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ENGINEERING
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Case Study

SINGAPORE, SINGAPORE

Pekan Quarry Floating Wetlands

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Project:	Pekan Quarry Floating Wetlands
Year Completion:	2021
Design:	Hexagon-shaped modules, Heron Nesting Platforms
Designer:	Hocklim Engineering Pte Ltd & Prof Ang Kok Keng of NUS
Installer:	Hocklim Engineering Pte Ltd & ISO Landscape Pte Ltd

The Challenge

Previously known as Ho Man Choo Quarry, the Pekan Quarry is one of the oldest quarries in Pulau Ubin. Over the years, the Pekan Quarry has transformed from a declining quarry, into a thriving freshwater wetland habitat, home to a variety of fauna and flora.

With the vision of revitalising the Pekan Quarry, the floating wetlands were first introduced to Pekan Quarry in 2015 as a pilot initiative to increase the area of usable wildlife habitat under NParks' habitat enhancement programme. With the success of the pilot program, the desire was to continue to increase the area of usable wildlife habitat to grow the thriving ecosystem .

Figure 1: Pekan Quarry in Pulau Ubin

Benefits of Freshwater Wetlands

Wetlands benefits the ecosystem by filtering sediments, pollutions and even heavy metals from the water, helping to prevent the contamination of the quarry.

Likewise, many animals and plants depend on the wetlands for survival. The variety of plants provide ideal nesting places and food for biodiversity such as migratory birds, mammals and insects.

Building of Floating Wetlands

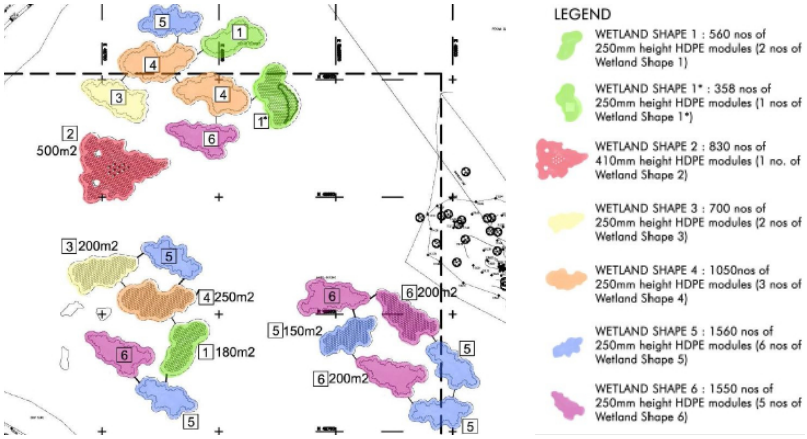

Figure 2: Drawings of the 3 clusters and the Nesting platform

Hocklim Engineering collaborated with ISO-Landscape Pte Ltd and Professor Ang Kok Keng of NUS to design and build the floating wetland system. Hocklim utilized the hexagon-shaped modules, developed by HDB to form the floatation system of the floating wetlands. The modules were made of High-density polyethylene (HDPE) materials and filled with PU foam so that they are unsinkable and buoyant with each module being able to withstand loads of up to 80kg, thereby supporting the growth of the eco-habitat. The modules are then assembled together to form shapes and sizes that replicates the natural shapes of islands.

Figure 3: Assembling the floating modules

Figure 4: Assembled floating modules

In total, 3 clusters of wetland platforms and 1 nesting platform were formed, using over 6,000 modules, spanning over 4,000 square meters. In each cluster several wetlands are connected together by linkages and moored by a customized anchorage system. This entire area is able to support the growth of 15,000 plants and 13 native flora species, creating a big eco-habitat in Pekan Quarry.

To ensure the structural integrity and safety of the entire system in a complex environmental condition, a detailed design analysis was carried out by NUS.

Design Checks

Checks on the hydrostatic equilibrium and stability under the given loading conditions are carried out for all 3 clusters and the nesting platform.

Firstly, the load estimation conducted is base on the weight of the modules and the weight of soil and plants. A comprehensive study was carried out to determine what should be the desired thickness of soil that should be placed on the wetlands and able to support the desired vegetation.

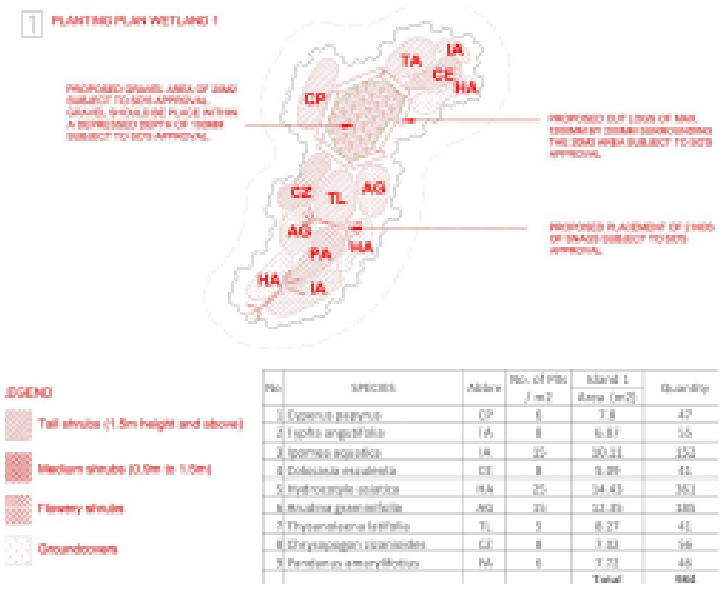

Figure 5: Planting designs of the islands

The plant weight is determined based on the planting design plan. The plants were categorized into ground covers, flower shrubs, medium shrubs and tall shrubs. Based on the module, soil and plant weights, the load of each floating wetland and the total load on each cluster can be calculated.

Next, a buoyancy check was conducted on all the clusters. This is to ensure that the floating wetlands will not submerge due to heavy load.

The buoyancy test was calculated based on Archimedes' principle where all the floating wetlands met the requirements.

A Hydrodynamic Analysis is conducted for the clusters under environmental loadings due to wind, wave and current factors. Based on the results that the dynamic responses of all clusters of floating wetlands induced by waves were all minimal. Hence, the hydrodynamic performance for all clusters is deemed to be acceptable.

Mooring Sytem

To keep the clusters of islands in position, an anchorage system had to be in place. Hocklim designed the mooring system with mooring lines tethered at four tethering points to anchor the floating module clusters together.

The mooring design consists of the anchorage design or mooring bracket that utilizes stainless steel plates and bar with a eyebolt to allow the islands of each cluster to be interconnected to each other through mooring lines.

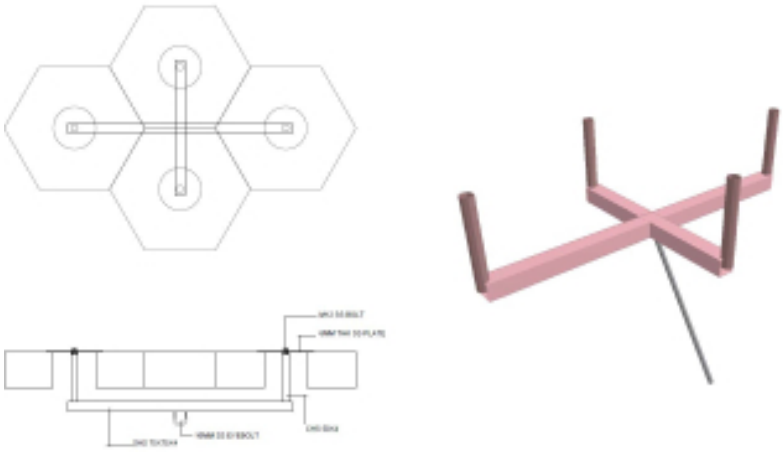

Figure 6: Mooring Design

Figure 7: Installing the Mooring system.

As the stiffness of mooring lines and its difference from the in-plane stiffness between the connected islands affect the force distribution inside the islands cluster and the motion, accurate estimation of mooring lines stiffness is crucial.

Figure 8: The mooring bracket installed on the floating modules

Figure 9: Installing the mooring bracket

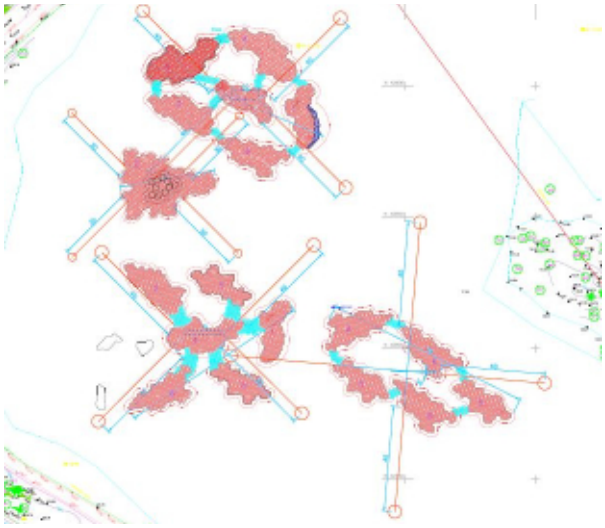

Figure 10: The mooring system drawings showing the mooring lines tethered at four tethering points anchoring the floating module clusters together

Figure 11: Installing the Floating crane

To deploy the sinkers into the quarry, Hocklim designed and constructed a floating crane that is anchored to the floating modules for stability. The crane will be constructed onsite with an electric winch installed on the crane structure to deploy the sinkers. Trial tests were conducted to ensure that the winch and the steel structure was stable and operating well.

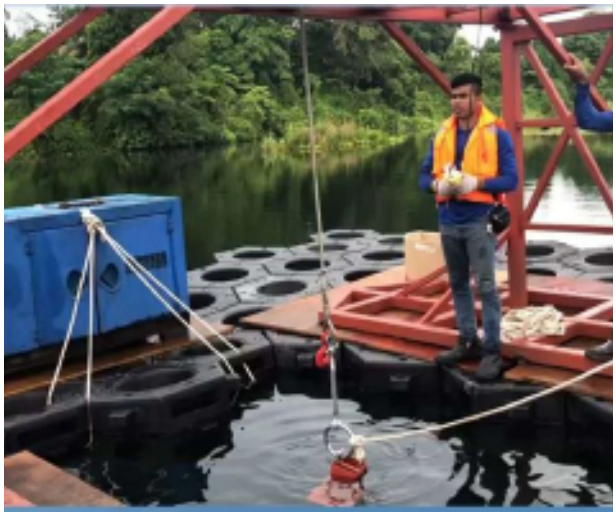

Figure 12: Running trail test on the winch system.

Figure 13: The anchor system of the floating crane to the floating platforms is covered with plywood, creating a secure and stable structure

Figure 14: The weight of the sinkers is checked with a weighing scale on a crane hoist.

Figure 15: Using Hydraulic Excavator to fill the Geosynthetic bags with granite.

Figure 16: Using marker buoy to mark the sinker location.

The sinkers consists of 2 ton of granite filled in a Geosynthetic bag. In total 26 bags were filled and prepared to be deployed in the quarry.

Figure 17: Using the winch to lower the sinker.

In order to facilitate the deployment of the sinkers, Hocklim had to locate the exact coordinates of the latitude & longitude of the GPS on the map and deploy anchor marker buoys at the exact location.

With the marker buoys in place, Hocklim is then able to lower the sinkers at their respective precise location using the electric winch to lower the sinkers to the riverbed.

Once all the sinkers were deployed, the assembled floating wetlands were moored to their precise location, the sinkers were then secured to the mooring brackets before carrying out post tensioning on the anchoring rope.

After the floating wetlands were anchored, the installation of the floating mats along the entire edge of the wetlands were carried out, followed by earthfilling. A layer of geotextile was placed over the floating modules before the top soil was placed on top.

Figure 18: Covering the floating modules with geotextile.

Figure 19: Installing the floating mat.

Figure 21: Earthfilling carried out on the floating platform

Once the soil was laid, various species of plants and scrubs was planted across the islands based on the planting design layout plan.

The construction schedule of the 3 clusters were done in an orderly process. The first cluster's design was checked, assembled and planted first before moving on to the second cluster repeating the same procedure.

Figure 22: Planting the plants on the floating platforms

Figure 23: Planting process

Heron Nesting Platform

Hocklim was also tasked to design and build the Heron nesting platform structures to replicate the natural nesting sites of herons and cater to other bird species looking for suitable places to build their nests.

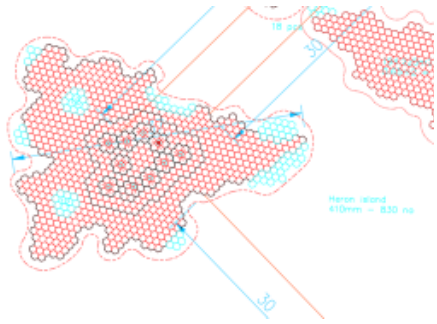

Figure 24: The layout of the nesting structure wetland

The nesting structure wetland comprises of a single floating wetland as shown below. Unlike the other 3 zones in which a cluster is formed by linking several floating wetlands that are used mainly to support vegetations, the nesting structure wetland is used primarily to house tree-like posts for herons to nest.

The nesting structure that Hocklim designed is modelled using finite elements and made up of Aluminium and steel to meet the design strength requirements.

The main post is made of aluminium circular hollow section (CHS), powder coated to mimic a natural tree. The post is held in position by a stainless steel (SS) CHS braced by SS angle members, which are mounted onto the HDPE floaters through C channel members bolt connected to the top surface of the floating modules. A post is equipped with several nesting platforms up to a maximum of four depending on the length of the post

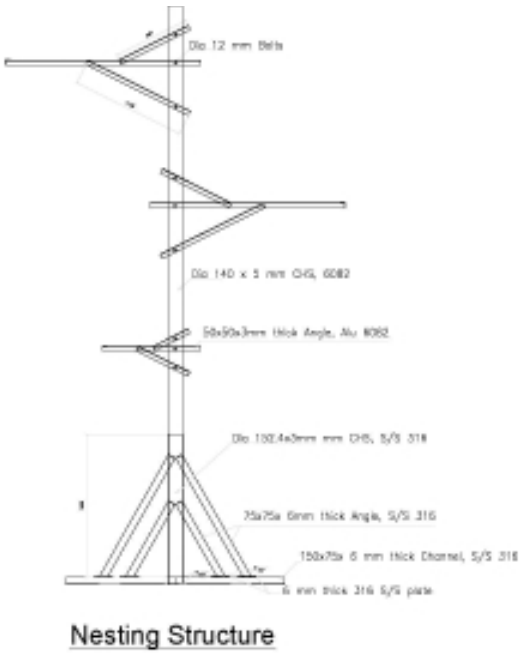

Figure 25: Drawing of the Nesting Structure

The nesting platform is modular in design and therefore enjoys the advantage of speed of manufacturing and installation. The platform structure comprises aluminium angle members with bracing members attached to the main post through an easy bolt-nut installation. The main nesting area ensures a spacious area for herons to nest. Furthermore, the aluminium angles have extensions that permits perching of herons.

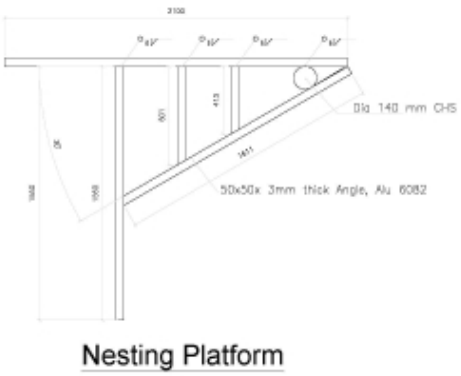

Figure 26: Drawing of the Nesting Structure

To ensure the safety of the nesting structure, analysis of the nesting post of its weight, weight of nests, loading from the herons, and environmental loads were conducted.

From the analysis of the nesting post, the proposed structural members and the connections between members were checked for design adequacy. Based on the results, both the structural members and the connections between members' design structural adequacy were satisfactory.

For the base frames mounted onto the floating platform, the connection can be made conveniently through the direct bolting with the C channel sections. Based on the available finite element analysis results, the design structural adequacy of the connection is found to be satisfactory.

Figure 27: Installing of the Nesting Structure onto the floating platform

Once the designs were satisfactory and approved, Hocklim proceeded with the manufacturing of the 10 nesting structures as specified in the design drawings. Hocklim install Chengal Wood Cladding on the aluminium platform to make it more appealing for the herons. The sharp corners of the wood would be rounded to be more friendly for the herons to rest on.

Once the 3 clusters and the nesting platform were completed, the installation of the 2 signages introducing the thriving freshwater wetland habitat of Pekan Quarry was carried out.

Figure 28: Completion of the Pekan Quarry. floating wetlands

Since the completion of the Pekan Quarry Floating Wetlands in 2021, it has been garnering local and overseas recognition of our innovative efforts in leveraging the floating wetlands system to create eco-habitats and conserve biodiversity. The Pekan Quarry Floating Wetlands project was awarded NParks' Landscape Excellence Assessment Framework (LEAF) Silver certification with a Special Mention for Conservation and Biodiversity. This project also received the 2021 Honor award from American Academy of Environmental Engineers and Scientists in the USA. As a result of the revitalised Pekan Quarry, it has drawn more visitors to Pulau Ubin and the Pekan Quarry floating wetlands to view the rich aerial-aquatic wildlife habitat.