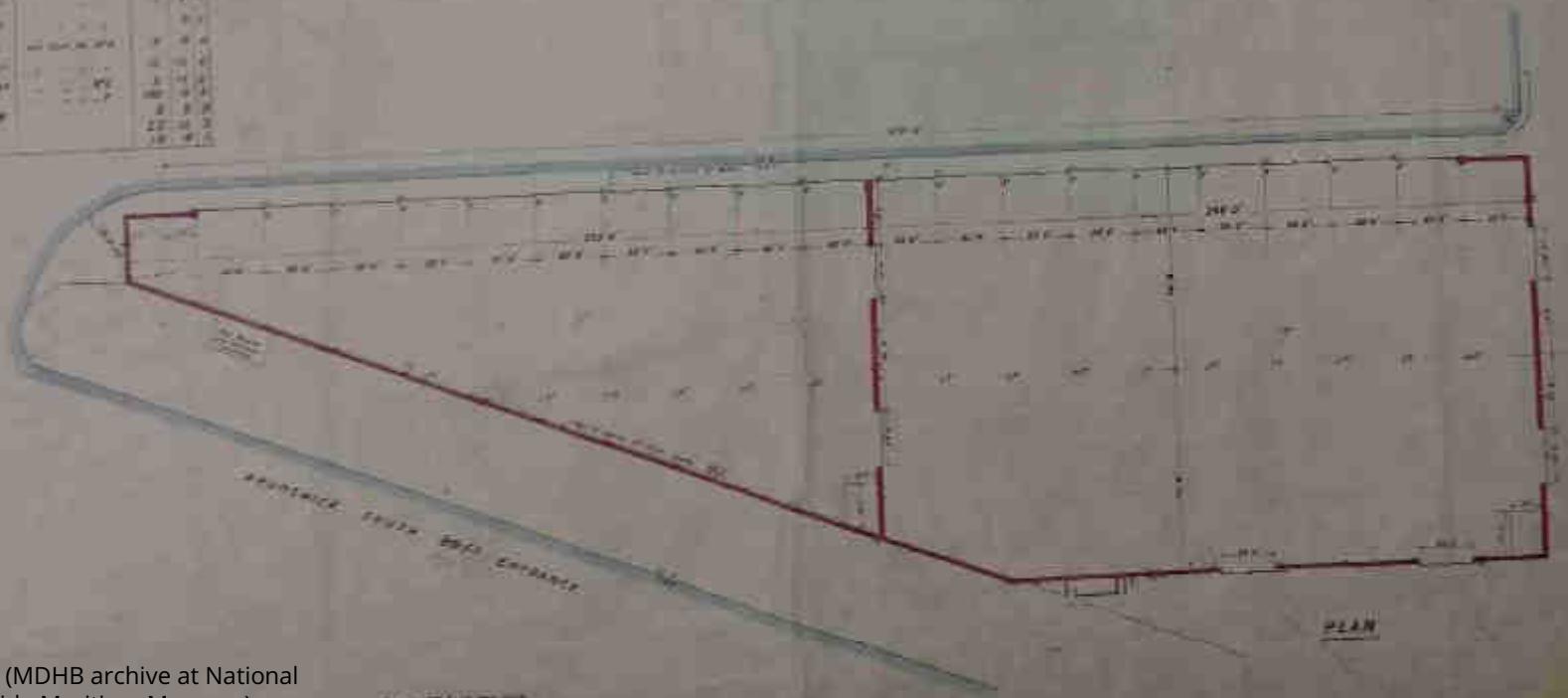
SOUTHERN (WORKS) ACT (1855)

BRUNSWICK DOCK EXTENSION

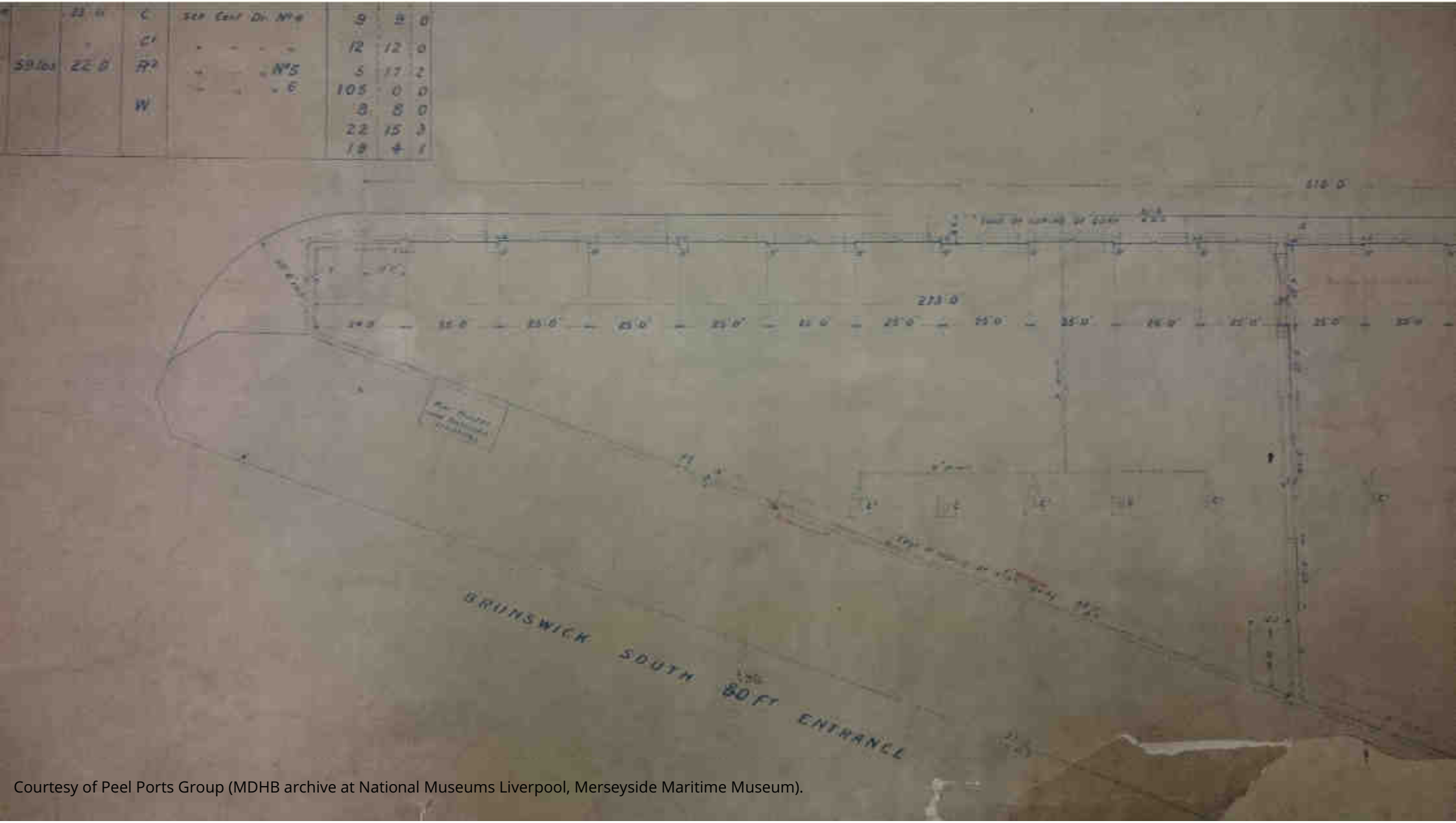
SINGLE STOREY SHED ON WEST QUAY

CONTRACT DRAWING No 7



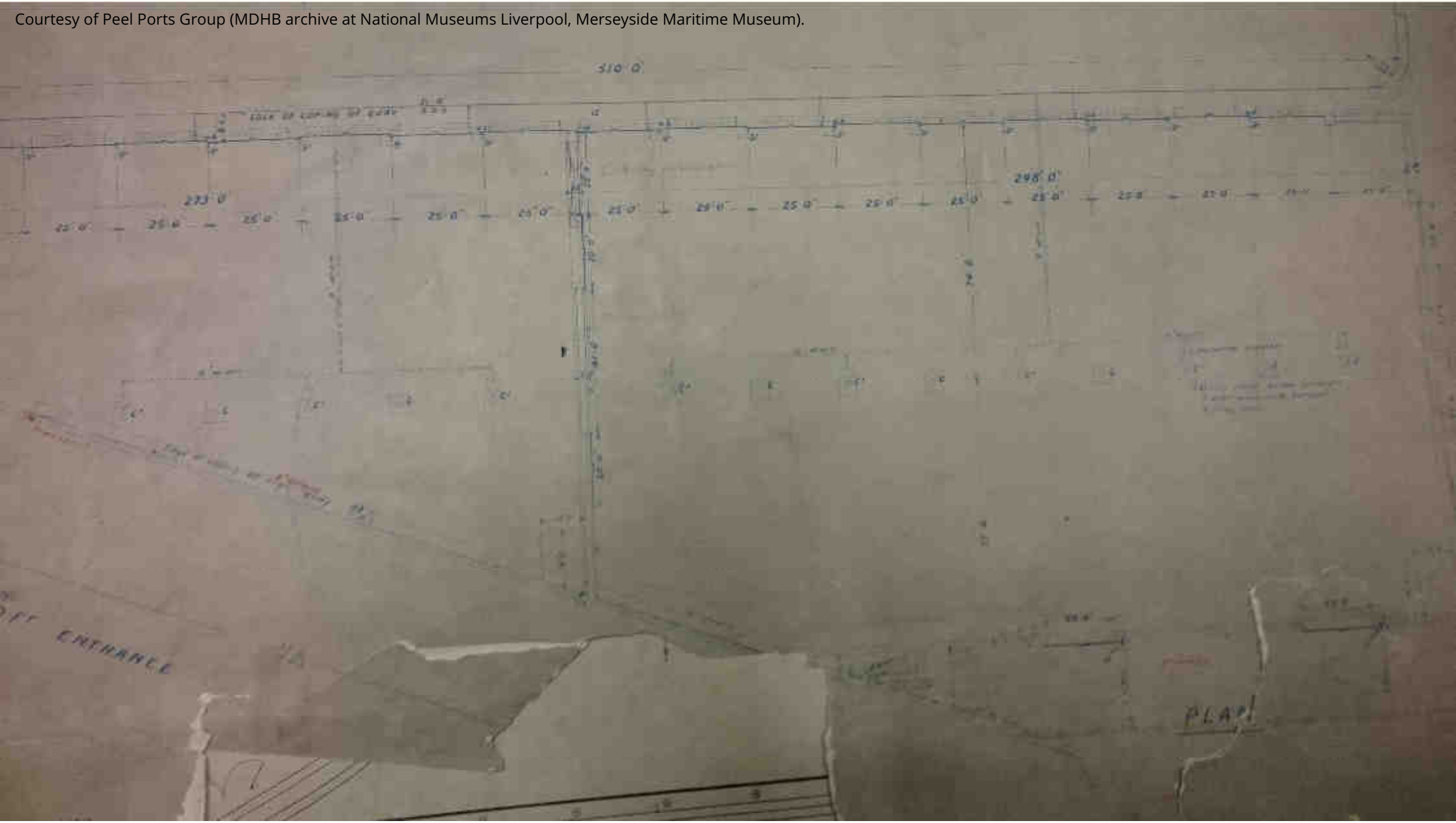


PLAN

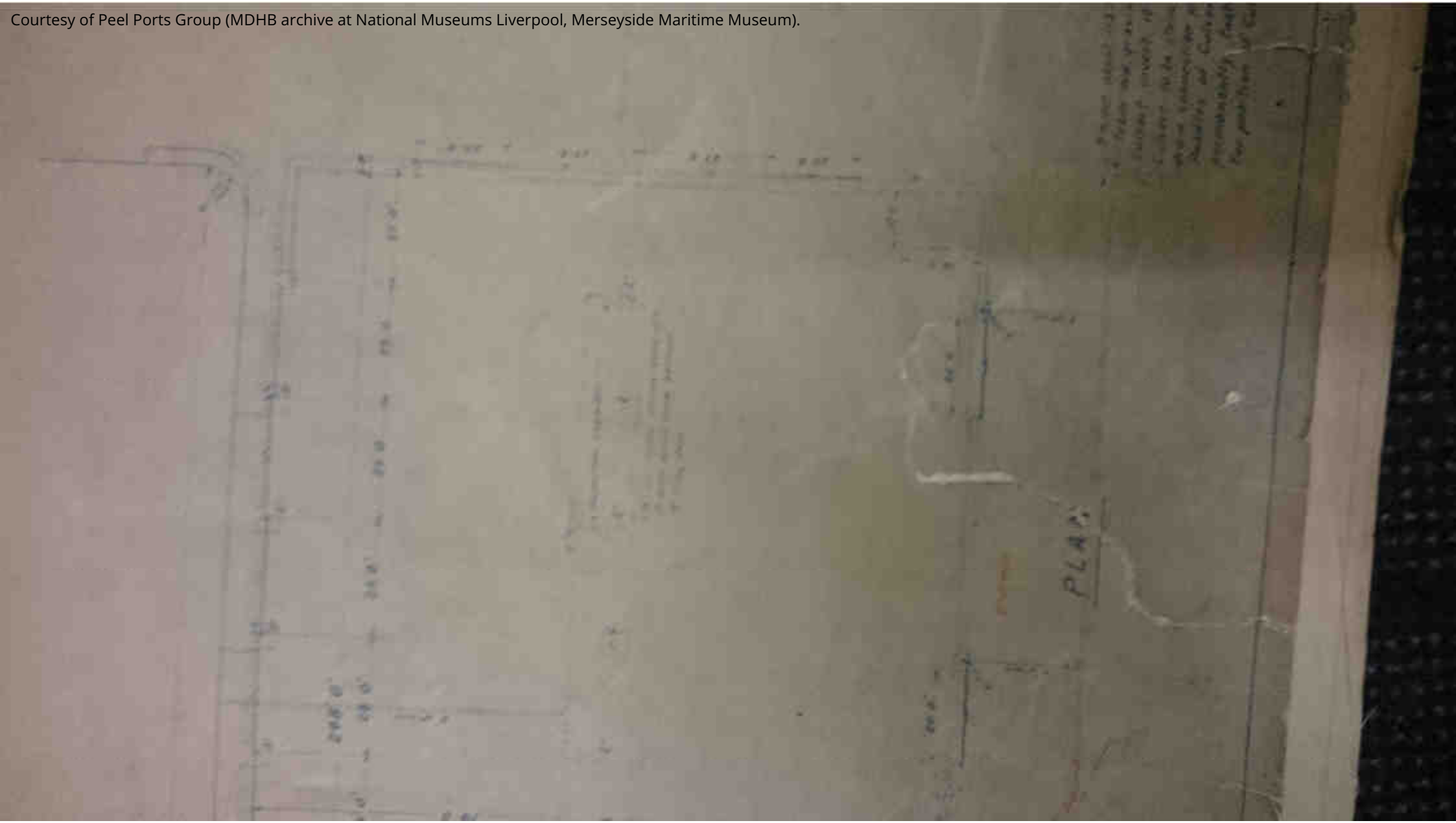


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).

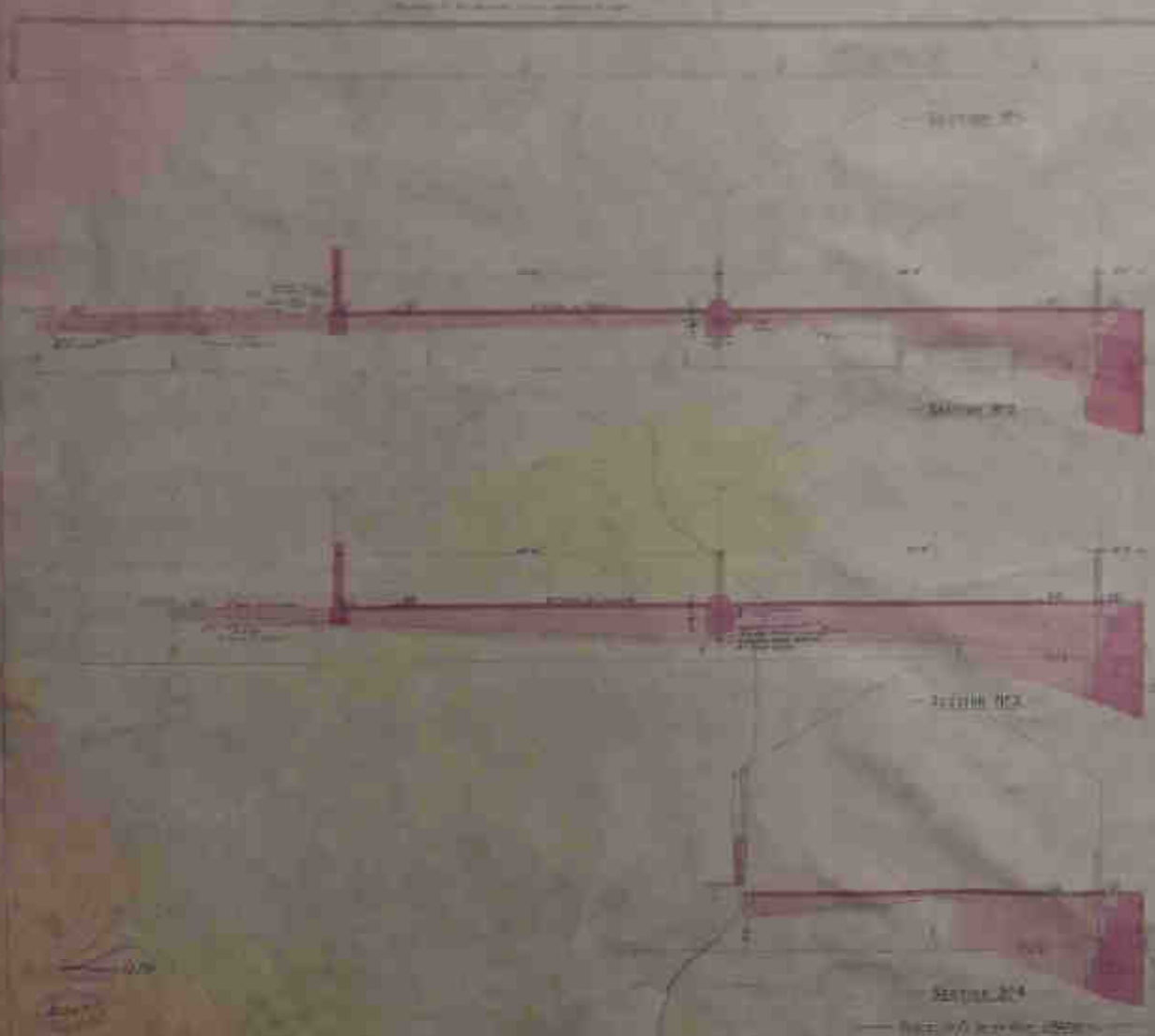


Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



BRUNSWICK DOCK EXTENSION

SECTIONS THROUGH WEST QUAY & ROADWAYS



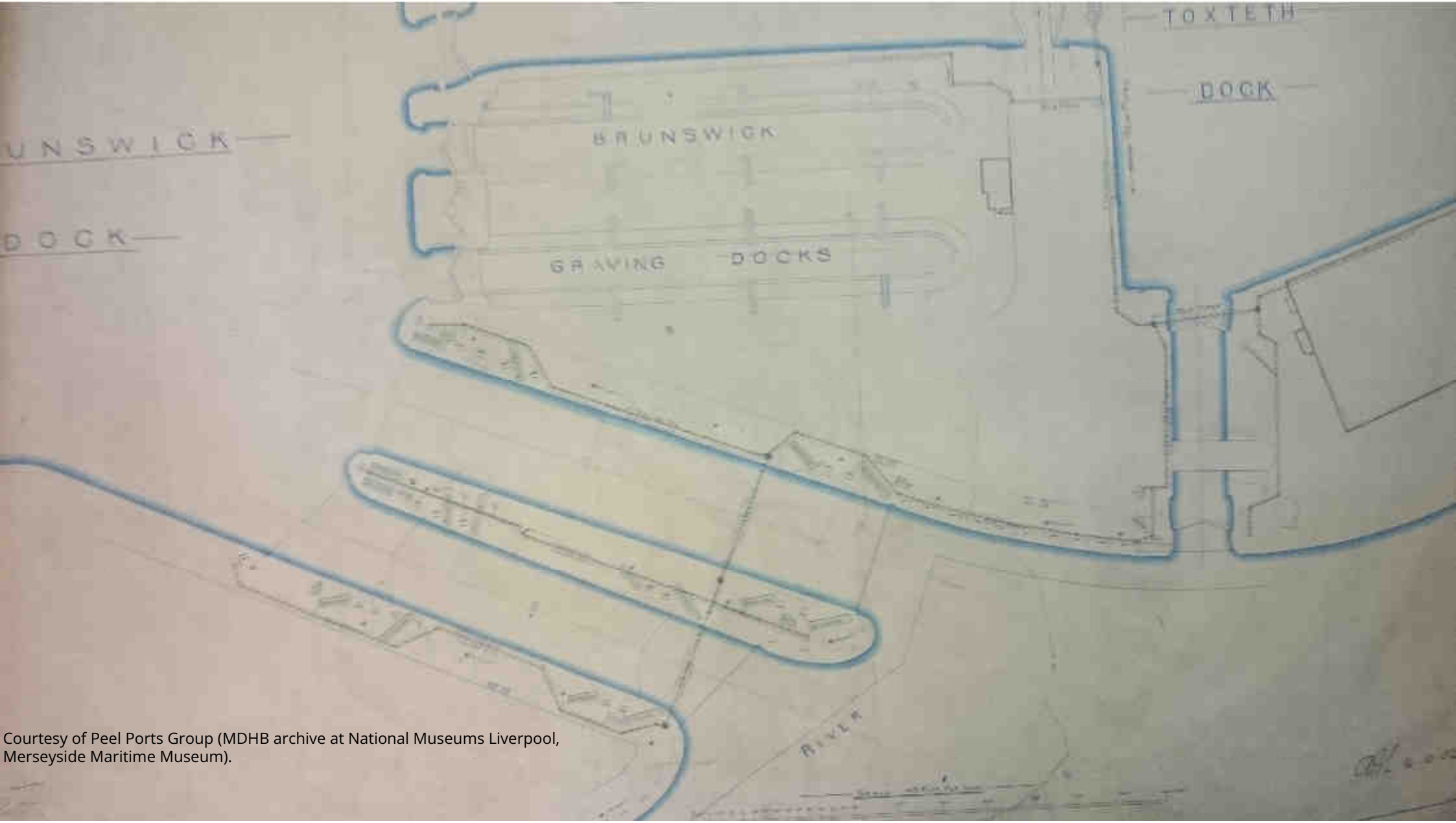
Resource 18

‘Plan Shewing Arrangement of Hydraulic Pipes’

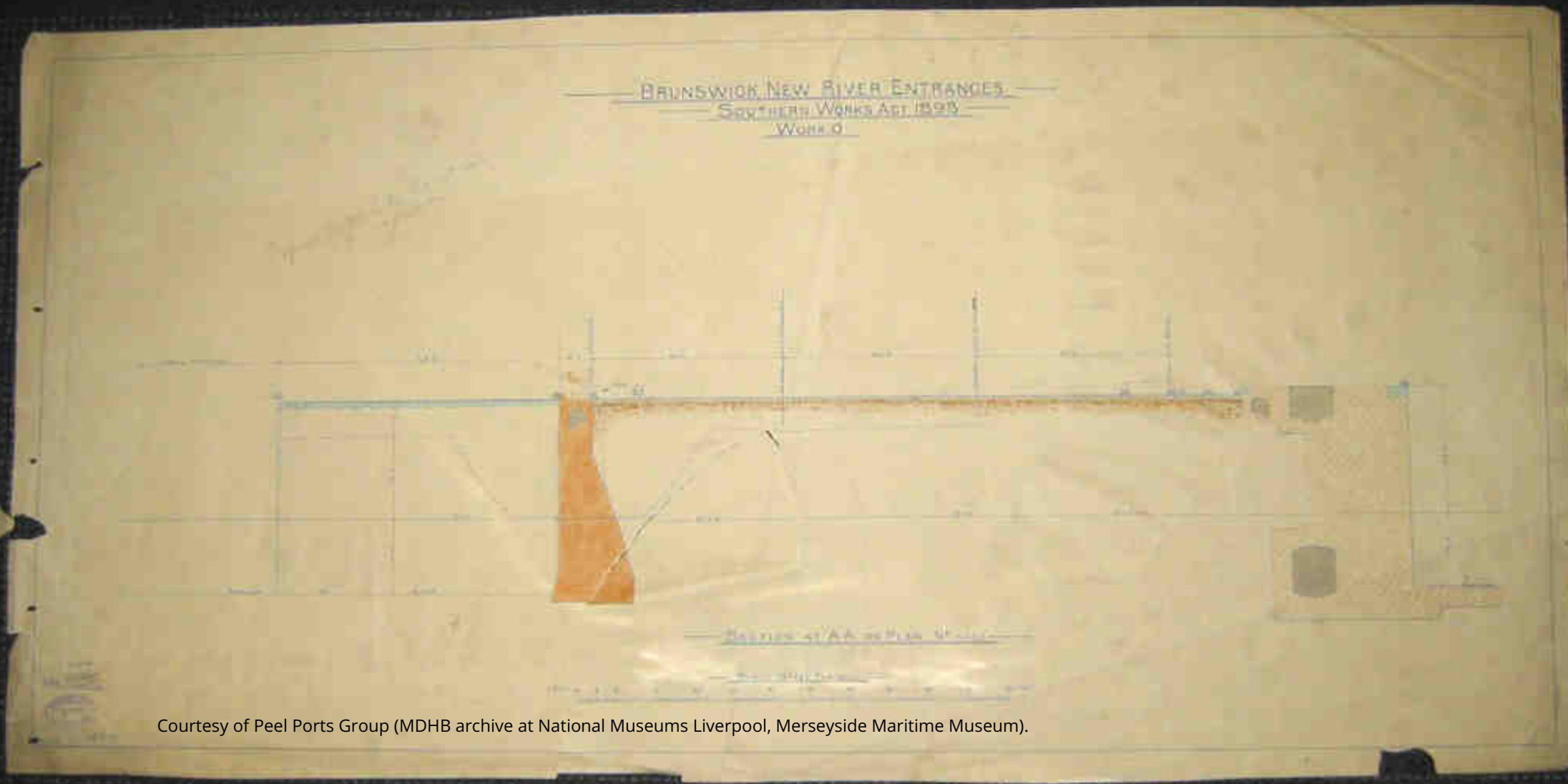
Plan view shows locations of hydraulic pipes within the deep culvert that passes below both locks and the shallow pipe trenches along the lock walls. Due to the age of these plans and that the 100ft lock has been infilled, it is anticipated that these pipes are no longer present, however, this cannot be discounted completely.

Section AA on this drawing shows a **cross section through the site**. This shows the 100ft lock wall construction. The site (does not show strata or subsurface features) contains 4 No. ‘centre line of column’ markers – it is unclear what these pertain to, possibly the historic warehouse, although it was not constructed at the time of drawing of the plan. The cross section shows the location of the historic ‘Brunswick No. 2 Graving Dock’ and a small part of the off-site Brunswick No. 1 Graving Dock. The old ground level at either side of them is shown to be uneven. The construction of the Brunswick Dock wall (approximately 16m deep) is right through the centre of the Brunswick No. 2 Graving dock (the base of which is at ODS, 9.45m bgl) and appears to be entirely constructed of concrete with a shallow pipe trench running along its length, not noted on any other plans. The depth to the bottom of the dock is given to be 16m bgl. A possibly paved area appears to extend past the dock wall, however, it is unclear what this pertains to as the cross section appears to show Brunswick Dock post construction of the extension to the south (due to the placement of the dock wall), therefore the area shown as land is expected to be water.

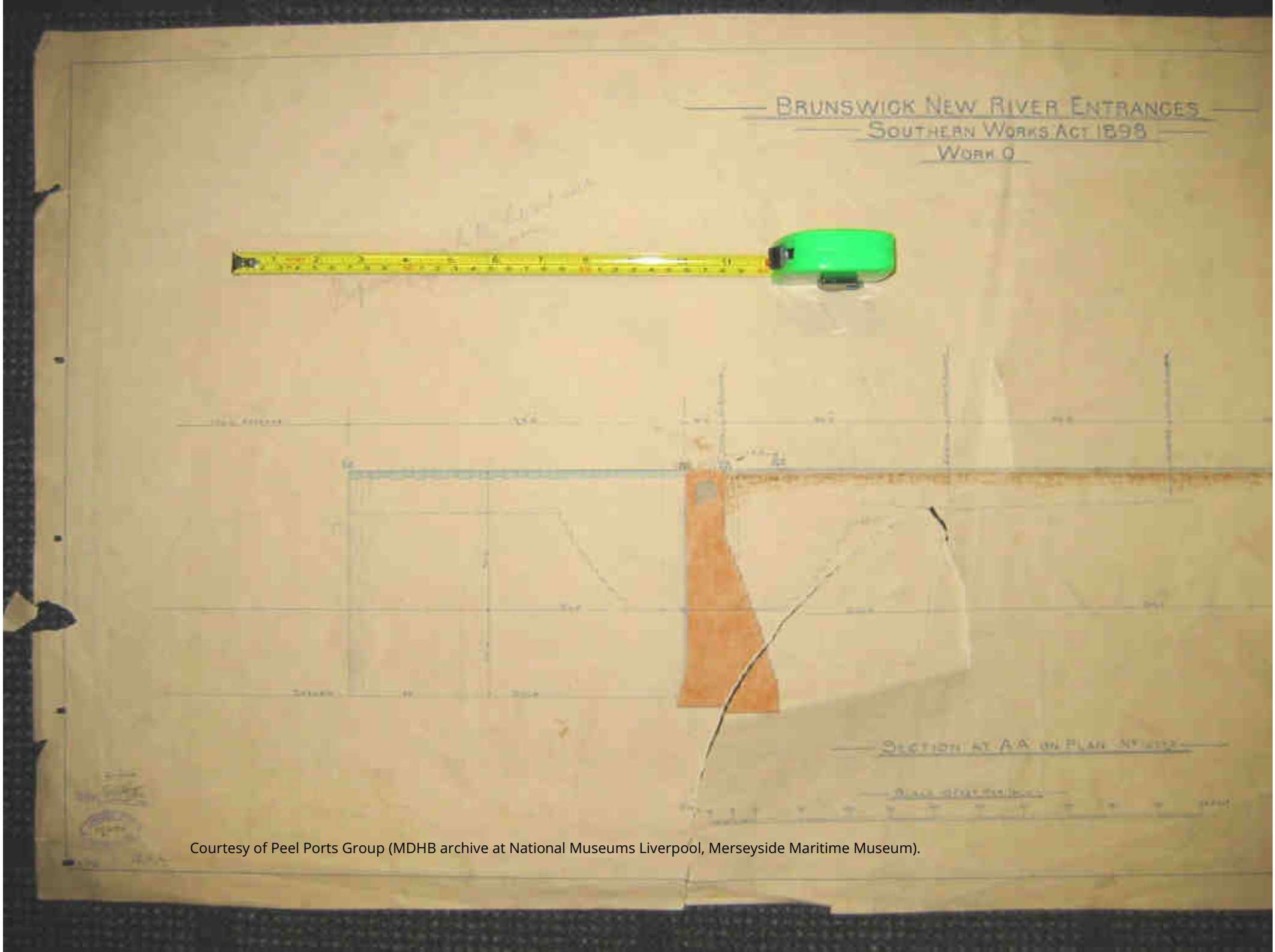
Following images courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



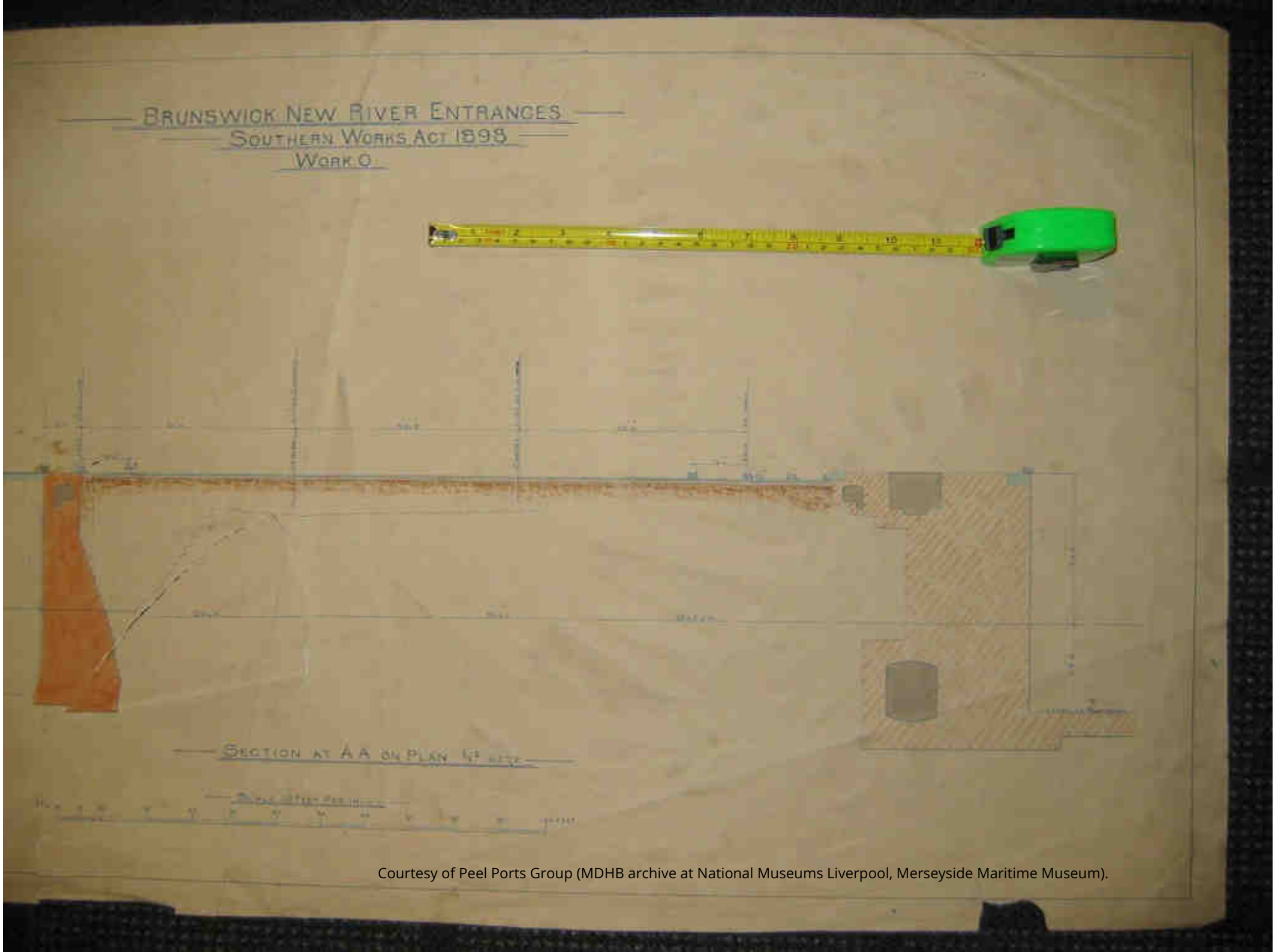
Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



Courtesy of Peel Ports Group (MDHB archive at National Museums Liverpool, Merseyside Maritime Museum).



APPENDIX 12

DIAGRAM OF CONCEPTUAL MODEL

Notes.

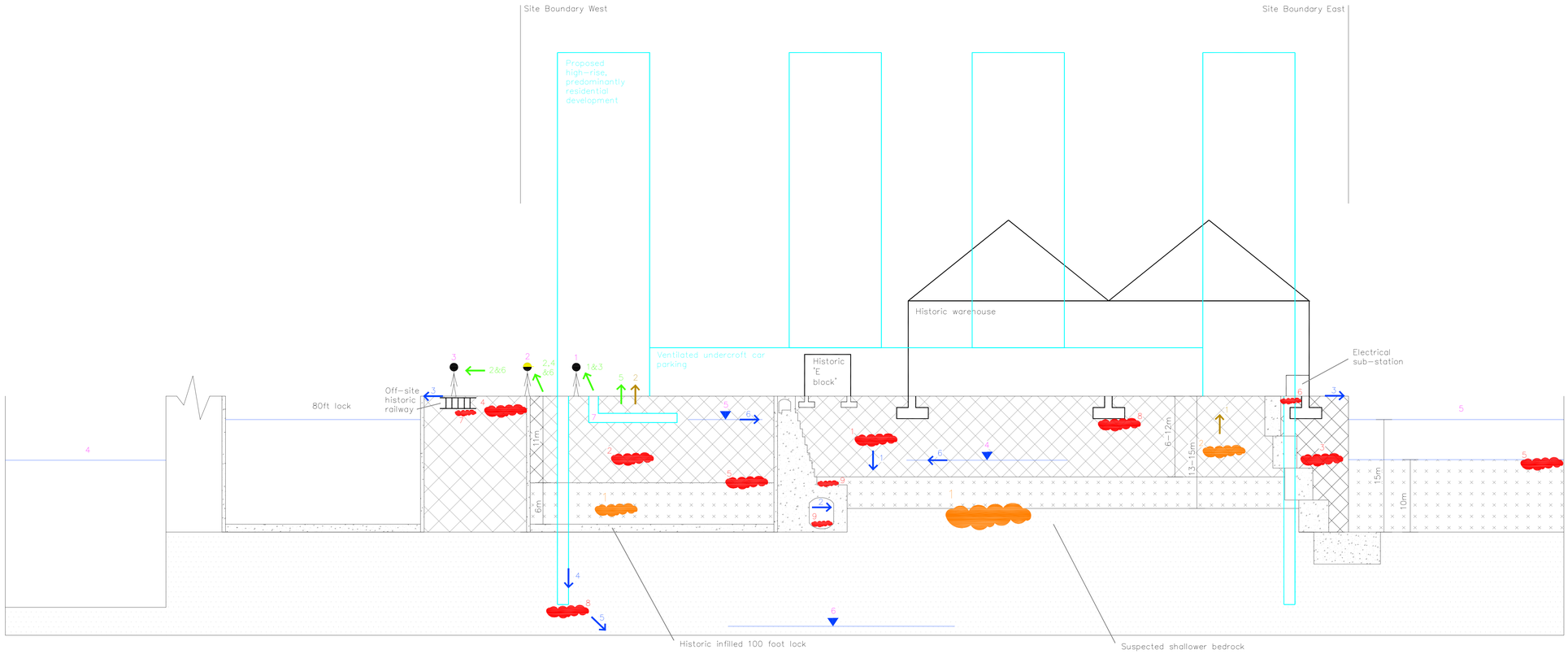
1 All dimensions are in millimetres unless noted otherwise.

2 All levels are in metres unless noted otherwise.

3 This drawing is to be read in conjunction with all relevant Architects and Service Engineers drawings.

Key

- Made Ground
- Concrete
- Alluvium
- Sandstone



Sources
1. On and off site dockyards and dockland
2. Infilling of historic Brunswick 100ft Lock
3. Infilling of historic Graving Dock
4. On and off site historic ship building industry
5. Possible microbiological (e.g. anthrax) contaminated silt
6. Current electrical sub-station
7. Off-site historic railway

Secondary Sources
8. Pooling beneath historic and future foundations
9. Pooling within conduits and around obstructions

Ground Gas Sources
1. Alluvium at the base of infilled areas
2. Organic inclusions in made ground

Human Health Pathways
1. Ingestion of contaminated soil and dust, indoors (end users only)
2. Ingestion of contaminated soil and dust, outdoors
3. Dermal contact with contaminated soil, indoors (end users only)
4. Dermal contact with contaminated soil, outdoors (construction workers only)
5. Soil vapour ingress through cracks and subfloor voids, accumulation in buildings and inhalation
6. Possible asbestos-containing material in made ground – inhalation risk during earthworks and material movement

Controlled Waters Pathways
1. Vertical migration of surface contamination into unsaturated zone
2. Lateral migration along historic conduits
3. Surface runoff
4. Vertical migration along foundations
5. Vertical and lateral migration through porous / high permeability sandstone and along fractures in the bedrock
6. Lateral migration along groundwater flow towards surface water

Ground Gas Pathways
1. Vertical migration through granular made ground deposits.
2. Ground gas ingress through cracks and subfloor voids and accumulation in buildings.

Receptors
1. End-users
2. Construction workers
3. General public
4. River Mersey and shallow groundwater possibly in continuity with River Mersey
5. Brunswick Dock and hallow groundwater possibly in continuity with Brunswick Dock
6. Principal Aquifer (>40m bgl)
7. Service pipes

Rev	Drawn	Date	Description

Drawing Status: INFORMATION

Contract: BRUNSWICK QUAY, LIVERPOOL
FOR: MARO DEVELOPMENTS LTD.

Drawing Title: CONCEPTUAL SITE MODEL DIAGRAM

integra consulting
Civil & Structural Engineers
Suite 4
14-32 Hewitt Street
MANCHESTER
M15 4GB
Tel : 0161 237 3400
Fax : 0161 923 4787
Web : www.integraconsulting.co.uk

Scales	Date
NTS	MAR 2018
Drawn: MB	Checked: AE
Contract No: 2939	Drawing No: SI-05