

# MARINE AND FOUNDATION ENGINEERING

COWI



# THINK FURTHER

COWI's history in civil engineering dates back to 1930 when the company was founded. Since then, COWI has pushed the boundaries of marine design through our involvement in more than 3,300 marine projects worldwide. These projects range from large and technically challenging LNG terminals, container ports and waterfront developments to equally challenging cooling water systems, offshore wind farms, flood protection, locks and dams.

Today, we are a world leader in marine and coastal engineering. It is a position we have achieved by diligently pushing the development of new technologies to stretch the limits of what is possible.

We are driven by innovation and by our ambition to work closely with our clients to deliver world-class marine structures. Our services cover the entire life cycle of a marine structure, from the initial ideas to the operation phase, decommissioning or rehabilitation.

With a full set of world-class competencies within marine and coastal engineering combined with local presence and experience, we are ready to take on the most complex projects anywhere in the world – no matter how large or small.

TOGETHER, WE WILL TAKE YOU THERE.



# WHY CHOOSE US?





**AIN SUKHNA PRODUCT HUB,  
EGYPT**

Arab Petroleum Pipeline Co. has established a fully equipped product hub at their Ain Sukhna complex on the Red Sea Coast in Egypt. The hub includes onshore and offshore facilities. The onshore facility comprises 61 product storage tanks with a total capacity of 2,125 million m<sup>3</sup>, and two 50 km long unidirectional pipelines to the city of Suez. The diameter of the individual product storage tanks ranges from 21 to 59 m.

The offshore facility comprises a jetty and berths (500-160,000 DWT) including a topside pipeline and other auxiliaries. The hub includes an off-shore single point mooring for very large crude carriers (VLCC), connected via a sea pipeline. The offshore facility is intended to accommodate future expansions to handle up to 24 million tonnes per annum of various products.

The entire project development is planned to be completed in five main development phases with a specific phase for LPG tanks and berth.

**DATA**

Project period	2012-2013
Client	Arab Petroleum Pipelines Co. (SUMED)

**SERVICES**

- › Topographic survey at fuel tank site and land pipeline corridor
- › Concept design of marine terminal, tank farm, single bay mooring and land pipeline
- › Plant layout and 3D modelling
- › Front end engineering design (FEED)
- › Preparation of tender documents.



**GORGON LNG PLANT,  
AUSTRALIA**

The Chevron-operated Gorgon liquefied natural gas project on Barrow Island will bring on stream a three-train 15 m t/y, exploiting offshore gas fields off Australia's north west coast.

It is the largest of more than a dozen planned LNG projects in Australia.

Venture partners with Chevron are Exxon Mobil Corp, Royal Dutch Shell Plc, Osaka Gas, Tokyo Gas and Chubu Electric Power. The Saipem-Leighton Consortium (SLC) was awarded the jetty and marine structure contact in November 2009 based on a design concept with caissons to be prefabricated off site, towed in and placed on gravel beds. A connecting trestle is made of steel trusses spanning 70-80 m between caissons. The jetty is located approximately 2 km off shore.

SLC engaged COWI to carry out the independent design verification of the marine facility design which included checking more than 2,000 documents and performing independent design calculations.

**DATA**

Project period	2009-2014
Client	Saipem-Leighton Consortium

**SERVICES**

- › Independent design verification (IDV)
- › Independent calculations for validation of the structural integrity.



### NEW CRUISE FERRY TERMINAL IN THE PORT OF STOCKHOLM, SWEDEN

The new port facility consists of three new ferry berths and two upgraded ferry terminals. Each berth is configured with a 30 m wide movable steel ramp, submerged bulbous bow protection structures, and berth equipment.

The water depth at the berth is 11 m and the total berth length is approx. 1200 m. The suspended deck consists of double spanned prefab reinforced concrete deck elements typically 8 m x 8 m supported on prefab pile caps and approximately 1,050 tubular driven steel piles (pile length varies from 30-55 m).

All prefab elements were cast in Poland and transported to the construction site, placed on the pile caps and then cast together with the other prefab elements.

Along the inner edge of the suspended pile deck a double anchored steel sheet pile wall was installed to retain the new fill above the existing sea bed. In areas with un-sorted existing rock fill, large anchored prefab concrete L-walls were installed instead.

Cement-limestone piles and jet grouting were used in the reclamation areas to improve soil conditions. Rock armour was placed to protect the existing slopes and the new retaining walls from propeller scour.

COWI is the design consultant for all structural design.

#### DATA

Project period	2013-2017
Client	Per Aarsleff A/S

#### SERVICES

- › Tender and detailed design
- › Geotechnical design
- › Marine structural design
- › Design of pavement, drainage and utilities.







**FREDERIKSHAVN PORT EXPANSION, DENMARK**  
The Port of Frederikshavn is expanding the port to improve business opportunities in cargo handling, maritime industry, and service and maintenance of off-shore structures. The project is divided in three phases with construction of the first phase to be completed in 2018.

Phase 1 comprises 2.6 km of main breakwaters and 600 m new quay with a water depth of 11 m, but allowing for future dredging to 14 m. A new port area of 330,000 m<sup>2</sup> will be reclaimed using material from dredging of the new port basin and enlargement of the approach channel to allow access of Panamax carriers. The project also comprises quay apron, roads, drainage, water and electricity, waste water and lighting. The total expansion is planned to comprise 2,000 m of quays and 1,200,000 m<sup>2</sup> of new port areas. COWI is the project management consultant (PMC) for the entire project.

DATA	
Project period	2012 - 2018
Client	Frederikshavn Havn A/S

- | SERVICES  |
|---|
| › Master plan   |
| › Numerical modelling of waves, currents, sediment transport and wave agitation |
| › Geotechnical investigations   |
| › Navigation studies  |
| › Concept design and construction budget  |
| › Environmental impact assessment   |
| › Design of all elements and phases of the port expansion                       |
| › Tendering and contracting as design & build contract                          |
| › Assistance during construction.   |



**BROOKLYN NAVY YARD PIER C, RECONSTRUCTION, NY, USA**  
Pier C, within the Brooklyn Navy Yard, was originally constructed in the early 1900's and was in service throughout the century. In the early 2000's Pier C was used to berth ferry vessels for the New York Harbour. Beginning in 2011, the pier suffered a series of partial collapses and required replacement. In 2016, NYCEDC proposed the new Pier C to become the Home Port for ferry vessels for the new NYC Citywide Ferry System to begin servicing New York Harbour by 2017.

NYCEDC retained COWI to provide the structural design for the new pier to be constructed within the same footprint as the original pier. The new pier was designed to be approximately 690 feet long by 81 feet wide with a deck capacity of 1,000 psf and included a Travel Lift at the offshore edge of the pier in order to service ferry vessels on the pier's deck. Twenty-one concrete floating docks are arranged along the pier to provide berths for the ferry vessels.

DATA	
Project period	2017
Client	NYCEDC

- | SERVICES                     |
|------------------------------|
| › Marine structural design   |
| › Site plan layout           |
| › Design of utility systems. |



AT ANY GIVEN TIME, WE ARE INVOLVED  
IN MORE THAN 200 MARINE PROJECTS  
WORLDWIDE

## WORLDWIDE REACH

In COWI, we take pride in our achievements. Since the 1970's, we have been at the forefront of marine engineering, setting the standard for tomorrow's best practices. Together with our clients, we have been involved in more than 3,300 marine projects all over the world – from Argentina to the far corners of Russia.

We can take your marine project further than you imagine. COWI's key marine and coastal engineering offices are shown here. With offices, around the globe, we are never far away. And regardless of the scope of your marine construction or problem, we deliver worldwide.

All other COWI offices are listed on [www.cowi.com](http://www.cowi.com)





### KRONBORG CASTLE AND ELSINORE HARBOUR, DENMARK

Cultural Harbour Kronborg is a comprehensive renewal of the area between the town of Elsinore and Kronborg Castle, which is on the UNESCO world heritage list. The area has been developed into a recreational area with a new harbour front with new quay walls, wooden promenades along the quay walls, approximately 12,000 m<sup>2</sup> of granite paving, lighting, and 1.1 km of benches.

The fortifications around Kronborg have been recreated or restored including the recreation of von Scholten's ravelin, a contemporary architectural interpretation of the original ravelin. Most of the soil was reused in the project to create the new King's Quay and the Ravelin. The project also comprises new access roads and parking for busses and cars.

The multidisciplinary project was developed in close collaboration with the Client and the landscape architect Jeppe Aagaard Andersen. Risk assessment was integrated in the planning phase and the successive cost calculation.

#### DATA

Project period	2007-2014
Client	Ministry of the Interior, Elsinore Municipality

#### SERVICES

- › Overall planning
- › Preparation of tender documents
- › Project management consultant for the implementation of the entire project
- › Environmental and geotechnical investigations
- › Cost estimations
- › Supervision of works.







LUSAIL DEVELOPMENT,  
QATAR

The waterfront development is located along the shoreline north of Doha. It covers an area of about 21 km<sup>2</sup> which is approximately the same size as the entire Midtown and Lower Manhattan in New York.

The project has transformed the present shoreline through dredging and reclamation, creating new islands, access channels and beaches. The new development includes low and high rise residential housing for about 200,000 inhabitants.

The development includes business, corporate and mixed use areas as well as quality beaches with top class hotels, two golf courses and an entertainment district.

COWI completed the planning and design activities of the marine and earthworks and subsequently designed marinas and beaches. Finally, COWI supervised construction of all marine works.

Project period	2004-2014
Client	Qatari Diar / Bechtel Overseas Corporation

- SERVICES
- › Master planning
  - › Bathymetric and topographic surveys
  - › Geotechnical investigations
  - › Environmental impact assessment
  - › Conceptual and detailed design
  - › Preparation of tender documents
  - › Assistance in the tendering and contracting phase
  - › Construction supervision.



LONDON ARRAY OFFSHORE  
WIND FARM, UK

With 175 monopiles, designed to carry the Siemens 2.6 MW turbines, the London Array offshore wind farm is the world's largest, with a peak rated power of 630 MW in 2013. Monopiles of 4.7 m and 5.7 m diameter have been installed at water depths between 0 m and 25 m. With lengths up to 85 m, these foundations are amongst the largest ever built.

Its turbines are capable of generating enough energy to power nearly half a million UK homes and reduce harmful CO<sub>2</sub> emissions by over 900,000 tonnes a year.

A consortium of DONG, E.ON and Masdar commissioned Aarsleff | Bilfinger Berger Joint Venture (ABJV) as contractor to undertake fabrication and installation of the steel foundations. To carry out the detailed design of the monopiles, ABJV engaged COWI as lead in a joint venture with IMS Ingenieurgesellschaft mbH, COWI-IMS JV.

The project is one of the first offshore wind projects to use the conical grouted connection. Significant advances were introduced in the geotechnical methodology for calculations of soil-structure interaction.

Project period	2009-2013
Client	Aarsleff / Bilfinger Berger Joint Venture

- SERVICES
- › Hydraulic load calculations
  - › Structural design
  - › Geotechnical design
  - › Driveability analyses
  - › Cathodic protection analysis and design
  - › Scour assessment
  - › Risk management.



**WIKINGER OFFSHORE WIND FARM,  
GERMANY**

The joint venture of COWI and IMS Ingenieurgesellschaft mbH, led by COWI, has been entrusted with the detailed design of the foundations and the basic design of the substation.

COWI was Iberdrola's representative in the preliminary geophysical and geotechnical investigations for the 1<sup>st</sup> German regulatory system's (BSH) release, and is finishing the detailed geotechnical investigations for the 2<sup>nd</sup> BSH release.

Before this, COWI carried out the feasibility study of the turbine foundation types, investigating concepts for monopiles, gravity based foundations and jacket foundations for depth variations up to 42 m. Based on our preliminary foundation design, we were awarded the basic design of the jacket foundations equipped with AREVA 5 MW turbine, for the application for the 2<sup>nd</sup> BSH release. The offshore wind farm is expected to deliver up to 400 MW.

For the offshore substation, COWI's scope of work includes the mechanical and electrical design services in addition to the topside and jacket structure design.

**DATA**

Project period	2010-2017
Client	Iberdrola Renovables

**SERVICES**

- › Structural design of topside and jackets
- › Hydraulic design
- › Geotechnical design
- › Electrical and mechanical design
- › Low voltage design.



OWF App





# OUR SERVICES

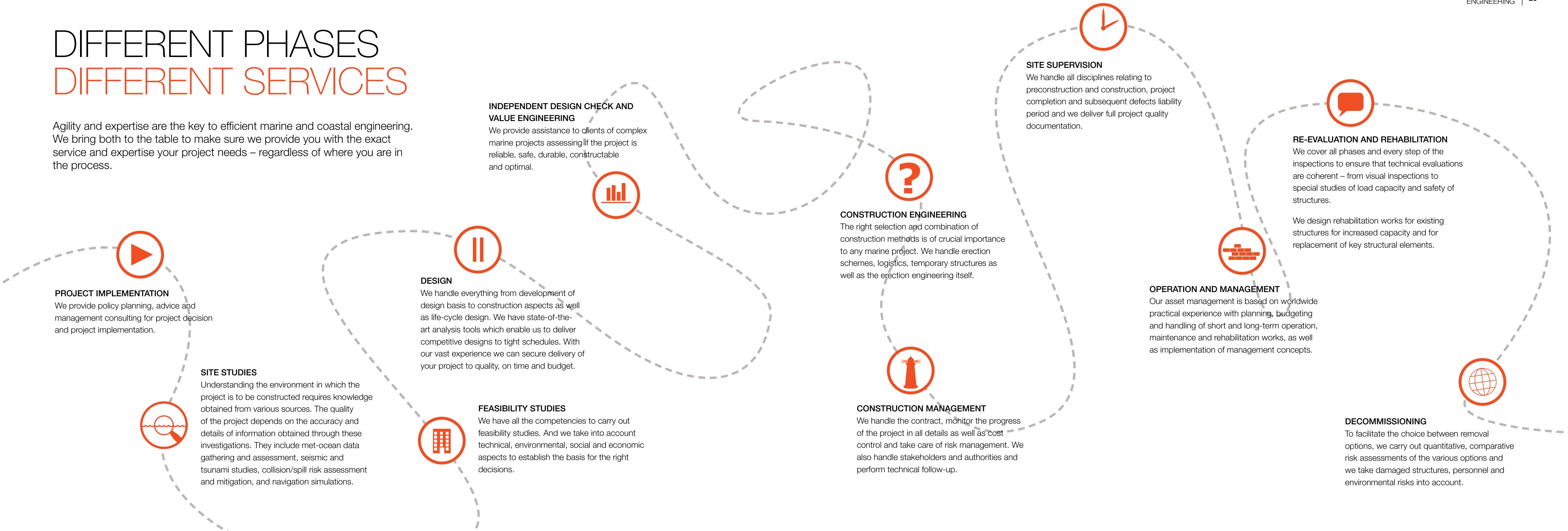
With our services, we cover the entire life cycle of a marine project from early ideas to the operational phase and rehabilitation – or decommissioning when the time comes.

We can handle the entire project, or we can step in at any given moment to provide your project with that extra expertise you need. The choice is yours.



# DIFFERENT PHASES DIFFERENT SERVICES

Agility and expertise are the key to efficient marine and coastal engineering. We bring both to the table to make sure we provide you with the exact service and expertise your project needs – regardless of where you are in the process.







YANBU 2 POWER AND WATER PROJECT,  
SAUDI ARABIA

The power and water utility company Marafiq is developing a new 850 MW (net to the grid) power and water plant for Yanbu 2 Industrial City to meet the increasing demand for power, process and potable water and seawater cooling.

The plant is located on the Red Sea coast of the Kingdom of Saudi Arabia, approximately 280 km north of Jeddah.

Saudi Archirodon Ltd. was selected as contractor for the marine facilities with COWI as consultant for the detailed design.

The marine facilities consist of a seawater intake facility and associated pumping station and a seawater outfall. Hydraulic modelling was used to develop near shore design conditions for marine structures (extreme waves, currents, water levels).

The scope of work includes preparation of design deliverables suitable to support the issue of technical tender documents to vendors and construction of the marine facilities by Archirodon

DATA

Project period	2011-2016
Client	Saudi Archirodon Ltd.

SERVICES

- › Met-ocean study and numerical modelling of waves and hydrodynamics
- › Recirculation modelling for confirmation of the location of seawater intake and outfall
- › Numerical flow modelling for optimisation of seawater intake channel
- › Layout and design of seawater outfall transition structure and GRP pipelines covered by rock protection
- › Design of seawater intake channel and breakwaters
- › Design of dredging, reclamation and foundation of structures
- › Structural design of pumping station, thrust block and culverts.





### RABIGH POWER PLANT NO 2, SAUDI ARABIA

The project is located in Rabigh, on the Red Sea coast, north of Jeddah in the Kingdom of Saudi Arabia. As part of the expansion programme for Rabigh Power Station, an additional four power generation units of 700 MW capacity each were installed.

Doosan Heavy Industries & Construction (Doosan) was awarded the engineering procurement contract (EPC) by Saudi Electricity Company (SEC) to deliver the Rabigh Power Plant No. 2.

Huta Marine Works Ltd. was sub-contractor to Doosan for the marine works. The marine sub-contract entailed a seawater cooling system for the power plant and it covers seawater intake pipes, intake basin surrounded by revetments, pumping station, outfall channel, outfall structure and breakwaters, and shore protection.

COWI provided numerical modelling and design services for the marine subcontract.

#### DATA

Project period	2010-2013
Client	Huta Marine Works Ltd.

#### SERVICES

- › Hydraulic engineering and numerical modelling
- › Management of physical modelling of pumping station, carried out in hydraulic lab, breakwater revetment, and outfall structure
- › Geotechnical engineering
- › Piping engineering for intake glass reinforced pipes
- › Electrical engineering for the cathodic protection of marine works.



### OLMSTED LOCKS AND DAM, IL, USA

The Olmsted Dam on the Ohio River is currently under construction 16 miles upstream from the confluence with the Mississippi River. It will consist of an 800-foot-long tainter gate section, a 1,400-foot navigable pass, two boat abutment sections, a fixed weir section, and upstream and downstream scour protection.

COWI provided the detailed design for the new navigation dam and also construction design support of the precast yard including the marine skidway for load-out of the pre-cast shell segments.

The construction design encompassed concrete and steel retaining walls, gantry crane beams, skidway rail including beam and foundation system both above and below water, precast shell cradle, steel frame tremie mat templates, lifting/mating details for the precast shells, mooring anchors and dolphins.

COWI also completed the shell design for the navigable pass precast segments, paving blocks and the lifting frame for the navigable pass segments and supported the design of the tainter gates.

#### DATA

Project period	2005-2020
Client	U.S. Army Corps of Engineers, Louisville District

#### SERVICES

- › Casting yards/launch system
- › Dredging
- › Heavy lift systems
- › Detailed design of all precast and insitu cast concrete elements
- › Foundation design
- › Mooring and berthing analysis
- › Seismic analysis
- › Cost estimation.



NEW ORLEANS FLOOD PROTECTION  
BARRIER, LA, USA

COWI was responsible for the detailed design of the flood barrier and the monolith foundations and guide walls, for the main sector gate structure; and a concrete swing barge gate; both of which will be used to regulate navigation, tidal flows, and storm surge into the inner harbour navigation canal (IHNC) in New Orleans.

This \$1.3 billion project is the largest civil works design-build project ever awarded by the United States Army Corps of Engineers. It won the American Society of Civil Engineers' highest design honor in 2014; and is an excellent example of innovative design and of fast-track construction.

The federally funded contract was for construction of a storm surge barrier to keep surges from entering New Orleans' inner harbour navigation canal. Failures of floodwalls overwhelmed by storm surge during Hurricane Katrina in 2005 along the IHNC contributed greatly to the flooding of the city.

The IHNC barrier was completed by mid-2012 near the confluence of the Gulf intracoastal waterway and the Mississippi River Gulf outlet, a natural funnel identified as an area of critical vulnerability.

DATA

Project period	2008-2012
Client	The U. S. Army Corps of Engineers

SERVICES

- › Numerical modelling
- › Concept and detailed design of the main sector gate monolith, batter pile floodwall, reinforced concrete by-pass barge gate, MRGO berm structure, GIWW approach walls, and scour protection.





## OUR TEAMS

Since we designed our first marine project, we have actively participated in the research and development of new techniques, the use of new materials and new technologies in the field of marine structures.

Today, our teams deliver cutting-edge know-how in all aspects of marine and coastal engineering. And we continue to push the boundaries to maximise value for our clients.



# DIFFERENT ASSIGNMENTS DIFFERENT COMPETENCIES

Our large pool of engineers and experts enables the project manager to set up a team with the right competencies to match your project.



> STRUCTURAL DESIGN > DREDGING DESIGN > COST ESTIMATION > REHABILITATION ENGINEERING > WAVE  
MODELLING > HYDRAULIC MODELLING > SOIL STRUCTURE INTERACTION > HYDRODYNAMIC FLOW MODELLING  
> CURRENT MODELLING > METOCEAN STUDIES > SERVICE LIFE DESIGN > LABORATORY TESTING > SEISMIC  
ANALYSES > FATIGUE ASSESSMENTS > FINITE ELEMENT ANALYSES > LIFE CYCLE COSTS > SUSTAINABLE  
ENGINEERING > MECHANICAL AND ELECTRICAL INSTALLATION DESIGN > OPERATIONAL RISK MANAGEMENT  
> CONSTRUCTION RISK MANAGEMENT > NAVIGATION SIMULATION > MASTER PLANNING > STRUCTURAL DYNAMICS  
> SHIP COLLISION RISK > UTILITIES > BUILDING DESIGN > MODEL TEST VERIFICATIONS > SHIP IMPACT PROTECTION  
> MOORING ANALYSES > HAZID/HAZOP > BIM

## THE CONSTRUCTION SPECIALIST

Our construction specialist works to secure the balance between design and construction.

## THE GEOTECHNICAL EXPERT

Our geotechnical expert specifies the geotechnical site investigations, analyses the results and establishes a geotechnical design basis for the project.

## THE PROJECT MANAGER

Our project manager is responsible for managing the contract with the client and for delivering the project on agreed time and budget.

## THE STRUCTURAL ENGINEER

Our senior structural engineers are responsible for all basic engineering aspects of the project – drawings and verification, to secure practical buildable structures.

## THE SEISMIC EXPERT

Based on information from the site, our seismic expert establishes spectra and time series to be used in the design process.

## THE HYDRAULIC AND COASTAL EXPERT

Our hydraulic expert is responsible for determining how the hydrodynamic processes influence the design and functionality of any structure.





**AL RUWAIS PORT DEVELOPMENT, QATAR**

Al Ruwais Port is located approximately 120 km north of Doha. The project comprises the development of the existing fishing port with new facilities to accommodate dhows, coastal trading vessels and passenger/car ferry traffic importing general cargo including fruit and vegetables, livestock and building materials.

The marine construction work included dredging, reclamation, concrete block quay walls, fenders, navigation aids, rock revetments, utilities and port furniture, floating pontoons, slipways, fuel storage tanks and dispensers, gantry cranes and block paving.

In addition, there are service roads and all utilities (sewerage, potable water, surface water drainage, LV, HV and ELV, telecommunication and landscaping including irrigation).

COWI provided post-contract professional general and site supervision and quantity surveying consultancy services for construction.

<b>DATA</b>	
Project period	2010-2014
Client	Public Works Authority (PWA) Ashghal

- SERVICES**
- › Project management
  - › Redesign of marine works
  - › Quality assurance program
  - › As-built drawing review
  - › Record documentation
  - › Post contract quantity surveying
  - › Site supervision.



**GSPC LNG TERMINAL AT MUNDRA, INDIA**

The Gujarat State Petroleum Corporation (GSPC) is developing a 5 MTPA (expandable to 20 MTPA) LNG receiving, storage and regasification terminal in Mundra Port in the State of Gujarat, India.

The terminal consists of LNG carrier berthing and unloading, storage tanks, boil-off gas handling, pressurization and vaporization, and connection to the natural gas grid.

The terminal is designed for handling LNG carriers of up to 285,000 m³ capacity.

The marine construction work includes a jetty with an approach trestle of 1.1 km, flare platform, shore protection works, sea water intake and outfall.

COWI provides the preconstruction and construction services including site supervision.

<b>DATA</b>	
Project period	2012-2017
Client	Whesoe Projects Ltd.

- SERVICES**
- › Front end engineering design (FEED) review
  - › Cost estimation
  - › Request for proposals
  - › Owner's engineering services
  - › Site supervision.



# OUR EXPERTISE

Every marine project is unique. To meet this challenge, we have world-class engineers and experts working together to integrate seamlessly all aspects of marine engineering – from the marine construction itself to traffic planning, geo mapping and environmental impact assessment.

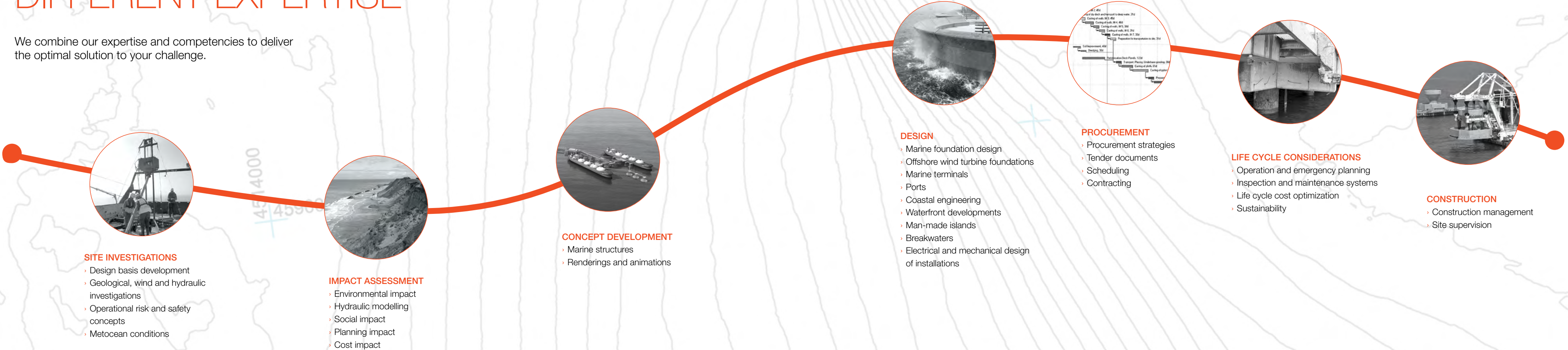
For every project, from a small coastal protection project to a major LNG terminal, we establish a specific team to ensure that we deliver the best solution for you.





# DIFFERENT CHALLENGES DIFFERENT EXPERTISE

We combine our expertise and competencies to deliver the optimal solution to your challenge.







### THE PEARL-QATAR

The Pearl-Qatar project involved detailed design of the reclamation works for the 400 hectare new island requiring approximately 13.5 million m<sup>3</sup> of fill and the associated sea defence structures for the 40 km of new shoreline.

The development included private beaches along most of the perimeter, which adds to the aesthetics and exclusiveness of the development. Various concepts were developed to create a variety of beach environments that are optimised to suit the local conditions and requirements.

Numerical hydrodynamic model studies were carried out to determine the metocean design basis.

COWI has, in addition to the island design, rendered technical assistance during construction and the design of the marinas.

### DATA

Project period	2003-2008
Client	United Development Company (UDC)

### SERVICES

- › Bathymetric survey
- › Design of marinas
- › Design of culverts
- › Design basis
- › Conceptual design
- › Detailed design
- › Preparation of tender and contract documents.





UPPER ZAKUM ARTIFICIAL ISLAND PMC,  
ABU DHABI, UAE

The Zakum Development Company (ZADOC) needed to construct additional facilities in order to increase oil production from the Upper Zakum Field. Based on site conditions and production/facility requirements, XADOC elected to construct four artificial islands to meet this need.

Each island was proposed to be approximately 35 hectares except for the central "m" island, which was proposed to be approximately 70 hectares. To manage the construction of these islands, ZADOC/ADNOC issued tenders for a project management consultant (PMC) and a design-build contractor. COWI was selected as the PMC and the National Marine Dredging Company (NMDC) as the design-build contractor.

COWI's primary scope of work was to manage the project to ensure that the islands were designed according to the specifications within the agreed schedule and budget. Our specific tasks included: establishing project objectives and requirements; preparing scope of services; contract tendering; evaluation and award; technical support; liaising with authorities; design checking and review; coordination, management, administration and quality control; monitoring; auditing; reporting; close-out and commissioning.

DATA

Project period	2010-2013
Client	Abu Dhari National Oil Company (ADNOC)

SERVICES

- › Design checking and review
- › Project management and construction supervision
  - › Administration
  - › Control
  - › Review
  - › Follow-up
  - › Commissioning
  - › Quantities for DCM clusters
  - › Technical assessment of possible non-compliant works.



HONG KONG THREE-RUNWAY SYSTEM  
DEEP CEMENT MIXING, CHINA

The Hong Kong Three Runway System project is a 650 ha extension of the existing airport at Chek Lap Kok planned to meet future demands. The marine elements of the project comprise six packages where package 1 through 5 cover deep cement mixing (DCM) of contaminated mud pits. Package 6 covers the main reclamation of all 650 ha including 12 km new seawall and about 6 km existing seawall to be either removed or changed.

This project covers part of the seawall and part of the loading platform zone with about 25,000 DCM clusters (one cluster consists of four overlapping DCM columns) or a volume of about 2.6 Mm³. The lengths of the clusters are up to 45 m and installed through a sand blanket into contaminated mud or soft clay and terminated in a competent stratum of alluvium.

Each DCM column has a diameter of 1 meter and a design strength between 800 and 1.000 kPa.

DATA

Project period	2016-2018
Client	Sambo

SERVICES

- › Detailed evaluation of the top of competent stratum
- › Required embedment depth of deep cement columns
- › 3D ground model
- › Quantities for DCM clusters
- › Technical assessment of possible non-compliant DCM works.



# WHAT IS NEEDED?

Protection against high tides and rain or an economic analysis of consequences or intervention. We are ready to take on whatever is needed on requests from the municipalities or the citizens.





# MARINE TERMINALS



## BAHRAIN LNG IMPORT TERMINAL

### DATA

- › Project Period: 2015-2019
- › Client: Whesoe Engineering Limited (main PMC consultant), Nogaholding
- › Onshore receiving facility and pipeline (4.1 km, buried)
- › Subsea pipeline (4.3 km, 10-15 m water depth)
- › Breakwater (600 m long, 15 m water depth)
- › Regasification platform with jacket substructure and regas. module
- › Berthing jetty for FSU (175,000 m³) and LNG carriers up to QMax size.

Bahrain LNG W.L.L. is establishing an LNG import and regasification facility with peak send-out capacity of 800 MMSCFD, approximately 4 km off the coast near the Mina Salman port.

### SERVICES

- › PMC sub-consultant for the marine works
- › Technical advisor to the National Oil and Gas Holding Company for certain interface-related activities.



## PORT OF REDWOOD CITY, CALIFORNIA, USA

### DATA

- › Project Period: 2011-2013
- › Client: Port of Redwood City

Deepwater access for bulk, neo-bulk, and liquid cargos. Existing Wharves 1 and 2, built in the 1930's and 1940's, are used for offloading aggregate, primarily from Panamax vessels. COWI was retained to lead a modernization project for Wharves 1 and 2.

### SERVICES

- › Coordination of site investigations including a geotechnical exploration, hydrographic survey, topographic survey, and hazardous material surveys
- › Marine structural design
- › Production of bridging documents for the design-build team
- › Permitting
- › Review and approval of the design-build teams' 75%, 95% and final designs
- › Quality assurance during construction.



## KNPC NORTH AND SOUTH PIER SURVEY, KUWAIT

### DATA

- › Project Period: 2012-2014
- › Client: Kuwait National Petroleum Company and Integral Services Co. W.L.L. (ISCO)

Terminal for gas import and export of crude oil and refined products, for vessels of up to 300,000 DWT.

### SERVICES

- › Sub- and superstructure inspections including underwater inspection of piles
- › Non-destructive testing and gauging with ultrasound equipment
- › Structural calculations of typical sections in North and South Piers
- › Finite element modelling and structural assessments
- › Survey and re-assessment study for the North Pier
- › Re-assessment calculations and rehabilitation strategy study.



## RUWAIS GASPORT, UAE

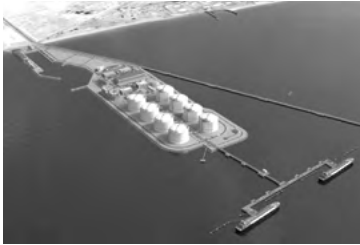
### DATA

- › Project period: 2015
- › Client: Excelerate Energy Limited Partnership

Abu Dhabi Gas Industries Ltd. (GASCO) intends to develop a gas port at the existing sulphur terminal in Ruwais, Abu Dhabi to provide a natural gas supply through a floating storage and regasification unit (FSRU). Excelerate provides the 138,000 m³ FSRU and upgrades the jetty topside HP loading arms and associated nearshore ancillary facilities, including a 24" pipeline linking to the local gas grid.

### SERVICES

- › Berth layout and mooring study
- › Desktop navigation simulation
- › Basic and detailed marine and structural engineering
- › Civil engineering for the onshore building and pipe racks.



## AL ZOUR LNG IMPORT, KUWAIT

### DATA

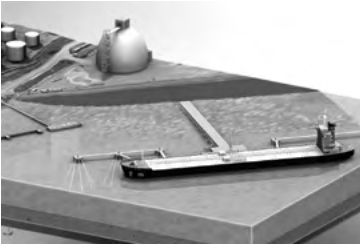
- › Project Period: 2016-2018
- › Client: Hyundai Engineering and Construction Company

New liquefied natural gas regasification plant to supply natural gas to Kuwait national gas grid.

### SERVICES

- COWI will provide detailed design of the following units:
  - › Jetty I and II: OP, BD, MDs and IB, Trestle: main trestle, arm 1 and arm 2, Approach channel and flare platform
  - › Intake tower, pipelines and pump station
  - › Outfall diffuser, pipelines and chamber
  - › Land reclamation and rock revetment.

# PORTS AND HARBOURS



## PORT OF ANCHORAGE, ALASKA, USA

### DATA

- › Project period: 2017
- › Client: Port of Anchorage

The Port of Anchorage is undertaking a modernization program to upgrade the port's facilities and provide new structures that can survive extreme seismic events and Cook Inlet's harsh marine environment, which includes extreme tidal fluctuations and winter ice impacts. The new resilient structures will have a 75-year design life.

### SERVICES

- › Structural design
- › Geotechnical engineering
- › Coastal engineering.



## PLANNING FOR CRUISE SHIP FACILITY, GREENLAND

### DATA

- › Project period: 2013
- › Client: Qaasuitsup Kommunia

Updating and clarifying current and future cruise ship operations at the Ilulissat Icefiord in Qaasuitsup Kommunia in northern Greenland.

### SERVICES

- › Review of current cruise ship traffic to Ilulissat town in terms of opportunities and challenges
- › Meetings and interviews with stakeholder groups to identify local concerns and preferences
- › Field trips by foot and by boat along the wilderness coast north of the Icefiord to identify suitable locations with potential for development of new marine facilities
- › Summary report with proposed next steps.



## CHHARA PORT, INDIA

### DATA

- › Project period: 2017-2018
- › Client: Simar Port Pvt Ltd

The greenfield port at Chhara 50 km to the west of Diu Airport will build a breakwater with a total length of 4.2 km comprising of 3.3 km section to protect the liquefied natural gas berths, container and multipurpose berths and coal jetties. COWI has been awarded the services related to the detailed design of the breakwater.

### SERVICES

- › Data collection and review of existing data
- › Establishment of design conditions
- › Concept design and detailed design for selected concept
- › Design basis for hydraulic design
- › Geotechnical design
- › Specification and supervision for 2D and 3D physical modelling tests.



## CARGO TERMINAL, PORT OF OWENDO, GABON, WEST AFRICA

### DATA

- › Project period: 2016
- › Client: AFCONS Overseas Project Gabon SARL

Gabon Special Economic Zone (GSEZ) Ports S.A. builds a new general cargo terminal comprising a 420 m long berth including quay, storage and service crane for general cargo and container vessels, dredged to -14.0m CD, for import of general cargo such as grain, re-bars and hydrocarbons, and export of palm oil and containers. AFCONS Gabon SRL is the contractor for design and construction of the works. AFCONS has appointed RH-DHV as its Lead Design Consultant COWI is the independent engineer.

### SERVICES

- › Independent design verification of marine and onshore facilities, including civil infrastructure and MEP works
- › Independent modelling of structures.



## SONAREF REFINERY MARINE TERMINAL, ANGOLA

### DATA

- › Project period: 2013-2014
- › Client: Odebrecht Angola Projectos e Serviços Lda

Sonangol is planning to build a refinery in Lobito including a marine terminal to receive Angolan crude oils, which will be processed into refined liquid products along with solid byproducts. The new marine terminal will consist of two berths, one capable of loading liquid products and solid products and for loading liquid products and for loading liquid products and unloading heavy crude oil as well as a materials offloading facility.

### SERVICES

- › Independent design verification (IDV) of marine facilities (blockworks, revetments, reclamation)
- › Technical assistance on dynamic compaction trial tests
- › Alternative design of revetment and heavy duty pavement.





# COASTAL ENGINEERING AND WATERFRONT DEVELOPMENTS



## BREAKWATER FOR VIZHINJAM PORT, INDIA

### DATA

- › Project period: 2017-2018
- › Client: HOWE Engineering projects (India) pvt Limited

COWI carried out the detailed design of the 3.1 km long rubble mound breakwater.

### SERVICES

- › Numerical modelling for establishing design waves
- › Detailed design with Accropode® II as primary units.
- › Detailed geotechnical design
- › Technical specs for physical model tests and visit to lab
- › Detailed structural design of wave wall
- › Technical specifications for breakwater
- › Interface with concrete armour licensor
- › Workshop on construction methodology
- › Bill of quantities and issue of good-for-construction drawings.



## HANSTHOLM PORT EXPANSION, DENMARK

### DATA

- › Project period: 2017-2018
- › Client: Per Aarsleff A/S

Hanstholm is a major fishery harbour on the Danish North Sea coast. It has launched a design-build tender for an expansion with new outer breakwater-sand quay wall. The eastern breakwater is 1 km long, the main western breakwater is 400 m long, both exposed to severe waves from the North Sea, with significant wave heights in the order of 7-8 m.

COWI carried out the tender design of breakwaters and revetments based on the port expansion layout provided by the port, and after the award of the design-build contract to Aarsleff, the detailed design.

### SERVICES

- › Tender design of breakwaters and revetments
- › Detailed design.



## SALWA RESORT HOTEL, MARINE WORKS, QATAR

### DATA

- › Project period: 2014-2015
- › Client: Tashgeel & Besix JV

Private Engineering Office develops a major high end resort. It includes a marina in the middle and man-made beaches at both sides. The harbour has an almost ellipsoidal shape in order to protect the basin from waves from W and NW. The beaches are constructed as a basin dredged along the coast. The beaches are stabilised with beach islands with a very special layout.

### SERVICES

- › Marina layout confirmation
- › Review of existing data and design
- › Basis of design
- › Geotechnical interpretative report
- › Detailed design of marina outer breakwater and beaches
- › Review of quay wall settlement analysis
- › Technical specifications.



## MONACO URBANISATION EN MER PHASE PRO/EXE

### DATA

- › Project period: 2015-2013
- › Client: SAM L'Anse du Portier

The Principality has contracted for a 60,000-sqm extension of the city of Monaco into the sea. SOCOTEC and COWI carry out the independent verification of the detailed design. The project comprises 17 perimeter caissons, a leisure boat marina and land reclamation for the construction of underground parking spaces as well as roads, utilities and high-rise housing.

### SERVICES

- › Independent verification of the detailed design of the caissons and their foundations as well as the marina and associated structures
- › Independent modelling of the wave agitation inside the marina and numerical calculation models of the caisson structures in order to verify the designer's numerical modelling
- › Assistance to marine environmental monitoring of construction activities.



## SHENZHONG LINK, CHINA

### DATA

- › Project period: 2016-2017
- › Client: Shenzhong Link Management Center

The 24 km link will connect the cities of Shenzhen and Zhongshan across the Pearl River Delta. The link comprises two approach bridges, two bridges, the world's widest immersed tunnel and two artificial islands. The islands are designed to minimize the blocking effect in the environmentally sensitive river delta and the loads from typhoon waves and associated water levels. Both islands will be reclaimed from sand dredged in the river and protected by revetments with armour of rocks and concrete blocks. The services include independent design checks of the two islands.

### SERVICES

- › Dredging
- › Reclamation and ground improvement
- › Initial perimeter of large steel cylinders
- › Protecting perimeter structures
- › Rescue harbours.

# OFFSHORE WIND FARMS



## RENTEL OFFSHORE WIND FARM, BELGIUM

### DATA

- › Project period: 2014-2017
- › Client: Rentel NV
- › Total: 550 MW
- › Water depth: 22-32 m
- › Foundations no: 42
- › Foundation type: Monopile

Rentel NV is developing an offshore wind farm in Belgian territorial waters with sand dunes of 5 m in height. Rentel has appointed Dredging International NV as EPCI contractor, and COWI (in joint venture with Technum-Tractebel) is Dredging International's design consultant for the detailed design of the monopile foundations and transition pieces for 42 Siemens Gamesa SWT-7.0-154 turbines.

### SERVICES

- › Design of foundations
- › Geotechnical design
- › Scour and corrosion protection
- › Designer's risk assessment
- › Risk management.



## MERKUR OFFSHORE WIND FARM, GERMANY

### DATA

- › Project period: 2015-2017
- › Client: DEME GeoSea NV
- › WTG: Alstom Haliade 150, 6 MW
- › Foundation no.: 66
- › Water depth: 27-33 m
- › Foundation type: Monopile

MERKUR Offshore Wind builds Merkur in the German part of the North Sea. The approval process for the development complies with the requirements of the German Federal Maritime and Hydrographic Agency (BSH). The construction is contracted to GeoSea for which COWI, with IPU as sub-consultant, carries out the detailed design of the foundations, viz. design of primary and secondary steel and transition pieces, bolted connection between monopole and transition piece, geotechnical design, hydrodynamic load calculation, scour protection, corrosion protection, low voltage design, and ship collision friendliness analysis.

### SERVICES

- › Detailed design and FEM analysis
- › Concrete and grout structures.



## THORNTON BANK OFFSHORE WIND FARM - PHASE 1, BELGIUM

### DATA

- › Project period: 2006-2008
- › Client: Dredging International n.v. Belgium
- › WTG: REpower 5.0 MW
- › Water depth: 30 m
- › Foundation no.: 6
- › Foundation type: Gravity based

Detailed design of foundations. In 2003-04 we carried out a concept study, including the innovative conical shell structure, eventually adopted by the project owner. In 2006-2008 we carried out the detailed design.

### SERVICES

- › Structural design of foundations
- › Geotechnical design
- › Numerical and physical hydraulic modelling of installation stages, including dynamic loads and scour
- › Appurtenances design, including boat landing and J-tubes
- › Project follow-up in construction stage.



## FORMOSA 1 OFFSHORE WIND FARM FOUNDATIONS, TAIWAN

### DATA

- › Project period: 2014-2015
- › Client: Formosa Wind Power Co.
- › Total: 144 MW
- › Water depth: 15-30 m
- › Foundations no.: 36
- › Foundation type: Monopile/Jacket

An offshore wind farm in East Asia on the western coast of Taiwan, consisting of 36 turbines in total, is planned to be installed in 2018.

### SERVICES

- › Front end engineering design and detailed design of foundation for eight positions
- › Front end engineering design of the entire wind farm.



## HORNS REV C, KRIEGERS FLAK A AND B, TRANSFORMER PLATFORMS, DENMARK

### DATA

- › Project period: 2013-2015
- › Client: Energinet.dk

Concept and basic design of two transformer platforms for the 600 MW Kriegers Flak offshore wind farms. Furthermore, COWI develops the concept and detailed design of Horns Rev C 400 MW transformer platform.

### SERVICES

- › Design of foundations
- › Basic and detailed design of 2x400 MW and 200 MW platforms including mechanical and electrical design.





# INDUSTRIAL SEAWATER SYSTEMS



**SEAWATER INTAKE RE-GASIFICATION TERMINAL 2, MALAYSIA**

**DATA**

- › Project period: 2015-2016
- › Client: Petronas CLINETAmec Foster Wheeler

Samsung C&T carries out the construction and the commissioning of the liquefied natural gas regasification facility project in Pengerang. The project includes the installation of facilities for receipt, storage and regasification of LNG in order to supply natural gas to RAPID, PCP and existing PGU system. Foster Wheeler E&C Sdn Bhd (AmecFW), designing the facility, has appointed COWI to manage the detailed design services of marine elements.

**SERVICES**

- › Hydraulic engineering for intake pipes, for bay/pump station and discharge outfall
- › Sizing of pump station and piping engineering for intake pipes
- › Geotechnical engineering
- › Structural engineering for concrete head structure and manholes
- › Design of shore protection structures
- › 3D physical modelling for the pump station.



**QURAYYAH INDEPENDENT POWER PLANT, SAUDI ARABIA**

**DATA**

- › Project period: 2012-2013
- › Client: Hula Marine Works Ltd.

New gas-fired combined-cycle gas turbine power plant of net power capacity 3,927 MW.

**SERVICES**

- › Hydraulic design of intake and outfall pipeline system
- › Design basis including met-ocean verification
- › Geotechnical interpretative report
- › Design of intake risers – velocity cap type structures
- › Design of dredging and reclamation
- › Design of diffuser structures
- › Review of details from manufacturer of glass fibre reinforced pipe for the outfall
- › Review of construction methodology
- › Design of lifting arrangements.



**GASCO 4TH NGL TRAIN, UNITED ARAB EMIRATES**

**DATA**

- › Project period: 2010-2012
- › Client: Target Eng. Cons Co.

The seawater cooling system of the 4<sup>th</sup> NGL train is a once-through cooling water system comprising offshore intakes, offshore supply pipes, pumping station, manifold, discharge pipes, discharge structure, sealing weir structure and outfall structure.

**SERVICES**

- › Marine and coastal design
- › Structural design
- › Geotechnical design
- › Hydraulic studies and design
- › Mechanical design
- › Piping design
- › Electrical and instrumentation systems
- › Smart plant design (3D modelling).



**RAS AL KHAIR, SAUDI ARABIA**

**DATA**

- › Project period: 2010-2011
- › Client: Archirodon Ltd.

The Saline Water Conversion Corporation (SWCC) developed a combined cycle power and desalination plant in Ras Al-Khair formerly known as Ras Az Zawr (RAZ) Power and Desalination Plant. The plant has a capacity of: 2,400 MW net power output and 1,025 Tm³/d water production.

The Ras Al-Khair power and desalination plant project was divided into two EPC contracts covering power production facilities and desalination plant.

**SERVICES**

- › Design of seawater intake channel consisting of two approximately 1.4 km long straight breakwaters orientated perpendicularly to the coast
- › Design of scour protection of outfall structures consisting in eight buried discharge pipes and an outfall structure with diffusers
- › Design of shoreline protection revetments
- › Design of transition between onshore structures and the eight discharge pipes with the diffuser structure.



**FOLSOM DAM SPILLWAY CA, USA**

**DATA**

- › Project period: 2008-2016
- › Client: URS Corporation, USACE-Sacramento District

Design of a new spillway and six new gates to allow release of more water in advance of major storms, taking earlier advantage of the river's capacity.

**SERVICES**

- › Structural engineering
- › Geotechnical engineering
- › Coastal engineering
- › Quantities and cost estimation
- › Construction engineering.



**CHARLEROI LOCKS AND DAM - LOCK #4, PA, USA**

**DATA**

- › Project period: 2003-2013
- › Client: USACE - Pittsburgh District

Design of a new river wall and upper guardwall at Charleroi Locks and Dam. COWI designed the upper guardwall. The guardwall consists of six piers and a sheetpile nose cell, which supports seven precast posttensioned concrete box beams, with flow skirts, that form the guard wall.

**SERVICES**

- › Detailed design
- › River navigation structures
- › Precast concrete construction
- › Construction sequencing and scheduling
- › Construction engineering.



**RAS LAFFAN NEW SHIP REPAIR YARD, QATAR**

**DATA**

- › Project period: 2006-2011
- › Client: QP/Nakilat

The marine part of the project consists of two graving docks to accommodate QMax and QFlex LNG vessels as well as VLCC's, one floating dock of panamax size, six wet berths with a total length of 2,400 m and a minimum depth of 11 m, a heavy lift berth and extensive lay-down and fabrication areas.

**SERVICES**

- › Optimisation studies
- › Design of finger piers and mass concrete block quay walls for vessel fitting-out, including substations
- › Design of load-out quay for heavy lifts
- › Design of a lay-down and fabrication area
- › Preparation of tender documents
- › Supervision of construction.



**BRADDOCK DAM LOCK 2, MONONGAHELA RIVER, PA, USA**

**DATA**

- › Project period: 1997-2008
- › Client: U.S. Army Corps of Engineers Pittsburgh District

COWI was retained by the USACE Pittsburgh District to design and assist with construction supervision of the New Braddock Dam. As the Engineer-of-Record for all final structural design drawings, we designed the float-in precast dam segments and developed in-the-wet construction methods and procedures. The Braddock Dam was constructed using a new and innovative float-in method, a first within the USACE. The application of this innovative in-the-wet approach is a landmark event, and one that could revolutionize the future construction of navigation projects. We successfully completed a major portion of the detailed design following an aggressive seven month schedule.

The challenges presented: developing a cast and launch facility for two, 11,000-ton dam segments; developing a 102 m long precast dam segment float-in and set-down sequence shell with sufficient strength for launch, transport, and immersion while maintaining a 3.1 m maximum draft; and developing a transport, positioning, immersion, and dam completion plan that would safely accommodate a 500-year flood at any time with 48-hour notice.

**SERVICES**

- › Detailed design
- › River navigation structures
- › Construction sequencing and scheduling
- › Construction means and methods
- › Tremie concrete mix design
- › Construction engineering.





# GROUND ENGINEERING AND RECLAMATION



## PEARL JUMEIRAH, UAE

### DATA

- › Project period: 2009-2014
- › Client: Meraas Development LLC

An offshore development area, constructed from Dubai sourced reclaimed sand and locally sourced rock. The sand is retained along the perimeter of the development with rockwork slopes that are designed to provide shoreline stability and a seaward defence of the upland areas.

### SERVICES

- › Assessment of subsurface conditions
- › Concept, preliminary and detailed design of marine, geotechnical and hydraulic services
- › Specification of surcharging and settlement monitoring of rock structures
- › Hydrodynamic numerical modelling.



## BUSAN-GEOJE FIXED LINK, SOUTH KOREA

### DATA

- › Project period: 2003-2011
- › Client: Daewoo Engineering & Construction Co. Ltd.

The Busan-Geoje Fixed Link connects the island of Geoje with the large city Busan in the southern part of South Korea, improving access from the city to the industrial and recreational areas on Geoje Island. The link comprises three major elements; one of the world's deepest and longest immersed tunnels and two long-span cable-stayed bridges.

### SERVICES

- › Preliminary design, detailed design and technical support during construction
- › Sand compaction piles (SCP) for sub-sea embankment
- › Deep cement mixing (DCM) for tunnel trench
- › Advanced numerical modelling for verification
- › Physical hydraulic model testingTrial testing for SCP and DCM.



## AL ZORAH DEVELOPMENT, UAE

### DATA

- › Project period: 2008-2012
- › Client: SOLIDERE

Technical support and construction supervision for dredging and reclamation, rock work, ground improvement, settlement monitoring etc. A 12 sq km parcel of land was developed along the coast of Ajman by Al Zorah Development. One of the features of the development is a mangrove area. The mixed-use development will stretch along 3 km of coastline and include commercial, residential, recreational, educational and healthcare facilities as well as a golf course, marinas and hotels.

### SERVICES

- › Design of dredging and reclamation
- › Marina design and design of marine structures
- › Beach stability
- › Numerical modelling of waves, currents and water levels
- › Environmental impact assessment
- › Power station impact study
- › Cost estimate
- › Construction supervision.



## HONG KONG THREE-RUNWAY MAIN RECLAMATION, CHINA

### DATA

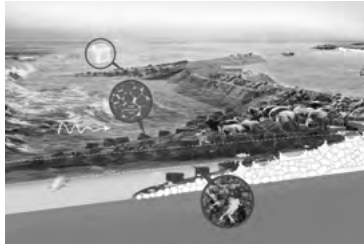
- › Project period: 2017
- › Client: Jan De Nul / Chun Wo JV

Hong Kong Airport is currently operating at near full capacity. In order to secure the airport for future expansion it has been decided to build a third runway and associated airside facilities. The current airport is placed on an artificial island off Lantau Island. The airport expansion covers 6.5 million m<sup>2</sup>, and will require reclamation of an additional 75 million m<sup>3</sup> of fill. The project site is characterised by very difficult ground conditions with up to 15 m of soft clay and dumped mud pits where contaminated material from other projects has been placed and capped.

In order to accommodate the ground conditions, while complying with strict environmental regulations, extensive ground improvement is utilised. The employer's ground improvement methods include: Deep Cement Mixing (DCM), Stone Columns, Prefabricated.

### SERVICES

- › Verification of land based DCM design
- › Settlement estimate for both natural and improved ground conditions
- › Stone columns: Verification and development of alternative optimised design for land based stone columns
- › PVD & surcharging: Verification and development of alternative design for combined PVD and surcharging design, providing reduced surcharge requirements
- › Vibro-compaction of reclamation fill: Review of compaction requirements. Preparation of alternative solution using resonance vibratory plate compaction
- › Geotechnical interpretation: Preparation of geological and geotechnical model for reclamation area
- › Sloping and vertical seawalls: verification of tender design
- › Preliminary Environmental Monitoring Plan (EMP)
- › 4D BIM model based on Contractor's programme
- › Review of Contractor's Method Statements for reclamation and ground improvement.



## LIVING BREAKWATERS, NY, USA

### DATA

- › Project period: 2017
- › Client: SCAPE/Landscape Architecture PLLC

Staten Island and Raritan Bay were hard hit by Super Storm Sandy in 2012 and much of the shore of Staten Island is being eroded as a result of creation of shipping channels, heavy fishing of the shellfish resources and exposure to wave action and coastal erosion. This project is one of ten projects selected by the Department of Housing and Urban Development (HUD) across the Sandy-affected region to be pursued in the final stage of the Rebuild By Design competition to create innovative solutions for resiliency. COWI was selected to provide coastal engineering and marine biology expertise. The proposed strategy, living, growing breakwaters, will combine offshore breakwaters with creation/restoration of finfish and shellfish habitats to enhance ecological benefits of the structure.

### SERVICES

- › Feasibility study
- › Evaluation
- › Cost estimate.



## NEW DOHA PORT, QATAR

### DATA

- › Project period: 2009-2019
- › Client: The Government of Qatar

The port will be built in phases with the first phase having a capacity of two million TEU (twenty-foot equivalent unit) per year and by 2030, when fully operational, the port will be able to handle six million TEU of container capacity per year. A total of five import/export terminals will be built on the 20 sq km area which will serve as the port of entry for cargo, containers, livestock, vehicles, bulk grain and other goods. Additionally, the port will include a cruise terminal, a base for offshore industry supply vessels and coastguard vessels. The excavation, including an 11 km long navigation channel dredged into the sea, required 95 million cubic metres of materials to be removed in the first phase.

### SERVICES

- › Environmental impact assessment studies (EIA)
- › Advice and monitoring during construction.



## GREAT BELT TUNNEL, CLIMATE CHANGE EVALUATION, DENMARK

### DATA

- › Project period: 2017
- › Client: Sund & Bælt

18 km long fixed road and rail link across the Great Belt comprising a low bridge, a suspension bridge and a tunnel, COWI was contracted by the owner Sund & Bælt to perform a climate assessment of the tunnel ramps. The study included an assessment of the effects of climate change based on newer statistical data as well as the potential impact of climate change in relation to the original design criteria.

### SERVICES

- › Risk analysis
- › Analysis of the robustness of the surface water systems
- › Update of the operational risk analysis
- › cost estimate.



## LEMVIG FLOOD BARRIER, DENMARK

### DATA

- › Project period: 2010
- › Client: Municipality of Lemvig

Floods have through many years been a threat to Lemvig, a low-lying town in Northern Jutland near the North Sea. In 2010, the Municipality initiated a project to counter the threat of climate change and created new qualities and development opportunities for the city. The solution was an aesthetically pleasing high-water barrier in the harbour.

### SERVICES

- › Project management consultant for the high water barrier and renewal of urban space, including relocation of utilities and new street furniture.



## STORM DAMAGE ASSESSMENT, DENMARK

### DATA

- › Project period: 2013-2014
- › Client: Danish municipalities

The storm Bodil in December 2013 coincided with very high water levels in Danish waters and caused much material damage. It gave impetus to many climate adaptation activities.

### SERVICES

- › Inspection
- › Surveys
- › Design and permitting of coastal structures following damage by the storm Bodil.





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