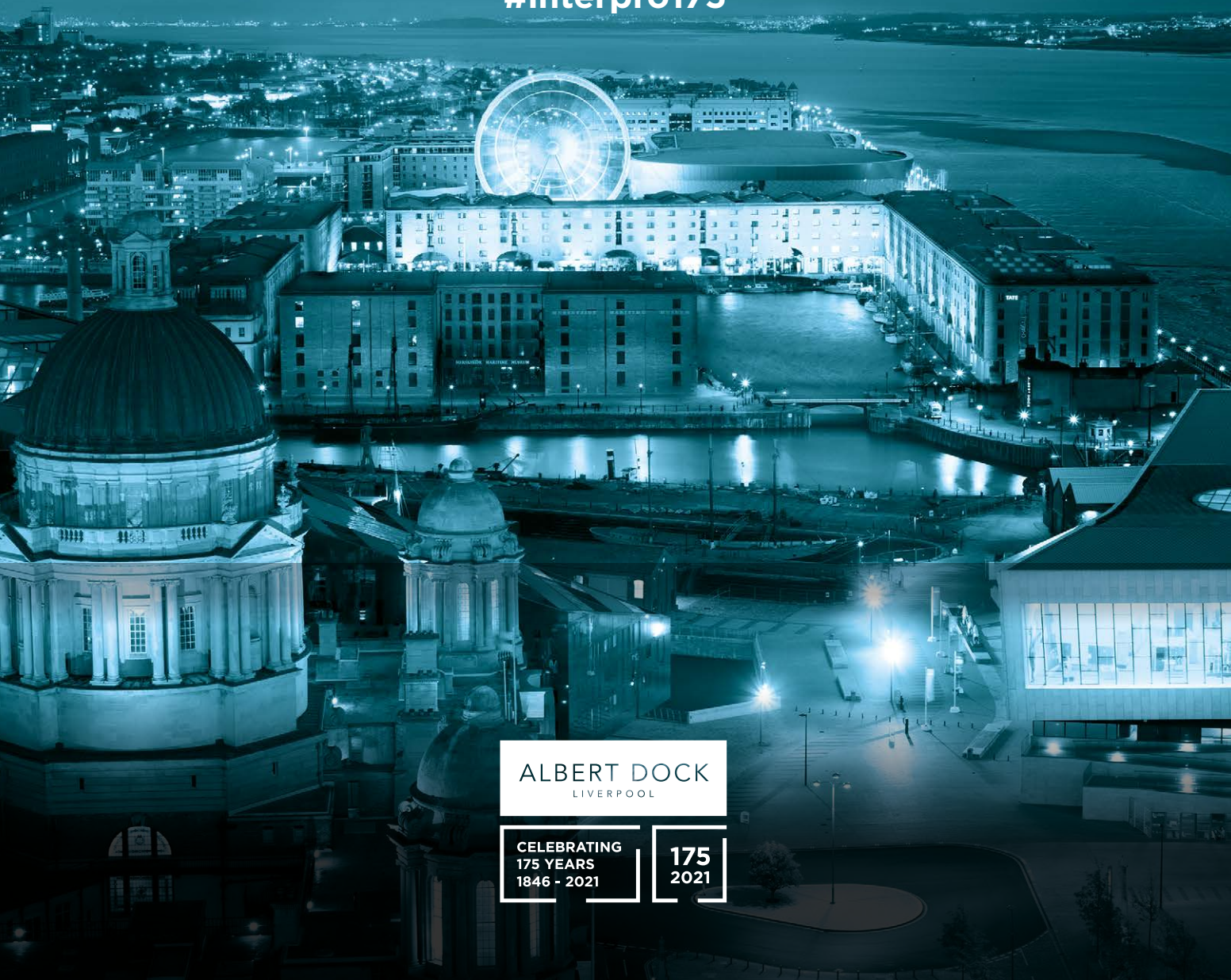
Albert Dock Lecture Series

Water engineering

Celebrating Albert Dock as an exemplar of heritage led regeneration and the contribution of built environment professionals to its success

6th September 2017
Merseyside Maritime Museum

#interpro175



INTRODUCTION

Water engineering and infrastructure was the theme of the third of Interpro's Albert Dock anniversary lecture events. This took place on 6th September 2017 at Merseyside Maritime Museum, and was organised by the Institution of Civil Engineers (ICE) North West Region. Three speakers gave personal perspectives on the water environment elements, from the inception and construction of Albert Dock in the 19th century to its regeneration in the 1980s, and last but not least the future ambitions for the transformation of the north docks.

Jim Parry, a retired chartered engineer and former senior lecturer in civil engineering at Liverpool John Moores University, gave an account of how the Albert Dock river walls and dock walls were constructed between 1841 and 1846. Before joining John Moores, Jim worked extensively on the Mersey Estuary Pollution Alleviation Scheme, which covered the whole of the dock estate.

Jim, who is also the chair of the ICE (NW) historical engineering special interest group, started with an explanation of why and how Albert Dock and its warehouses came to be built, then gave a fascinating insight into how the river walls were built out in the river, including from the perspective of the labourers who worked in treacherous conditions against the tides and the dangers of mud and quicksand.

He told how Jesse Hartley, with a background in bridge building, brought experience and innovative construction methods to Liverpool's dock-building programme, both in terms of materials and his working practices.

As MDC project manager for the engineering and reclamation works for the South Docks water regime from 1981, Roger Rumbold was closely involved with the restoration of the waterspace of the four historic docks - Albert, Canning, Canning Half Tide and Salthouse docks.

Roger, who was MDC's chief engineer from 1986 until its winding up in 1997, explained the dredging programme that required the disposal of two million cubic metres of silt from Albert Dock, and the repairs and rebuilding where necessary of the dock and river walls, dock gates, causeway and bridges. Water quality management up to the current operation by the Canal & River Trust was also discussed.

Lindsey Ashworth is development director at Peel Land and Property, which has a 32-year planning consent to redevelop the dockside land and waterspaces north of the Three Graces and across the river at the Birkenhead docks. Lindsey's presentation dealt with the future development of Liverpool Waters, but first he told the story of the past and present of Peel's vision for Ocean Gateway, the 2007 concept of which Liverpool Waters is a key element.

He discussed the heritage challenges inherent in working with historic sites and buildings, and the ambitions for a Shanghai-style tall building development along the river. He highlighted the economic, social and cultural value provided by the water infrastructure elements to Liverpool, Merseyside and the wider region.

TIME AND TIDES: HOW ALBERT DOCK WAS CONSTRUCTED

JIM PARRY
Retired civil engineer and chair of ICE
(NW) historical engineering special interest group

INTRODUCTION

Before Jesse Hartley's time as Liverpool's dock engineer, there were no warehouses on the dock estate. But after a series of horrendous fires in the privately-owned town warehouses, and the Act of Parliament that allowed the building of St Katherine Docks in London, Hartley decided that Liverpool should have warehousing space on the waterfront.

> The government's revenue and customs men had opposed the idea of warehousing at the docks in case they couldn't collect the taxes. Local warehouse owners also resisted but eventually Hartley's plan was pushed through and the idea for Albert Dock emerged.

SITE CHALLENGES

The site for Albert Dock ran south from the Canning Dock basin and Canning Half Tide Dock basins – both of which were being redeveloped at the time - to Duke's Dock. The modus operandi for constructing a dock in those days was to go out into the river at low tide from the original beach line (where Strand Street now runs[1]) and build a wall out as far as you could go in terms of tidal ranges and the ability to work "in the dry". The depth of water needed to get the ships in and out over the sill of the dock also had to be considered.

All the levels on the dock estate were related to the dock sill on the original Old Dock and it was essential to know about the tidal ranges and times if you were working out in the river at low spring tide or other tides. Armed with this knowledge, you could go out there and build your dock, starting with the river wall.

Once the Liverpool Dock Trustees had agreed to the plan, and the money was raised, Hartley prepared his engineer's report. This entailed a level survey of the foreshore and trial borings to determine the state of the ground before the building could start.

Before Albert Dock was built, a lot of the site had been gradually reclaimed during the 17th and 18th centuries. Building docks is difficult in Liverpool. The land rises fairly rapidly to the east, so there's no choice but to go out onto the foreshore, between the beach line and the low tide mark. The River Mersey also has a very strong tidal race and carries a huge load of solids, sand and silt on each tide in and out.

At the north-west corner of Albert Dock, Hartley encountered quicksand, and this is where he "failed", within the context of contemporary knowledge and technology, that is. He did take account of the quicksand and built to the best current practice available but, as history reveals, he did not succeed. The quicksand could have been there because of the state of the sandbanks at Pluckington Bank, but also because the old pool must have affected this part of the river.

The pool was a much more powerful system than we think it was and a lot of water came out of it, particularly from storms in the hinterland. The north-east corner of the Old Dock is the focus for all the overland flow coming down from the hills of the town. There are also tales of a buried inlet channel thereabout.

Limited by the technology of the time, the composition of the riverbed also caused many problems for Hartley. He had to contend with rock (local sandstone) sloping away from the foreshore into the middle of the river where it formed the glacial channel; above that was glacial till and then a lot of alluvium made up of gravel, gravel beds, sand, silt and other deposits. There were also at least two horizons of peat beds from former shorelines.

The levels determine the line of the walls. The straight river wall you see today is a long way out into the river, up to a third of a mile. Going this far out entailed the higher costs of enabling and protecting the works, but Hartley had no choice, and he had to find the balance between rising costs and the depth of the walls needed for the size of the ships.

The Albert Dock scheme also involved the reconstruction and redevelopment of Salthouse and Canning docks and the creation of the Canning Half Tide Dock, the basin that serves all of the docks. The work began in November 1841 when the Canning and Salthouse docks were run dry and blocked off at the river entrance. The fifty-nine occupiers on the Albert Dock site - mostly shipyards and one alehouse – were bought out and removed. Albert Dock and the associated works cost £156,475.

JESSE HARTLEY

Jesse Hartley was born in Pontefract in Yorkshire and trained as a stonemason. His father was the bridgemaster for the West Riding of Yorkshire and the young Hartley worked with him on Castleford Bridge before going to Ireland. On his return he worked as bridgemaster for the Salford Hundred before coming to Liverpool in 1824. Hartley was considered the finest stonemason Britain has ever produced and the scope of his works support that assertion.

By 1844 Hartley was earning £3,500 a year, which made him the highest paid and the first fully professional dock engineer. His time coincided with steamships and the railways. He was the man in the middle, the man who had to make the docks work and he had a huge effect on the dock estate, which he completely remodelled. He also expanded the system to the north and south.

He was familiar with as much theory as he needed to be, but was more of a practitioner and an expert in management. He used contractors for part of the works but built up the direct labour at the dock estate. He did this to acquire and retain in house the empirical knowledge and the experience for the huge dock works going on at the time. He tightened up the administration systems, the cost control and the quality assurance. Hartley was also an innovator who embraced, after considerable research, any new technology that came along that would make the dock system more efficient.

WALL THEORY AND DESIGN

The walls are there to resist the force of water, from the tides, from storms and also from the superimposed loads from the warehouses, the offloading areas and so on. All this had to be done within the available technology of the 1830s and 1840s. Walls can fail in lots of different ways, for example by sliding, overturning or shearing, and there were failures.

There was a gradual improvement in retaining wall theory and in soil mechanics as the eighteenth century progressed. It started in 1717 with the French engineer Henri Gautier, followed by Bélidor's engineer's handbook in 1729, then Coulomb's work on applied mechanics in 1773.

MATERIALS AND MORTARS

The first dock wall at Liverpool in 1715 was made of brick and it was a disaster - the Romans did it better at Chester. They then moved onto sandstone, using locally available ashlar blocks, which were reasonably durable when well selected. They did have a brief flirtation with limestone around George's Dock and one or two of the other docks but Hartley switched to granite.

The Liverpool Dock Trustees bought a quarry in Scotland and they also had a ship running up and down to bring the blocks of granite and the rubble, which comprised smaller, irregular pieces of stone for filling in, and without the modern connotations of rubble today, meaning rubbish. These were carefully selected and placed, a bit like 3D crazy paving, and it was all held together with extremely thin layers of hydraulic lime mortar.

Hartley sometimes mixed sandstone with the granite for durability. It was readily available locally and good enough if the best was selected. He used it in the bottom of the walls up to low water ordinary neap tides. Above the waterline, they were granite faced with a rubble interior.

Hartley specialised in extremely thin hydraulic lime mortar beds. He had to consider costs, but his main aim was to achieve strength and integrity. He brought his experience of bridge building and his sound understanding of forces on structures, selecting mortars and rock for soundness. He built up the docks enterprise virtually from scratch. He got practically nothing of use from the previous dock engineer, John Foster, who was accused of financial mismanagement. Records show that at Prince's Dock there was enough rock on the bills to fill the whole dock, let alone build the walls.

RIVER WALL CONSTRUCTION

The standard solution to wall building in this period was to make them heavy and solid so they didn't move. Hartley, however, built comparatively slender walls with a lot of piling. This did create ground bearing problems, but he relied on excellent construction and quality assurance, very good supervision and attention to detail.

In terms of design and construction, the big question for Hartley was whether to use contractors or bring it all in house. He brought all the core dock jobs of the piling, the quay walls, the passage masonry and the gates in house to be done by direct labour. Everything else - the traditional navvying jobs - went out to contractors.

The wall for the river entrance to Canning Half Tide Dock and the Albert Dock river wall had to be built out in the river. The men were working in tidal conditions "in the dry", out at the low tide mark on the foreshore. The first job for the contractor was to dig a trench out in the riverbed down to the level required. The contractor shored it up using timber and iron sheet piles and maintained the trench. The direct labour went out behind this and did the piling and the timber capping on the pile heads, and then they built the masonry of the walls gradually upwards to certain levels determined by the tide levels.

The walls were built like a wall train from one end to the other, and it's clear from the timescale that it went along quite rapidly. Once at a certain level, more remote from the tide, the trench excavations would move on to the next section, where the sheeting and shoring would be done, then the piling and masonry, and the works would move forward in sections leaving the completed wall behind.

At a certain level they would start the backfill behind the completed wall, once it was cured to the engineer's satisfaction. Hartley was very particular about backfill.[2] He selected it and closely supervised the process, allowing nothing bigger than wheelbarrows on site to place it. This way he could keep the compacted layers to a controlled thickness and in the proportions needed to match the compactive effort available.

Some of the massive binding headers were built six feet deep into the wall. They had dressed frontages, some with chiseled sides to aid its cohesion and integrity under the strains it was subject to. There was the granite face above the low water ordinary neap tides, sandstone below that, all built up behind with rubble placed in very thin hydraulic lime mortar beds.

The construction was solid – there was no concrete at the time but some of the mortars came close. Engineers were very good at making mortars by then, and generally used hydraulic lime mortar with slaked lime, sand and furnace ashes all mixed in various proportions. John Rennie had experimented with Pozzolanas in the early 1800s, and Hartley was also always experimenting, even importing lime from Halkyn Mountain in North Wales.

Fourteen thousand timber piles were used in the construction of the dock, and these were placed in rows with a timber grillage on the top. There were many orders for sheet piles in the Albert Dock records – they had been available since 1823. A combination of wood and iron sheet piles was used in the trench support at the bottom of the wall. Sometimes Hartley left them in, particularly around the Canning Half Tide Dock entrance where he was having trouble with the ground. He put the piles in deep and tried, unsuccessfully, to pin the walls by stopping the movement of ground from underneath them.

DOCK WALL CONSTRUCTION

Albert Dock wall has massive copings but the body of the wall consists mainly of rubble, which is the main difference from the river wall. If a retaining wall is going to collapse it will happen when the water is out – this would be the ultimate test. Luckily it didn't. At this time Hartley was building quite sheer walls with very little batter on them, and Albert Dock walls are 40ft high and built straight up, almost to the vertical.

The river wall and the dock wall have virtually the same profile. The dock wall is piled all the way down to the rock, and of course it takes the weight of the structure above with the big cast iron columns. He did use counterforts from time to time, but their positions are unknown and the only record of them is when contractors excavated them during the renovation on the south wall of Canning Half Tide Basin.

A diagram in the paper on the renovation by B I Jones[3] shows the counterforts but this author has doubts whether they are Hartley's work or some later addition when the wall started moving. Like all of the builders at the time, Hartley suffered from the materials having no tensile strength, so most of the counterforts have sheared away with the tensile forces on the wall.

SITE CONDITIONS

The dock construction site was complex with diverse interdependent operations on many levels. It was also extremely compact. There were no locomotives on the docks until 1872, and for the construction of Albert Dock wagons were used, all pulled by horses. They had stationary steam engines but very little in terms of excavation machinery, which was typical of dock construction work almost until the 20th century.

The works were carried out on a muddy greenfield site out on the river. The men worked day and night in all seasons, in awful conditions, with no lighting in the modern sense. The work was very labour intensive, with the labourers capable of shoveling 15 tons a day into a wagon, and the next day, and the next.

Everything was dug by hand, by a huge labour force of between two and three thousand men – a very complicated site for somebody to supervise and get good quality results from. Records for the number of men employed are not available before G.F Lyster's time as dock engineer later in the nineteenth century, but there were roughly 1200 to 1500 men for the Albert Dock contractor, and 800 to 900 men for the direct labour. As well as the busy dock site there was also the attendant labour for the building work on the warehouses.

A boat that had been built in 1815 enabled the piles to be driven through the water so the workers didn't have to wait for low water or spring tides. There were also a lot of piling rigs on the dry site. Everything was done by hand because it wasn't worth setting up the machinery out on the walls and leaving it out there for the water to run over it. They would also have had to go out and clean it all up, which would have been quite a chore.

The Liverpool Dock Trustees were very reluctant to bring railways onto the docks because they were afraid of losing their authority and control. Even up until the 1950s there were still just little locomotives running along under the Overhead Railway, with a man walking along in front with a red flag. When they did eventually allow railways on the docks, they were for construction purposes and not for moving cargo.

Old style pumps that a Roman would recognise controlled the water on the site. This was always a responsibility of the direct labour, critical to the workings and also to health and safety. This was not formalised as it is nowadays but the safety of thousands of men on the site had to be secured, because they were at risk of drowning from the tide coming in, and the dangers from water in the material, seepage, rain and so on.

> Because of the prevailing winds and the strong tidal race in Liverpool, most of the dock entrances face south or southeast. Ships were turned and driven into the prevailing wind and the tide. But the Canning Half Tide Dock has a complicated entrance straight out into the river and with very narrow dock passages of just 45ft. So it is difficult to manouevre into and around the dock, and then into Albert Dock for unloading. Ships were then shunted round to Salthouse dock for loading, then out again.

CONCLUSION

Albert Dock was an unloading dock for high value cargo from the Far East, India and America. It was designed for small sailing ships, and Hartley determined its size on the basis of Isambard Kingdom Brunel's ss Great Britain. At 322ft long and 3,500 tons, this was the largest steamship of its day and the first ocean going steamer.

Once steamships started to become much larger, in size and tonnage, Albert Dock went out of date very, very quickly. From its opening by Prince Albert in 1846 it only lasted 50 years in terms of its economic success. In 1880 around 60% of the ships coming into Liverpool were sailing ships; by the end of the century this statistic had dropped to 7%. Albert Dock ran out of economic viability and from the 1920s there was virtually no economic activity in the dock. It was Grade I listed in 1951 and was redeveloped as a tourist attraction in the late 1980s.

Footnotes

1. Strand is an Old English word for land bordering sea or other water
2. Hartley's son wrote a paper for ICE on the backfill, On the Formation of Embankments and the Filling-in Behind Retaining Walls, J B Hartley, Minutes of the Proceedings of the Institution of Civil Engineers, January 1841
3. The Restoration of the Historic Docks of Liverpool, B I Jones, BEng, CEng, MICE, MIWES, Proceedings of the International Conference on Infrastructure Renovation and Waste Control, 8-10 April 1986. ICE Virtual Library

RESTORATION OF THE WATERSPACE IN ALBERT DOCK AND THE HISTORIC DOCKS

ROGER RUMBOLD
BSC, FICE, FISTRUCTE, Former Chief Engineer,
Merseyside Development Corporation

INTRODUCTION

The progressive decline of the Albert Dock arguably started in the 1920s, but it's surprising how long it hung on as a structural and functional entity. It saw service during the Second World War when the Navy moored small vessels there and the warehouses were used for land-based storage until the 1960s. However, by September 1972 the Mersey Docks and Harbour Company (MDHC) had decided to shut up shop on the south docks, and the docks were allowed to become tidal. The river entrance gates at Brunswick Dock were fixed open and eventually the Canning River Entrance gates also failed, resulting in the whole of the dock system becoming tidal. It remained tidal right up until Merseyside Development Corporation (MDC) was set up and commenced its regeneration programme.

MDC opened for business in March 1981, at the same time as the London Docklands Development Corporation and these were the first of a new breed of Government-funded regeneration bodies for derelict inner-city areas. The Toxteth riots in July 1981 turned the spotlight on to some of Liverpool's social and economic issues and helped to focus further interest on MDC's regeneration programme.

I joined MDC in August 1981 as Principal Engineer, initially studying engineering reports and structural surveys and generally preparing to be thrown into the fray. MDC had already taken possession of a large part of the south docks system, but the MDHC played a bit of a ransom game with the Albert Dock and there was a delay in formally acquiring it until April 1982.

OVERALL WATERSPACE STRATEGY

Overview

Liverpool was already committed to hosting the finish of the Cutty Sark Tall Ships' Race in July 1984 and as it would be the first time it had come to the River Mersey there was a very strong desire, for historical reasons, to have big sailing ships moored in and adjacent to the Albert Dock. It would also send a clear signal to the outside world that Liverpool had turned the corner and that its regeneration was finally getting under way.

The formal reopening of the Albert Dock by Prince Charles in 1988 mirrored the original and much-celebrated official opening by Prince Albert in 1846.

The MDC was finally wound up in 1998 as part of the closedown of most of the urban development corporations throughout the UK. Our work was far from finished but we had made a pretty good fist of it and it was left for others to take up the challenge.

At wind-up, the unsold parts of the south docks and the operational waterspace, including dock gates, pontoons and bridges were transferred lock stock and barrel from MDC to the Commission for New Towns, which subsequently became part of English Partnerships. In 2003 the responsibility for the dock waterspace and many of the dock walls was handed on to British Waterways, who continue to manage and operate them to the present day in their new guise as the Canal & River Trust, a registered charity.

Gower Street Estates Ltd was set up in 1997 to own and manage the Albert Dock complex, which includes the buildings, adjacent land areas and dock walls, and they work closely with the Canal & River Trust regarding the waterspace and its operation.

Dredging and water management strategy

To set the scene, the Old Dock Sill (ODS) was the original construction datum used in Hartley's day. This was the level of the entrance sill of Liverpool's (and the world's) first enclosed commercial dock, which opened in 1715. The Old Dock Sill was 1.5m below ordnance datum (OD) and this datum was still in use late in the 19th century.

However, the datum that we worked with all the way through the regeneration project was the navigation-related Liverpool Chart Datum (CD), which at 4.93m below OD saved us from the complication of going into negative figures with the construction levels. Chart Datum is roughly equivalent to lowest astronomical tide in the Mersey and the highest astronomical tide is about plus 10m CD.

> The accumulated silt in the docks had reached equilibrium levels by about 1979. On most high tides, however, the silt was covered in water so the docks didn't look too bad for an hour or two each day, but it was highly desirable aesthetically and operationally to get rid of enough silt to be able to float vessels. The retained water also needed to be cleaned up and the water levels controlled.

First of all, the tidal flow had to be stopped because you couldn't achieve anything in the docks with water coming in and out twice a day. The river entrances at Canning Dock and further along at Brunswick Dock were closed off with temporary dams of brick rubble hardcore and clay. The docks were cunningly closed off at low tide so water didn't have to be pumped out, and that immediately gave us a controlled situation to work with.

The regeneration strategy studies had concluded that Canning and Canning Half Tide docks should be separated from the rest of the dock system to prevent contaminated and silt-laden impounding water from the river mixing with the cleaned-up water in the rest of the docks when vessels were entering from the river. The remaining docks could then be cleaned up and made safe and attractive enough for recreation and leisure purposes.

> Studies concluded that a water level of 8.5m CD, around average high tide, would be the most sustainable as this would minimise both leakage losses and the need for top-up impounding, with the inevitable introduction of yet more silt and pollutants from the river.

It was also confirmed that dredging to a water depth of 3.5m throughout the south docks would accommodate a wide range of recreational uses, as would an air draft of 3.5m for the fixed bridges.

There were a number of strands to this strategy, two of which had particular significance for the Albert Dock area.

The first called for the construction of a causeway closing the Canning-Salthouse passage and this served a number of purposes. It severed the connection between Canning and Salthouse docks; it gave access to the Albert Dock area for pedestrians and vehicles; and it created an access route for mains services, which were almost non-existent on the estate, and those that did remain were defunct, dating from the 19th century.

The second strand was the construction of a new dock gate in the passage between Canning Half Tide Dock and Albert Dock, which would only be opened when required for vessel movements.

SILT REMOVAL PROGRAMME AND TALL SHIPS 1984

Over the nine years that they were tidal, an estimated 4.4 million cubic metres of silt was deposited in the south docks, equating to around 1-2mm per tide over that period.

The required water depth for the recreational purposes planned for most of the docks was 3.5m (dredge level 5.0m CD), but it needed to be 6m (ie at 2.5m CD) in the Albert Dock to allow historic vessels to moor at the Merseyside Maritime Museum quayside. In Canning Half Tide Dock we decided to dredge right to dock bottom (1.1m CD) as that gave us a bit more leeway when bringing in deeper ships from the river, and it allowed some future storage capacity for the silt that would inevitably come in with the impounding water, giving a maintenance dredging cycle of 10 to 15 years.

That still required a total of two million cubic metres of silt to be disposed of, and for that amount alone the dredging programme would take up to two years, with a further one to two years to find suitable disposal sites, obtain licences and appoint contractors.

With only two years and three months to get ships into Albert Dock it was a race against time to execute an advance dredging contract for the four historic docks (Albert, Canning, Canning Half Tide and Salthouse) and to build the new dock and river entrance gates.

September 1982 was the earliest that we could mobilise this dredging programme. The target was to dredge the historic docks as quickly as possible so we could then carry on with the rest of the dock engineering works.

A cutter suction dredger worked 24 hours a day, seven days a week and often under floodlights, to remove the silt. This was then pumped out through a 2ft (60 cm) diameter pipeline running for about a mile along the river wall to Coburg Dock, where it was discharged for temporary storage. The silt could not be disposed of off-site at that time, and a total of 370,000 cubic metres was temporarily stored in the Coburg and Brunswick Docks until it could be disposed of permanently under the future main dredging contract.

> Historic movement in the south wall of Canning Half Tide Dock was a matter of some concern. The cause was uncertain but there was evidence that there had been attempts to repair it in the past. As the silt was being removed, a bank of brick rubble hardcore was placed against the wall to stabilise it because the sudden removal of seven metres of consolidated silt, that could well have been providing propping to the dock wall for many years, could have triggered further movement or even collapse. In all, it took about four months to remove the silt from the four historic docks.

At the same time, building restoration works were also in progress on the shell refurbishment of the Block D warehouse, which was to become the Merseyside Maritime Museum, as well as a range of other jobs. At this point in early 1983 there were 37 contracts running concurrently on this narrow quayside site, which effectively had access from one end only, so there was a lot of very careful stepping around other contractors and their operations.

Before moving on to the detail of some of the other works, it's worth mentioning that the Tall Ships arrived on schedule in July 1984 and we made the docks ready with just a few weeks to spare. There were a lot of sleepless nights and a few frights but the Albert Dock opened for the first time ever to the public in July 1984 - it had never before been a public space - and around a million visitors came to Liverpool for the festivities at the finish of the Tall Ships Race.

DOCK WALL DEFECTS AND REPAIRS

The massive granite dock walls in the Albert Dock are an integral part of the substructures to the buildings themselves, forming the basements as well as the actual dock basin. Apart from some Second World War bomb damage from 1941 that needed some local stitching and grouting, on the corner by the partly-destroyed Atlantic Pavilion, there wasn't much repair work for us to do there.

Elsewhere it was a different story, with a range of dock wall defects requiring attention. The older sandstone walls on the east side of Canning Dock had become heavily eroded and many joints were very open, so pressure pointing was required to fill the voids behind, with pressure grouting to fill the open joints. Where blocks were missing or badly weathered, we employed sprayed concrete tinted to match the colour of the sandstone, and these repairs seem to be holding up pretty well.

Localised damage in Salthouse Dock also had to be repaired. Several corners had failed, possibly due to vessel impact, and there were blocks missing on each corner of the Salthouse-Albert passage.

> However, the most significant repair was that needed on the south wall of Canning Half Tide Dock. It had bowed and moved north by about 60cm at the centre and had probably been moving since Jesse Hartley's time or perhaps later in the nineteenth century. Investigations on site revealed that there had been one or two attempts to arrest the movement and to repair the wall in the past but these had not been successful.

MDC's consulting engineers, Ward, Ashcroft and Parkman, designed the solution we eventually adopted.[1] After drilling down through the masonry, two rows of compression piles were installed. The front row was vertical and the back row was slightly raked towards the back face of the wall, and combined with a row of inclined tension piles and rock anchors installed through the wall face at 35° to the horizontal; these successfully fixed the wall in position. The rubble bank once more came in handy because it could be reshaped as a working platform for installing the tension piles, before it was finally removed.

There was also some lateral movement in one section of the River Wall, about fifty metres south of the Canning River Entrance. A somewhat similar technique was adopted to stabilise that too, though without the raking tension piles.

NEW DOCK GATES

When originally constructed, all of the dock gates in the historic docks were timber mitre gates and the dock passages were 45ft (13.7m) wide. These gates would open freely with the rising tide and self-close on the falling tide, trapping the water at or close to the previous high tide level. Including the inevitable leakages, water levels in the docks could therefore vary by as much as two metres throughout the tidal cycle and considerable volumes of silt would also accumulate in Canning Half Tide Dock.

The future operating regime required new gates to be installed at Canning River Entrance and at the entrance to Albert from Canning Half Tide Dock, with the capability of remaining shut under frequent reversals of hydraulic head and having minimal visual impact on the historic fabric of the area.

It was not feasible to re-engineer the existing mitre gate system to meet the new operating requirements and a wide range of options was studied, resulting in the selection of bottom-hinged steel flap gates powered by hydraulic rams with vertical hydraulic latches to cope with the head-reversal case. The original dock passage width of 45ft/13.7m was retained.

The hydraulic power system for both gates is located in an underground chamber in the quayside near the Piermaster's House and the operating controls for each gate are interlocked so that only one gate can be opened at a time.

Canning River Entrance Gate

This gate opens inwards into the dock and when open it lies horizontally in a rebate below the entrance sill level. The rapid tides in the Mersey limit the safe operating window for vessels entering or leaving the docks to one hour either side of high tide.

Sill level is set at 3.5m CD, which roughly corresponds to the equilibrium level of the silt bank in the Mersey outside and is low enough to permit entry by vessels of up to 6m draft on the highest tides. Flushing ports on the gate and a spraybar arrangement on the flank wall help to keep the sill in front of the dock gate free of silt.

The gate is 8m high and weighs in at around 50 tonnes. When it was originally installed, it was lifted into place using MDHC's 1,000 tonne floating crane.

The level of the gate top at 11.5m CD allows for a Spring High Tide of 10m CD plus 1m storm surge, which is the accepted surge height for the River Mersey and which occurs every few years, plus 0.5m of wind-driven "slop". This gate height ensures that it is rarely over-topped to any degree.

The gate is normally operated using the two hydraulic rams operating in tandem, but either one of them can raise the gate in an emergency. In the event of total failure of the hydraulic system the gate can be raised using a 250 tonne crane and a portable hydraulic powerpack to secure the latches, ideally within the turn of the tide.

Canning Half Tide-Albert Dock Gate

This gate opens into the Albert Dock and is positioned so as to clear the lower chords of the Hartley Bridge when it is being lowered and raised. The gate sill level is 2.5m CD, matching the dredge level in the Albert Dock.

The gate is of a similar design and construction to the Canning River Entrance gate and I was slightly surprised to find from my research that at 8m it is also the same height, so its top is at 10.5m CD. The sill level is lower because it's within the dock system and as it leads a rather more sheltered life, it was decided that it could operate satisfactorily on just one ram. It too is equipped with hydraulically-operated latches and is normally kept closed unless vessel movements between Canning Half Tide Dock and the Albert Dock are planned.

THE CAUSEWAY, SLIPWAY AND BRIDGES

Improved access and circulation were essential to support the regeneration of the Albert Dock area, which had previously been served by swing bridges and roadways built in the 19th century.

Canning-Salthouse causeway and slipway

The causeway was required to provide both a permanent closure of the Canning-Salthouse passage and a new fixed route into the Albert Dock area for mains services as well as for traffic. It also provided the opportunity to create a slipway for vessel access into the dock system – a facility previously lacking in the south docks as none had been needed when it was a commercial port.

The core of the causeway is a steel sheet pile box with an in situ concrete base cast onto the floor of the old dock passage. Compacted crushed stone was used to fill this up to road sub-base level and to construct the base for the concrete slipway into Salthouse Dock. The slipway provides direct access to the water for maintenance and for a range of recreational uses, as well as pedestrian access to the canal boat moorings.

The Hartley Bridge, 1843

When we inherited it in 1982, the Hartley Bridge was in a derelict and damaged condition and totally inoperable, but as the last surviving example of around six Hartley-built bridges in the dock system, it was clearly imperative to retain it. This two-leaf swing bridge across the Canning Half Tide – Albert passage had cast iron ribs and a timber deck.

Two of the ribs had been repaired some years earlier with bolted mild steel plate doublers, but these plates had corroded heavily and recasting replacement ribs was investigated, but no foundry had a casting bed long enough. Instead, it was decided to repair the ribs using the "Metalock" casting repair system frequently used to repair cracked cast iron engine blocks.

The bridge was lifted out and taken off site for renovation at an early stage in the regeneration programme, then reinstalled after the new dock gate had been completed. The two halves of the bridge pivot on a circular wheeled undercarriage and until just a few years ago the bridge was opened manually by means of the cruciform windlasses at each end, each of which turn a crown wheel and pinion mechanism engaging with a toothed rack at the rear edge of each leaf.

However, accumulated corrosion, wear and tear and distortions in the structure made it an increasingly difficult task for three grown men per side and the bridge is now opened using powerful portable motors attached to high-ratio gearboxes and driving the original crown wheel and pinion mechanisms. The bridge can now be opened by just two operatives in about three minutes.

While the bridge is normally for pedestrian use only, it has been structurally checked and passed for crisis use by a 17 tonne fire engine, to give emergency access to the Tate Gallery and Albert Pierhead in the event of the riverside access route becoming blocked.

Albert-Salthouse Bridge, 1985

This new fixed bridge was built in 1985, and was given something of a historic feel by incorporating characteristic features of the Hartley Bridge, particularly the pierced ribs supporting the deck. These structural steel ribs support an in situ concrete deck and two timber-decked cantilevered walkways that are surfaced with non-slip panels, and the bridge is designed to carry two lanes of standard highway loading.

The 3.5m air draft is maintained over the middle three metres or so of the span, tapering off towards the abutments.

DOCK WATER QUALITY

Arriving at a means of achieving and maintaining satisfactory water quality, both from an aesthetic and a public health viewpoint, was enigmatic right from the start of the reclamation programme. Initially, substantial sums were included in the budget for installing and operating aeration and/or filtration equipment but no convincing technical solutions had been identified, so it was decided to wait and see what problems needed to be solved.

After a few months, the water started to clarify as sediment settled to the bottom and after a couple of years the water started to take on a more sparkling clarity. At this stage, a study by marine biologists from the University of Liverpool concluded that the extensive and self-seeded colonisation of the water body by the common or blue mussel, mytilus edulis, was the cause of this impressive clean-up and these filter-feeders continue to do the job free of charge to this day!

This study also identified at least thirty different species of marine life, including sea fans and numerous fish that had become established in the docks in the first few years after dredging.

The water in the docks has been sampled and tested on a regular basis for almost thirty years and, with a few exceptions, meets or exceeds EU bathing water standards. The exceptions are Canning Dock and Canning Half Tide Dock, due to periodic impounding and vessel movements, and Liverpool Marina where there are occasional hotspots because of waste leakages from moored vessels.

PRESENT DAY DOCK OPERATIONS AND WATERSPACE ACTIVITIES

Present day dock operations have changed a bit since MDC's time. The most significant change came in 2009 when British Waterways completed and opened the new canal link across the Pier Head. This joins the south docks to the Leeds and Liverpool Canal via the Central Docks, and this has led to a major growth in canal-borne traffic. It's now a popular destination for canal watercraft – before this they had to brave the tidal river lashed together in groups of two or three, sometimes with tug assistance.

The Albert Dock remains the focus for the annual River Festival and continues to host visits by Tall Ships fleets and other visiting historic sailing vessels. In August 2017 it hosted the start of the Clipper Round the World Yacht Race, which finishes back in the Albert Dock in July 2018. In addition to resident sailing vessels such as Zebu, there are regular visits during the sailing season from other tall ships and sail training vessels from many other UK and foreign ports.

Footnotes

1. The Restoration of the Historic Docks of Liverpool, B I Jones, BEng, CEng, MICE, MIWES, Proceedings of the International Conference on Infrastructure Renovation and Waste Control, 8-10 April 1986. ICE Virtual Library

LIVERPOOL WATERS AND OCEAN GATEWAY

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INTRODUCTION

Liverpool Waters consists of approximately two million square metres of proposed floorspace along the banks of the River Mersey north of the Three Graces, from Liverpool One in the city centre to Liverpool's Wastewater Treatment Works at the north docks. It forms part of Peel's Ocean Gateway concept that was set up in 2007, as part of a £50bn investment strategy across the North West. Liverpool Waters has a planning consent for a 32-year period to regenerate these docks.

The large container ships that sail around the world today cannot be accommodated in these mainly 19th century docks because of their increased size, so the southern docks have become derelict and underused. Part of Peel's business is to invest in ports and airports, and regenerate the surplus land that is no longer usable for its original purposes.

When the concept of Ocean Gateway was announced over ten years ago, one of the aims for both Liverpool Waters and Wirral Waters on the opposite side of the River Mersey was to propose tall building developments. Historically, Peel has taken on many ambitious projects, and this is no exception, so these "Waters" projects start with a blank canvas. We consider that tall buildings on each side of the river would be a physical spectacle at the entrance to the River Mersey and a visual gateway into the North West that would also act as a symbol of prosperity for the region.

With significant land ownership in the North West, particularly along the Manchester Ship Canal, it made sense for Peel to take the regeneration loop not just around Wirral and Liverpool but also around Manchester and Liverpool as a way of bringing these two city regions together. Rather than fighting against each other as they were a century ago, they would work together to benefit the whole region.

> Former Chancellor of the Exchequer George Osborne's Northern Powerhouse economic strategy included Leeds, Hull and the North East and this dovetails with Peel's Ocean Gateway proposals. With Peel's interest extending to more regions across the North, there will be a bigger impact on the economy, and the separate regions and locations will work better together and more effectively on the international market.

WATERFRONT VISION – PAST AND PRESENT

Peel wanted the two schemes of Liverpool Waters and Wirral Waters to work together and be the start of other Peel Waters schemes such as in Salford Quays and at Chatham in Kent, now named respectively Trafford Waters and Chatham Waters. These former dockland areas are being regenerated to bring out the best of water, docks and rivers. Peel is delivering its vision at Liverpool, set out ten years ago and now being carried through the detailed planning stage.

From the initial vision, Peel wanted Liverpool Waters to be world class, high quality and one of the best regeneration schemes of its type in the UK, without sacrificing anything on its way through. Liverpool Waters is unique in its nature, its scale and size, and Peel saw it as a great opportunity and catalyst for other River Mersey developments.

Not only is Peel developing its own land, it is also setting a standard for other developers to develop their land. It's the pebble in the pond theory where the ripples of regeneration move outwards. It doesn't stop at the boundary of Peel's ownership, and this approach is borne out by our current projects and those nearby proposed by other developers. Our wider aim is to increase tourism, attract new businesses and create new residential communities that work with the existing residential communities. This all helps to redress the balance of the North West as a region.

There were a number of proposals designed to show how the Liverpool waterfront could have been developed over a century ago - architectural and engineering visions with tall buildings beyond what we now call the Three Graces. They were never realised - one reason being that the movement of people up and down in lifts in those days was quite slow and inefficient. Nevertheless this was their vision and it's not dissimilar to Peel's in that they wanted height and scale just as we wanted tall buildings.

> It's worth remembering that the proposal to construct the Three Graces was controversial at the time they were built. They were built on reclaimed land and three docks had to be infilled which caused people to object. Liverpool Waters faced objections for similar reasons but would anybody want to re-open the docks where the Three Graces now stand?

EXTENDING THE CITY

Before Peel's recent £300m investment into the Port of Liverpool, we could only service 10% of the world's largest ships. With the new cranes we have installed, 90% of the world's largest ships can now use the port. Technology has changed and there's no going back: containerisation has left many dock systems around the world redundant, ships have got bigger and bigger and you simply can't get them into these old docks, as is the case with those that form Liverpool Waters.

However, redundant docks present great opportunities for property development. The land is level and the space for transport infrastructure is good. Liverpool Waters aims to add to the city, expand its core and use the waterfront with more appropriate uses. It is very rare to have port land immediately adjacent to a city centre; in most places around the world cruise liner passengers have to disembark at a port that is remote from the city centre and a taxi or bus is needed from the cruise liner terminal to the city centre. Liverpool has the huge advantage of the city centre being just a walk away from this port land.

Liverpool Waters is Liverpool's front porch to the world. It is the first impression those passengers get when they arrive at Liverpool and the last thing they see when they leave. Much of the land that forms Liverpool Waters is unsightly, used for what could be described as scruffy bad neighbour uses.

Such land uses should not be adjacent to a city centre. There are also heritage concerns, but a balance has to be maintained between the demands of the heritage lobbyists and future development needs. We have had no less than 57 meetings with English Heritage, and around eighty artefacts have been preserved, including small items such as the stub of a column from the old overhead railway, and listed openings in dock walls.

For a scheme of this nature, you need to look at all the precedents around the world for inspiration. We were motivated to find the good and the bad of dock developments in places such as Vancouver, Hong Kong and Shanghai, Liverpool's sister city. I spoke to masterplanners, architects, developers and local authorities to try to find what had worked well for them. What became clear is that waterfronts need scale and a presence. If you want people at ground level, you have to build upwards. We don't want Liverpool Waters to be like a ghost town when it's finished, but a place full of people and life, buzzing with activity.

Shanghai is perhaps the most appropriate example of how I would like Liverpool to look. The aim is not to build a mini Shanghai, but the similarities between the two cities are striking. Shanghai is much bigger of course, and has a milder climate, but it's got a river, with a lot of heritage buildings on one side and big developments on the other. The old buildings mix well with the new, they are all occupied, and the waterfront is full of thousands of people at all times of the day.

I want Liverpool Waters to bring people onto the waterfront as a way of invigorating the city as they have done in Shanghai. Liverpool's Three Graces are remarkably similar to some of the buildings on the Bund on the Shanghai waterfront, which were, after all, designed by English architects and engineers. Anything on the Shanghai waterfront would sit quite comfortably in Liverpool. There are more than thirty "graces" in Shanghai, whereas we only have three, but nevertheless they are all great buildings, and we have the opportunity to create something in Liverpool that synergises with the best of Shanghai.

BOUNDARIES AND EXTERNAL PROJECTS

The Liverpool Waters masterplan has four particular boundaries. The first is the waterfront where we are developing on land that was previously reclaimed land and where another dock system lies underneath which has presented some challenges. Our buildings have been positioned to retain the remains of the old docks so as not to disturb them.

The second boundary is the Grade II listed dock wall, and this also presented a conundrum. At the onset, Liverpool City Council suggested that we should remove the wall to enable our regeneration plans to expand across the dock road so our masterplan could plug into surrounding area. The aim was to help regeneration in what would become the council's Ten Streets project.

On the other hand, English Heritage insisted that the wall should stay up and that we use the wall openings as best we could. Ironically, if the wall wasn't there, we would not be able to get planning to permission to build it but because it already exists we couldn't get planning permission to pull it down.

The third boundary is Great Howard Street, where road improvements are of benefit to Liverpool Waters, especially in terms of getting traffic and people in and out of the site. The fourth and final boundary is the railway line and that's always going to be there, so we work with that as the ultimate boundary.

Liverpool Waters is also about attracting and encouraging other projects, which now includes Liverpool City Council's Ten Streets where some of the redundant buildings are to be brought back into use as a creative and cultural hub, and the Stanley Dock/Tobacco Warehouse that has been redeveloped with the Titanic Hotel and new apartments.

With Liverpool Waters starting to deliver its proposals, other developers in the area are gaining confidence and following suit. Developers often buy land around the Peel project on the basis that we always deliver. It takes many years to get to the stage where you feel confident you have the right approach, but it is all starting to come together now because we have taken our time and done it properly.

I was disappointed that the two tallest buildings were not included in our planning permission. These would have framed Victoria Tower, the Grade II listed clock tower at the entrance to Salisbury Dock. The clock tower is on the line of the Leeds & Liverpool Canal and would have made a great setting for the canal, but on a heritage-protected site new buildings are required to be lower than such heritage buildings.

English Heritage wanted us to create what is known as horizontality across the waterfront, but we didn't feel it appropriate to build lots of replica Albert Dock style buildings across the site. Albert Dock is unique and original and we wanted something that would make Liverpool distinctive and different from other cities, and not look like an old Russian waterfront. The aspiration for Liverpool Waters is to achieve a 24-hour part of the city that has presence and scale, and makes Liverpool a more memorable place to visit and experience than it is at the moment.

Our scheme is sustainable and economic and exists in a market where people want to live and work. With the equivalent of around 300 football pitches in terms of proposed floorspace, it creates a strong international expansion of the city centre for Liverpool and meets the modern demands of what we all require in buildings. A series of replica Albert Dock buildings could never do that.

FINANCIAL CHALLENGES

There have been many challenges along the way. The 2008 recession was difficult for Peel as it was for everyone. But it would be difficult to stop a scheme like this once it had gained momentum, particularly as I was also dealing with Wirral Waters at the same time. So both schemes carried on and ultimately moved forward and planning permission was granted without the need for a public enquiry or a judicial review for either side of the river.

> Liverpool Waters has 88 plots with over 100 buildings. It's part of a UNESCO world heritage site and has Enterprise Zone status. While we are not fully out of the recession, Liverpool Waters is progressing well. Liverpool Waters has a 32 years' planning permission and Wirral Waters has 28 years which was set primarily because every ten years or so the UK has some form of recession to deal with.

NEW BUILDINGS AND SENSITIVE SITES

Peel needs to be satisfied that every building project is high quality. Our process is to have what I call collective meetings, where all the developers, architects and investors for each project sit with representatives from the council, the heritage experts, the Local Enterprise Partnership and so on to consider every new scheme in a friendly and informal atmosphere. We then take projects to an independent design review panel, followed by public consultation, pre-application meetings and then submit a planning application.

The new cruise liner terminal will be a starting point and an end destination. When it was at Langton Dock we had four ships a year. We now have over 60 ships a year and when the new terminal opens next to the new Isle of Man ferry terminal, it will cater for over 100 ships a year, and many of these will be much larger ships than we have at present. It will also free up the land where the temporary cruise liner terminal is currently sited, a site which has its own complexities being historically sensitive and having a canal link running under it.

We have had to adapt our initial plans along the way, for example to allow for new roads and extensions of existing roads that the council requires for citywide benefits. At Waterloo Docks a road is to be constructed to link with and service the proposed Isle of Man ferry terminal. There will also be a new road to link up with Princes Dock. Without the work done by the city's planning and engineering departments, progress would be very slow. Fortunately we have the infrastructure going in first.

We also have planning permission for a large cultural building, originally called the House of Culture though that concept has now developed to include music, art and sport. The idea and hope is that at some point it will become a government-sponsored building for the whole of the North West, containing a cluster of different entities on what is a fantastic site. Along with the cruise liner terminal and the Isle of Man ferry terminal, Peel will allow the House of Culture site to be released for this public purpose as our contribution to Liverpool's regeneration.

The original masterplan from ten years ago is being reviewed to reflect today's market conditions and building typologies, and good progress has been made in this respect. The office market remains static, so smaller buildings than we originally envisaged are to be proposed that will provide more permeability to the waterfront.

At the northern docks, the original idea was to transform Nelson Dock and Bramley-Moore Dock into a residential community. We had planning permission for about 3,000 apartments that would probably have been built by a consortium of developers, including Peel. The desire was to create something at Nelson Dock that activated the waterspace in a different way, with unique floating buildings that you see in high quality developments around the world.

But then Everton Football Club came along wanting to build a new stadium at Bramley-Moore Dock, so that meant the masterplan had to change again. With Liverpool's bid for the 2022 Commonwealth Games we had to then accommodate that too[1].

All the different projects, however, continue to move forward. Our land at the Great Howard Street site may have an environmentally friendly heat and energy plant that would service all of our land and perhaps even a new stadium, some of the Tobacco Warehouse, and Ten Streets.

In terms of the public realm, we already have lots of events in Liverpool Waters and we want this legacy to continue, so we plan to create public areas with bandstands, green spaces, street theatre and so on. All this ensures that Liverpool Waters is set to become a special place.

Footnotes
1. Birmingham was chosen as the UK's preferred bidder for the 2022 Commonwealth Games the day after the Interpro event

CONCLUSION

This lecture series has been put together to celebrate the history and construction of Albert Dock in the 1840s and also the role the different built environment professionals that have played in its successful regeneration in the 1980s and continued development to date.

The half-yearly lecture events focus on different aspects of this exemplary heritage-led regeneration project that saw the redundant, bomb damaged Albert Dock transformed into a successful cultural and commercial hub.

The third event, focusing on water engineering and infrastructure, considered the past, present and future of Liverpool's waterfront. The speakers highlighted the incredible complexity of the site and the challenge of dock building, and also of managing the thousands of labourers who worked on the river and dock walls in often dangerous conditions.

> Liverpool's dock engineer Jesse Hartley tamed the River Mersey to provide safe docking and warehouse space for the thousands of ships that brought goods and people from across the world to Liverpool and beyond. Despite the achievement, Albert Dock became redundant relatively quickly as larger and larger steamships were built that could not navigate the narrow dock entrances and waterspaces. Tall-masted sailing ships were superseded almost entirely by the end of the 19th century.

After a period of dereliction Albert Dock and other parts of the historic dock system are operational again. It was a race against time and tide to get it constructed in the first place, and then again to get it restored in time for the Tall Ships Race in July 1984. Now the urgency is to regenerate Liverpool's north docks to bring these once bustling docks back to life. They may not now be fit for their original purpose, but they have huge potential for ambitious and exciting new developments that will restore activity, pride and prosperity to Liverpool.

It was a testament to Hartley's skill, innovation and courage that he managed such high quality results that can be seen and admired to this day. Heritage sailing ships and modern watercraft still use the waterspaces and delight millions of people every year. As the Peel development shows, other waterside and waterspace activities, from festivals to floating buildings will enliven these historic, atmospheric and potentially profitable waterspaces.

The future melding of the historic fabric and exciting modern interventions to create a new skyline is planned not only to impress the thousands of cruise liner passengers that will enter the Mersey, but also to signal that Liverpool is an exciting place to visit, live and work in.