ALL AT SEA

'THE CITY OF THE FUTURE'

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ABSTRACT

This paper investigates the credibility of building 'oceanic' settlements off the coast of Britain. In this process a variety of factors will be looked at:

Firstly, why there is a demand for offshore settlements. I will look at the influence of rising population, coastal erosion and global warming (rising sea level) and how these environmental factors are putting pressure on the land, forcing us to look for an alternative lifestyle. In this section, I will also investigate the best areas for locating these settlements, based on environmental and geographical data.

I will then study a selection of existing off-shore communities from around the world, to try and establish how they evolved, how they function and how they are constructed, in order to determine what aspects, if any, could influence the design of a settlement off the coast of Britain.

I also look at proposals for ‘oceanic settlements’ that have been made in the past, but as yet have not been realised. Schemes that were considered ambitious or ‘futuristic’ at the time now appear much more realistic and could prove to be useful precedents.

In the final analysis, I use the examples cited above to determine the materials, structure and form most suited to a settlement in British waters. I also endeavour to discover the utilities, services and industry that could sustain an ‘oceanic settlement’.

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Introduction

"The seemingly infinite waters confront human mortality and smallness, but their extensive presence on Earth surrounds us with a feeling of immediacy, intimacy and belonging."[1]

Living on the Edge

Three-quarters of the earth's surface is covered by water, and it is a scientific fact that life could not exist without it. In fact our evolutionary history began in the "biological soup" we call the seas. The oceans and seas, however, are also incredibly large volumes of water with immense destructive power. It is this paradox, perhaps, that has spurred mankind to confront these untamed waters. From the early navigators to deep-sea divers, man has had a fascination with the ocean and yet this vast desert remains largely uninhabited and unexplored.

The relationship between a society and the sea is most manifest in its architecture. The seas' contempt for man-made structures is a challenge to designers, but this has not stifled our efforts. The coast is the area of land where earth, water and sky mix. It is also the place where architecture meets the sea.

Oceanic Architecture

According to Akio Kuroyanagi, the term 'oceanic architecture' refers to "architectural space created by directly or indirectly using the features of the waterfront or ocean in the design."[2]

Initially oceanic architecture was concerned with coastal defences, in the form of ports and harbours. Although harbours are in intimate contact with the sea, by the very nature of their role they are introspective, and don't engage fully with the oceans.

The first structures to reach out into the sea were the piers, boardwalks and decks, built to receive steamship passengers at the beginning of the nineteenth century. The pier became an essential focal point for resorts, where people could meet and enjoy the stimulating atmosphere of the ocean 'without getting their feet wet' (Fig.1).

1. Eastbourne pier: a traditional English seaside pier

The ‘pleasure pier’ was essentially a British phenomenon, however the idea of ‘extending the edge of the land’ to accommodate different needs has universal appeal. Recent projects abroad have incorporated restaurants, conference facilities and aquariums into off-shore structures. The sight, sound and smell of the ocean still offers a sense of openness and escape for modern earthbound society.

Over the last few decades ‘oceanic architecture’ has undergone a radical change. In the quest to tap off-shore resources, the capacity to construct decks over deep water has been transformed (Fig.2). With the technology now available there is enormous potential for new pier design, man-made islands and even off-shore cities. The notion of deploying man-made structures in the sea, to be inhabited by people, is not as far fetched as it would first seem. After all, on a global scale, all islands are simply platforms in the sea. For Britain, an island nation with a strong sea-faring tradition, the idea of building a city in off-shore waters could be very appealing.

2. A concrete production platform in the North Sea

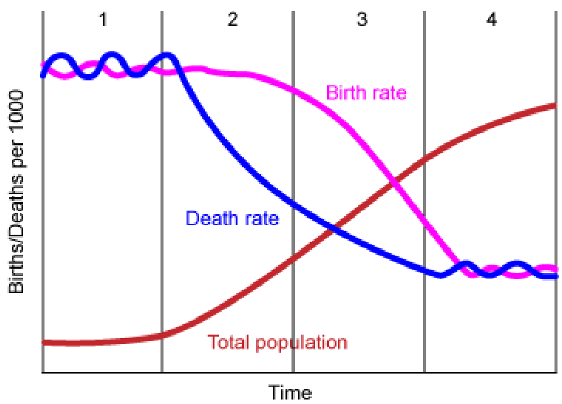
In Britain, there is a serious shortage of land for building, putting increased pressure on ‘green belt’ and agricultural land. In addition, the coastline of Britain is constantly under attack from the sea and the threat of global warming and rising sea levels is only going to exacerbate the situation. If the ocean rises, people will be displaced and the demand for land will increase, drastically inflating its value. Faced with this scenario, the concept of building an oceanic settlement off the coast of Britain becomes even more appealing. The sea could become the building site of the future!

Global Warning!

"...the danger of atomic doom, whether real or imagined, has now been replaced by the threat of planetary environmental catastrophe"[3]

Population Explosion and Shortage of Land

The population of the world has been rising steadily since the middle of the eighteenth century, and although estimates vary, the number of inhabitants increases by approximately 170,000 every day.[4] At this rate the world's population will exceed 10 billion by the year 2050. The rate of increase in individual countries depends upon their economic and industrial development. In the more developed Western economies of North America and Europe, a 'population explosion' occurred in the last century, coinciding with a revolution in manufacturing technology. Growth became concentrated around industrial areas, creating huge cities, as people migrated from more rural communities in search of work. The benefits of industrialisation and economic growth eventually led to a higher standard of living for the population with better medical, educational and welfare facilities. As a result infant mortality began to fall and life expectancy increase, causing the population to rise rapidly. However, with a reduced demand for manual labour and little incentive for the traditional large family, the birth rate in 'industrialised' countries has slowly declined, resulting in a steady, but less dramatic population growth. This story is reflected in other parts of the world that are at different stages in their economic development (Fig.3).



3. Demographic transition model of global population

Although at the moment most Asian countries have much lower population densities than those in Europe, the rate of population increase in this part of the world is so rapid that 'overpopulation' is a real threat. The term 'overpopulation' can be applied to any country or area where there are too many people for the resources to support. Parts of India, South America and Africa are overpopulated because they have insufficient food, minerals and resources, a situation aggravated by famine, disease and poverty. In Europe and parts of South East Asia however, the threat of overpopulation is largely as a result of a shortage of land.

The U.K population is projected to rise to over 61 million by the year 2023.[5] In addition to extra housing, land will be required for roads, reservoirs and other utilities to cater for the predicted population rise. This will dramatically increase the urbanisation of the country, reducing agricultural and 'green-belt' land. Already one of the most densely populated countries in the world, England in particular is facing a critical shortage of land. According to Lord Holford, former professor of town planning at University College, London: "There is a critical population density that a given agricultural and ecological system can support and the United Kingdom has already passed this."[6]

Coastal Erosion and Sea Defence

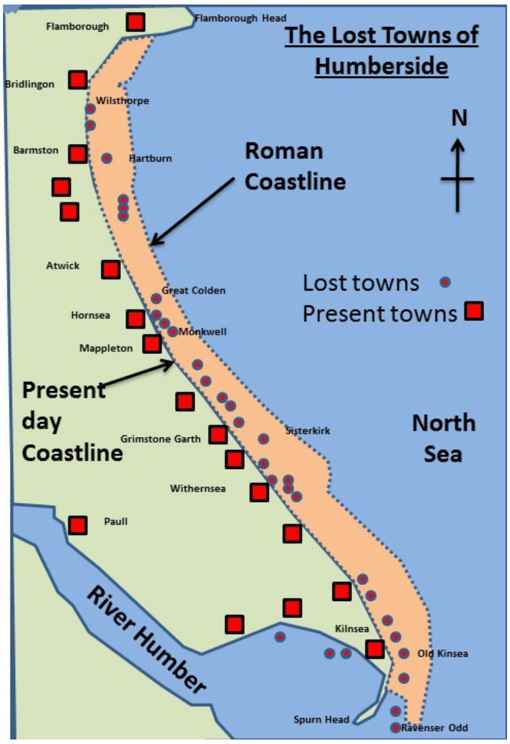
About a quarter of the coast of England and Wales has been developed for housing, industry, or some other purpose.[7] The coast provides some of the most desirable places for people to live and work. The attractions of flat and fertile land, access to ports and the therapeutic benefits of sea-side activities are all incentives to live on the coast. However, there are inherent disadvantages in a sea-side location. The natural forces of flooding and coastal erosion pose a risk to both man-made and natural resources.

The coastline of Britain can be divided into two categories, the mainly low-lying soft coasts of the South and East, and the predominantly cliff coasts, associated with harder rocks, in the North and West. This division is reflected in the corresponding rates of erosion caused by the sea. According to C.M Stapleton of Hull University, "We can think of the coast as a large machine whose function is to absorb the energy of the waves and the currents..."[8] One of the symptoms of absorbing the sea's energy however, is coastal erosion. The harder cliff faces of the north are much more efficient at absorbing the sea's energy without damage. Although some parts of the low-lying areas are protected by sand dunes or shingle banks, in the more vulnerable areas the constant action of the sea can have devastating consequences.

Historically people have tried to minimise the effects of these forces with a variety of engineering works such as flood embankments, harbour walls, spits and barriers. These attempts to curb the effects of the sea's action were generally considered in isolation and on a small scale. Recent thinking on this approach however, has changed and experts in this field now believe that interfering with the natural coastal processes may actually increase the risks rather then reduce them. In particular it is important to consider the coast as a single entity, as interference at a local level can have repercussions in areas far removed. The concept of coastal 'cells' is a recent development designed to prevent mismanagement of the coast. The coastline of England has been divided up into stretches of land or 'cells', within which changes will not affect the neighbouring coastal sections (Fig.4).

4. Primary coastal cells around England and Wales

The stretch of coast from Flamborough Head in the north down to Gibraltar Point, including the coast of Humberside and most of Lincolnshire has been designated as a coastal cell. The high chalk cliffs of Flamborough, the soft clays of Holderness and the beaches of Lincolnshire, as well as the areas in-between are all connected to each other by tidal flows, wave action and the movement of sand and mud on the sea bed.[9] This stretch of coast is vitally important to us for both economic and recreational purposes. However this 'cell' is particularly prone to the effects of coastal erosion, with 29 villages and towns becoming victims of the sea to date (Fig.5).



5. The lost towns of East Yorkshire

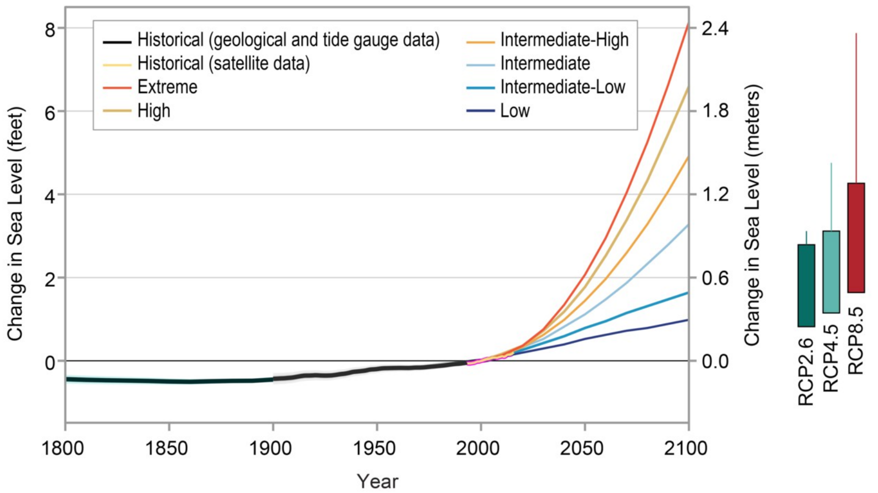
Loss of property is not the only concern; the Humberside coastline supports an extremely varied array of wildlife, flora and fauna, which is also at risk. The desire to protect property and the natural habitats of wildlife can stir up strong emotions. However experts such as Mike Elliot of Hull University, believe it is futile to try and "stem the tide" and despite the loss of land and even whole communities, there is no option but to let nature take its course. The coast needs to be subject to natural forces and free to respond to them if they are to maintain themselves: "On the coast conservation rarely equates preservation."[10]

Climatic Change and Rising Sea Level

Changes in the volume of water held in the 'world ocean' caused by the melting of the fresh water stored in ice caps are referred to as 'eustatic changes'. Although our present sea level was reached more or less 6000 years ago, there has always been minor fluctuations. However, the consensus of opinion is that over the past century mean sea level has risen by some 10-15 cm.[11] This relatively recent change is believed to be caused by 'global warming'.

Global warming is the result of the increase in carbon dioxide and other gases released into the atmosphere since the industrial revolution.[12] These gases trap the incoming solar radiation and consequently the surface temperature of the earth increases. In addition, certain gases have been identified as being responsible for the depletion of ozone, a protective layer of gas in the earth's atmosphere that reduces incoming solar radiation. Scientists have recently identified holes in the ozone layer above the polar ice-caps. The combined effect of increasing levels of carbon dioxide and a reduction in the ozone layer, is causing glacier and polar ice sheets to melt and the oceans to expand. Unless emissions of these harmful chemicals is curbed, the rate at which the sea level is rising will continue to increase.

There is a wide variation in the forecasts of sea level changes over the next century. Estimates vary from 0.5 m up to an extreme 3.5m.[13] Predictions of sea level increases over the next 50 to 100 years were published by the intergovernmental panel for climatic change (I.P.C.C) in 1990 (Fig.6).



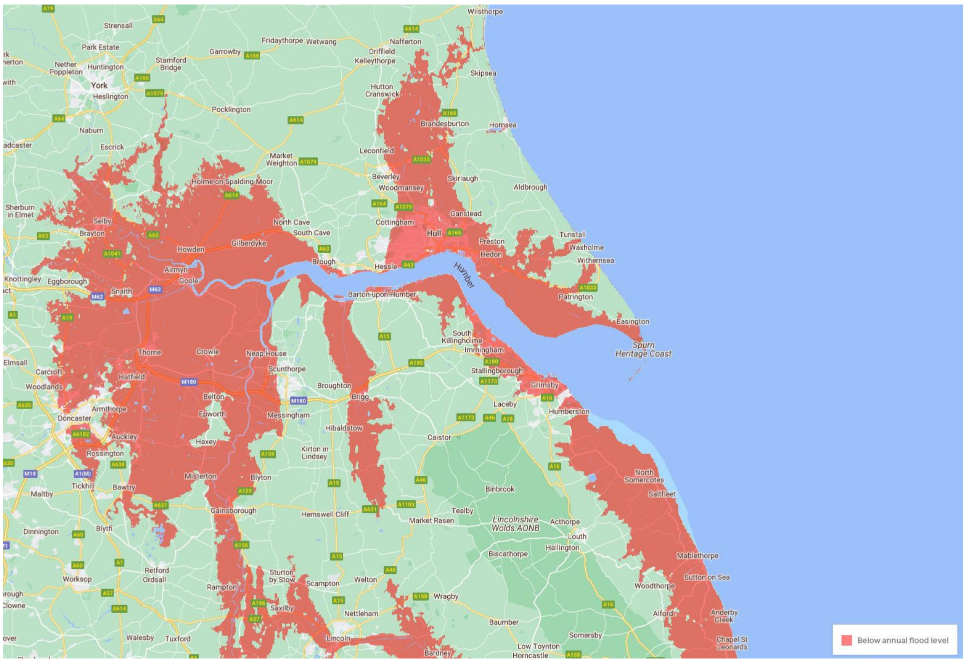
6. Predictions for global sea level rise under a 'business as usual' scenario

The change in the eustatic rise in sea level is not the only problem. The change in the level of the land relative to the sea, known as 'isostatic' change, can exaggerate the effects of global warming. If the land is sinking relative to the sea, then the problem of a rising sea level will be much worse. In Britain, changes in the land surface are still taking place as a result of the melting of the ice which formed over Scotland in the last glacial period. The removal of this enormous weight caused the land mass of Scotland to begin to rise, while Southern England suffered a commensurate depression.[14] In fact the whole of the Southeast of England is gradually sinking into the North Sea. Again, estimates vary as to the rate of 'isostatic' change, but they could be in the order of 3mm per year.[15]

7. Areas of Great Britain most at risk from flooding (2050)

In Britain, it is the areas most susceptible to rises in sea level that are sinking relative to the sea (Fig.7). The Southeast coast is experiencing the maximum rate of relative sea level rise with rates of over 5mm per year being recorded.[16] This rate is the result of the combined effect of global warming and glacial rebound, however there is another factor to take into consideration. Global warming will not only melt the polar ice caps, but the increased temperature will cause the water in the oceans to expand.

This in turn may increase the rate of eustatic change. Studies commissioned by Humberside County Council, have shown that if this is taken into account, the cumulative effect could give a total annual increase in the level of the Humber of up to 1.13cm per year.[17] At this rate the level of the sea will be over 0.5m higher by the year 2050, with serious implications for the 4 million people who live and work in those areas of Humberside and Lincolnshire already at risk from flooding (Fig.8).[18]



8. Areas of Humberside and Lincolnshire most at risk of flooding (2050)

Given the predicted rises in sea level, increased flooding and erosion are inevitable, the only question that remains is how we should deal with the problem. Although existing sea walls protect almost the entire length of the Humber estuary and Lincolnshire coast, the height of these would have to be increased significantly if they were to remain effective. In addition to the cost of raising existing sea defences, the vast majority of gravity outfalls would require modification or replacement. Alternatively new sea defences could be constructed at even greater expense. Major estuaries such as the Humber could be protected with impermeable barriers, however the practical and financial implications of such a huge project are virtually incalculable.

The cost of additional sea defences and their constant maintenance will be too great a burden for most Maritime authorities. It is also impossible to protect the entire length of the coast. The only solution it appears, is to abandon parts of the coast in order to concentrate resources on defending those areas of economic or political importance. Unfortunately, under this policy small coastal communities and farmland, along stretches of coast subject to severe erosion, will have to be sacrificed in order to save the fate of larger settlements. It would seem that in the face of this new threat we are going to have to make a dignified retreat.

Oceanic Settlements

"The sound, the light, the wetness of living on water changes earthbound society, offering a new perspective of openness, a new sensitivity to human relationships which are not defined by earth's boundaries."[19]

There are basically two types of oceanic settlement in existence, the difference between them being the method of construction. The traditional method of constructing a settlement above water was to raise the accommodation on stilts. This technique has a rich heritage, from Asian 'water villages' to the British pleasure pier, and is still practised today.

The second method of existing on water is to construct a floating settlement. The houseboat probably represents the first step in this direction, but it was the off-shore oil industry that brought it to fruition.

Oceanic settlements in British waters could help solve the problems of overcrowding and replace the towns and villages threatened by coastal erosion and the effects of global warming. The existing oceanic settlements, from around the world, are useful precedents in determining the social and physical structure best suited to a contemporary settlement off the coast of Britain.

Water Villages

The hot and humid climate of South-east Asia supports vast areas of tropical rain forests, which provide the region with an abundance of building material. The timber framed 'house on stilts' is the archetypal building form of South-east Asia and variants can be found throughout the plains, uplands, river estuaries and numerous islands. These structures are usually built as single family units, grouped randomly in clusters, or 'Kampongs.' The raised, free standing arrangement maximises the cooling effect of the air, whilst providing the occupants with protection from snakes and flooding. The boat-like form created by sweeping high pitched roofs and wide-spreading eaves, suggests the sea faring origins of many of the tribes.[20]

9. Kampong Ayer (water village), Brunei

Kampong Ayer, in Brunei, is the worlds largest community built on stilts.[21] Begun in the early Nineteenth century, this ‘water village’ is actually a series of ‘Kampongs’ built at the junction of the Kedoyan and Brunei rivers. The open veranda (pantaran) and walkways (titian) link several thousand houses. Piping systems for sewage, running water and electricity are the only tangible link with the mainland (Fig 9).

The physical separation from the mainland however, belies the inter-dependence of the off-shore and shore based communities. Water buses circumnavigate the settlement and make regular crossings to the mainland. These ironwood vessels not only ferry people and their wares between villages, but provide a vital communication link. The traditional brass and silverware products of Kampong Ayer have always guaranteed visitors from the mainland, but more recently tourism has brought an influx of foreign people and cultures.[22]

Kampong Ayer has developed into a thriving off-shore settlement, but it has not done so in isolation. Similarly, a contemporary settlement at sea will have to maintain strong links with the mainland. Even with modern communications a more tangible link with the mainland will be essential if a city at sea is to survive. A regular ferry service could play the role of the water buses at Kampong Ayer, thus ensuring a healthy exchange of people, produce and culture.

The rural kampong is the Malaysian equivalent of the modern planners concept of an urban ‘neighbourhood’ or satellite town. The size of the kampong means that everybody is familiar with each other and this generates a sense of security and belonging. The kampong dwellers are often related by kinship and share common values and beliefs.[23] The community evolves as individuals and families with common interests and values join the kampong. This sense of community spirit and co-operation will be essential for a contemporary settlement in the waters off the coast of Britain. By the very nature of the settlement, it will attract people who share the same aspirations, but they must also share their lives and support each other in this isolated environment.

The Malaysian kampong also demonstrates how a settlement at sea could grow. Just as Kampong Ayer consists of a group of separate kampongs linked together, additional units could be added to a core community in the sea, as and when required. In this way, if an initial ‘satellite town’ in the sea proves popular, it could eventually form the hub of an entire city at sea.

Nefrianye Kamni Development

In Azerbaijan at Baku, the Russians have built an entire town in the Caspian Sea (Fig.10). The development was established in 1950, as a result of off-shore oil exploration, and includes warehouses, workers accommodation, a central dining hall and even a ‘Hall of Culture’. Conditions, however are harsh in this exposed location and the community has to endure gale force winds and a hostile sea at times.[24]

The Russians have shown very little imagination in the design of their ‘off-shore city’. The working platforms consist of prismatic or pyramidal forms stacked in the sea by crane barges, until they are above the level of the water. The platforms carry the drilling rigs and well heads, together with offices, supply depots and living quarters. Light bridges or trestles connect the platforms and carry all services, vehicles and pedestrians. Initially the structure consisted of wooden piles and earth, but as the oil field developed further from the shore steel-piping was used. The life expectancy of the steel structure has been increased by cathodic protection beneath the surface and plastic paint above the sea.[25]

10. Nefrianye Kamni development, Baku, Azerbaijan

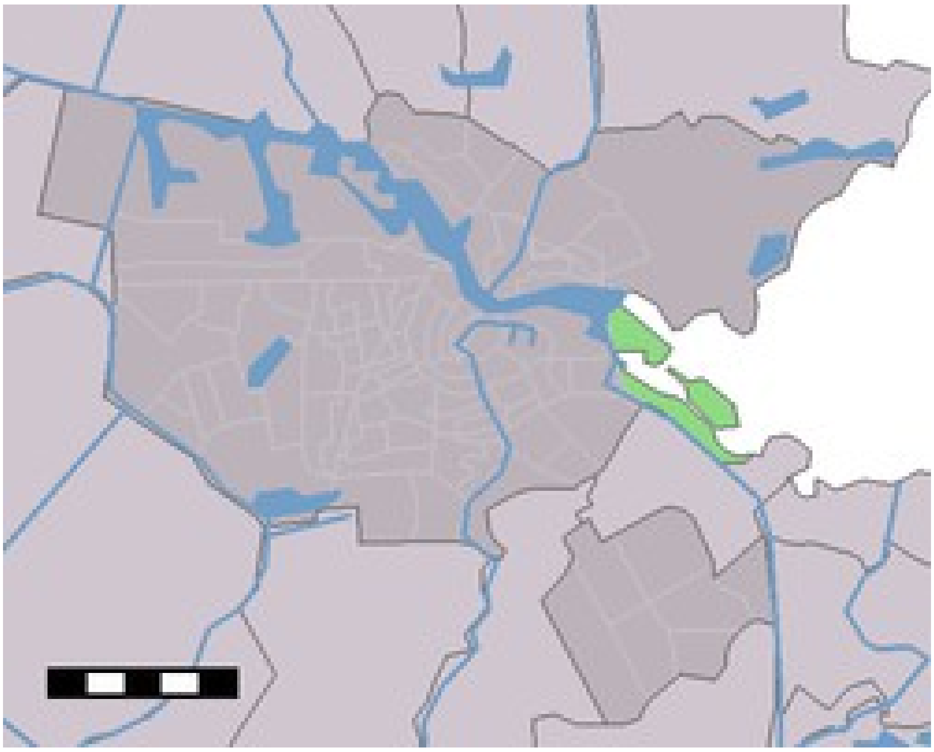
The Nefrianye Kamni development maybe lacking in imagination, but represents the first attempt to establish an off-shore community in an otherwise inhospitable area. Because of its isolated location the development incorporates all the facilities necessary to support a small community. A city at sea would also require a mix of amenities if it is to be a self sufficient and attractive place to live. What is also unique about the Baku project is that the settlement developed simultaneously with the oil field. The community work, rest and play around the industry that supports them. Similarly, a city at sea will only become a reality if it can support itself economically as well as socially.

Historically, settlements have tended to develop around sources of power - water, coal and now oil. The natural reserves of oil and gas in the North Sea are a real incentive for establishing a settlement in the vicinity. The oil industry would benefit from having an in-situ workforce and an operations base from which to oversee North Sea activities, whilst the employees would enjoy more permanent and comfortable accommodation. The oil industry may well prove to be the catalyst that makes a sea city a reality.

Dutch Coast

In Holland the practice of reclaiming land from the sea is a long established tradition. The conventional approach is to separate areas, adjacent to the coast, from the sea by building a dyke and then draining the land behind. This process involves hydraulic engineering and sometimes landfill to create a suitable base for farming or building. The whole operation is slow, laborious and dubious in terms of its environmental impact.

However, Nieuw Oost (or Ijburg) is a new expansion area of Amsterdam, in the waters of the I J-meer.[26] Although the proposal still relies on hydraulic engineering to a certain extent, it includes a series of residential islands, elevated above the water on concrete poles. The islands will be connected to the mainland and each other by jetties and quays, and will eventually house up to 45,000 residents, with schools, shops, leisure centres and restaurants (Fig 11 & 12).



11. Location of Nieuw Oost (Ijburg), Amsterdam

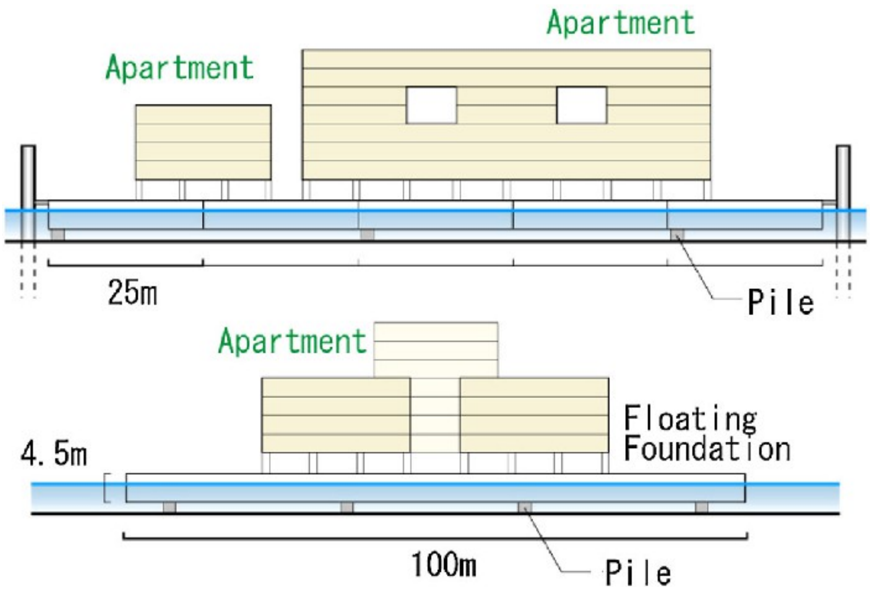
12. Ijburg Under Construction

This approach to the predicament in Holland - occupying the water rather than extending the land - both reduces the environmental impact and the time scale involved. Although located in the relatively sheltered waters of the Dutch coast, this represents the first tentative steps towards a sea-based settlement in Europe.

House Boats

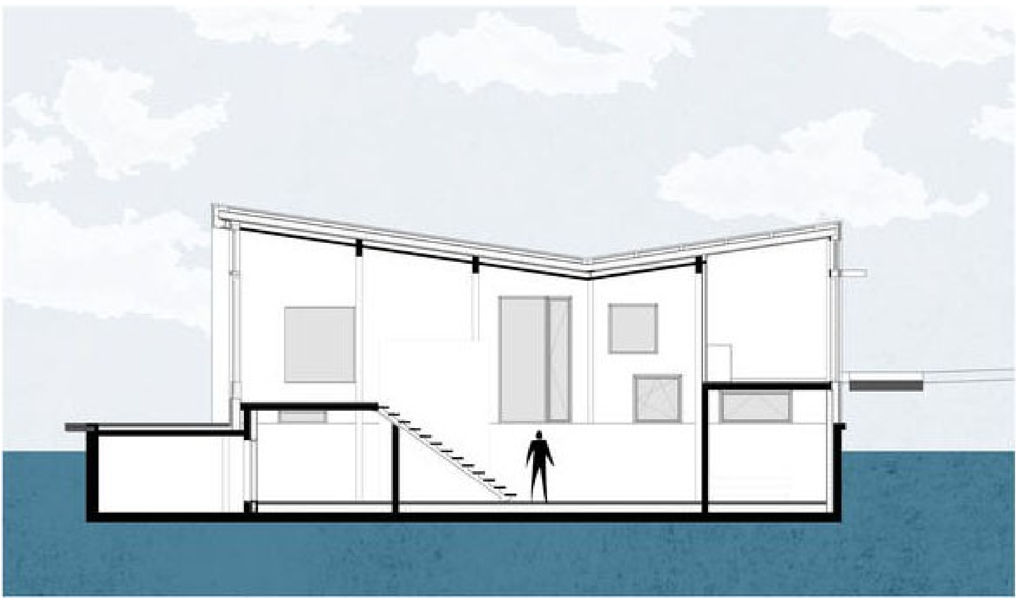
Houseboats are said to have originated on Lake Washington and Lake Union in Seattle, in the latter half of the Nineteenth century, but they can now be found on various rivers and lakes along the Eastern shore of the Pacific, from California to Canada.[27]

Houseboats probably represent the first examples of floating communities. Although they have the potential to move, they generally remain moored to the shore or riverbank. Whilst in Europe, canal based communities reside on barges and are much more inclined to make use of the inland waterways, North American houseboats are a more permanent fixture.



13. Pontoon (floating pile) foundation: most common and economical type

The ‘floating foundations’ used for houseboats can be divided into four types: the traditional log type, the barge type (based on old boats), pontoons with pile foundations, and box type foundations.[28] The most common type is the pontoon or floating pile foundation (Fig.13). However, in terms of accommodation, the box foundation is more efficient, since it allows rooms to be created beneath the surface (Fig. 14).



14. Box type foundation: the best in terms of accommodation

Although largely restricted to lakes and sheltered bays, the floating foundations used for houseboats could be influential in the design of an oceanic settlement. The versatility of floating foundations would enable the structure to be towed out to sea before being secured on the seabed. This would facilitate land based, or dry dock construction and enable an off-shore development to be constructed in a piecemeal fashion. The settlement could then grow and evolve, in a similar way to the water villages of South East Asia.

Aquapolis

'Aquapolis', by Kiyonori Kikutake, was the Japanese pavilion at the Okinowa International Ocean Exposition in 1975/76. Designed as a microcosm of a marine city, Aquapolis became the symbol of the exposition (Fig.15).

15. Aquapolis: floating pavilion for the Okinowa International Ocean Exposition

The main feature of Aquapolis was that it actually floated on the sea, using contemporary off-shore drilling rig technology. The superstructure was supported by sixteen columns on four ‘buoyant foundations’. The buoyancy could be adjusted by pumping water into or out of the ‘lower hulls’ thus altering the height of the structure in the water . In addition the structure was able to move horizontally by winding on the chains that anchored Aquapolis to the seabed (Fig.16). This manoeuvrability improves accessibility and enables the structure to withstand the most severe environmental conditions.[29]

Although not strictly an oceanic settlement, Aquapolis gave an insight into what could be achieved with modern technology. For practical reasons a bridge linked Aquapolis to the mainland, but given the right facilities and scale this life line could easily be cut. The versatile deck of Aquapolis incorporated a helicopter landing pad that would serve to maintain links with the shore, if the bridge was removed.

The most revolutionary aspect of Aquapolis was the design of the sub-structure. Although familiar technology to the oil industry, this was a new application for adjustable ‘floating’ foundations. For the first time the public could experience the excitement and pleasure of a truly oceanic structure, that offered stability and safety as well. The architecture might have appeared alien to land based society, but that was because Aquapolis was designed to coexist in complete harmony with the sea.

With Aquapolis, Kikutake had pioneered a new type of oceanic settlement. Although only a prototype city at sea, unlike many of his contemporaries, Kikutake had at least realised his idea. With Aquapolis, Kikutake demonstrated how technology could be used to help solve the worlds accommodation problems. Aquapolis challenged preconceived notions about settlements and form. In effect, Aquapolis was a ‘houseboat’ for the twenty-first century, but on a scale that offered a real alternative to the traditional fixed method of constructing settlements over water. A floating oceanic settlement of this nature would be both versatile and environmentally friendly, in terms of its effect on existing coastlines.

'Floatels'

The exploration of off-shore resources around our coasts has seen a new type of oceanic settlement evolve. Floating structures have now been designed to provide accommodation for workers engaged in the construction and servicing of oil-rigs in the North Sea.

‘Polycastle’ was completed in 1982 and is basically a floating hotel for up to 600 residents. The ‘floatel’ is equipped with eight recreation rooms, a cinema, gym and a sauna, to enable the workers to fully enjoy their recreation time. Given its proximity to oil-rigs, safety features included fire fighting equipment and fire detection systems, as well as emergency flotation devices, which will ensure the integrity of the structure in an emergency.[30]

‘Polyconfidence’ is a slightly larger ‘floatel’, with six storeys and facilities to accommodate up to 800 residents. Again safety was a crucial element in the design and a ‘worst scenario’ study was used to predict the structures behaviour in the event of fires, collisions, explosions and sinking. In addition, a dynamic positioning system utilises underwater thrusters to maintain the platforms stability, even in areas where anchors and mooring lines cannot be used.[31]

‘Polycrown’ was completed in 1984. Like its predecessors, it was fitted with its own cranes and space was allocated for storing equipment as well as for workshops and offices; however accommodation was its primary function. Its luxurious outfitting earning it the nickname of the “North Sea Hilton” (Fig. 16).

16. Polycrown: a floating hotel - nicknamed the 'North Sea Hilton'

These 'floatels' have made small oceanic settlements a reality, albeit for temporary, highly specialised residents. Technology has dictated the aesthetic, and until these structures are more prevalent they will inevitably appear alien. The addict ‘form follows function’ is certainly applicable to these structures, but they don’t as yet have to attract residents.

An oceanic settlement off the coast of Britain would have to be more than just an utilitarian structure. Even if a settlement was to evolve as a product of oil and gas exploration in the North Sea, residents would expect a more civilised environment in which to make their homes. However, Polycastle, Polyconfidence and Polycrown demonstrate that there is a demand for accommodation in the North Sea and that communities can exist in these seemingly hostile waters.

Barrier Reef Hotel

The Barrier Reef Hotel was the first floating structure specifically designed solely for recreational purposes (Fig.17). Construction began in June 1986 and the hotel was opened for business in March 1988. Moored at the John Brewer reef, 72 kilometres off the Queensland coast, the hotel was intended to create an off-shore resort for tourists to one of the natural wonders of the world. The hotel was fitted out to luxury specifications, with en-suite accommodation, bars and restaurants. Due to the distance from the shore, facilities also included shops, a library and even a registered post office.[32]

17. The Barrier Reef Hotel

However, the project was beset by financial problems, and in June 1989 it was decided to move the Barrier Reef Hotel to Ho Chi Minh City, Vietnam.[33] Although it was never intended to move the hotel from the reef, except for periodic dry dock inspections, this new role for the Barrier Reef Hotel demonstrates the inherent versatility and mobility of floating structures at sea.

The hotel consists of an 89.2 x 26.6 x 6m steel barge, supporting the main superstructure, which in turn, supports five additional 'modular decks'. The barge-type structure is a departure from the floating foundations of similar projects, and more reminiscent of the houseboats of North America. This type of foundation however, increases contact with the ocean and improves access by boat.

Unfortunately, another departure is not such an improvement. The Barrier Reef Hotel imported a distinctly urban aesthetic into the oceans. The uncompromising 'oil-rig' architecture has been replaced with a floating 'high-rise', which has even less relevance to the oceans.

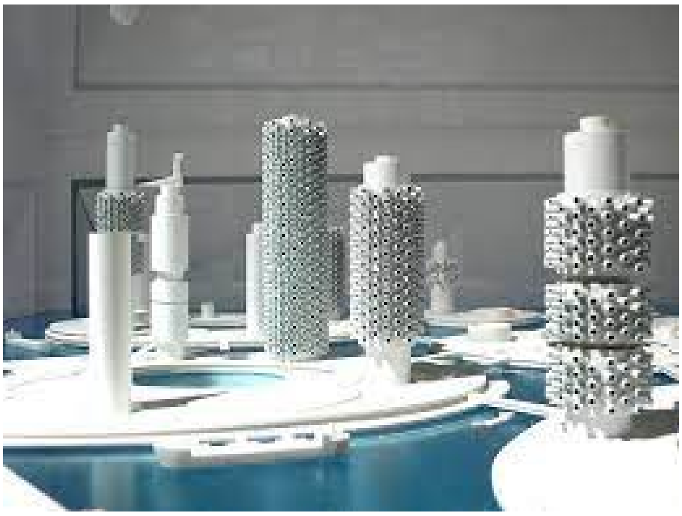
“Piering” into the Future

“The Ocean’s a Heritage for the Future”[34]

A number of innovative architects have become interested in oceanic architecture over the years. Schemes have been proposed for a variety of floating and fixed megastructures, aimed at solving local and global problems. Japan has attracted particular attention, no doubt due to its economic wealth, as much as the problems of overcrowding; however the dynamic nature of many of the proposals gives them universal appeal. Although nothing on the scale of these proposals has yet been built, the architects concerned were pioneers in the field of oceanic architecture and their work still warrants scrutiny, especially in the light of the continuing crises on land.

Marine City, 1958

Marine City was an early conceptual project by Kiyonori Kikutake, based on the principles of ‘Metabolism’. The metabolist theory is a complete architectural system based on the need for continuous adaptation to suit the needs of the people. In particular Kikutake was interested in the ideology of ‘replacement’ and believed that the idea of a ‘finite architecture’ was delusory.[35] Kikutake has been responsible for a number of innovative projects for future cities, including the Aquapolis pavilion described earlier. Marine City, however, was his first attempt to design a metropolis on the ocean (Fig.18).



18. Marine City concept project, 1958

Planned on a long-term and multi-disciplinary basis, Marine City was intended to be the “ultimate artificial city”.[36] True to form, the city was based around a mobile “parent body”- a floating industrial park, around which a succession of “cells” would evolve. The city would be renewed or reassembled in response to social needs or change and finally, at the end of its useful life, laid to rest in the depths of the ocean. The city was designed to be pollution free and self-sufficient, with energy provided by deep ocean water and solar heat, while desalination and recycling systems would supply limitless amounts of drinking water.[37] Kikutake was particularly concerned that Marine City dwellers would coexist with each other and the environment. He optimistically predicted that civilisation on the sea would promote a new era of hope and long lasting peace: “ Fresh air, a healthy and mild climate, panoramic scenery, an horizon, the blessings of the sun from dawn to dusk, a sense of liberty that transcends racial and national borders, opportunities of diverse yet orderly lifestyles - these are the benefits with which Marine City will be born.”[38]

Kikutake’s concept of a continuous evolution is particularly suited to an oceanic settlement. The design for Marine City, like Aquapolis, is based on floating structures or pontoons. Not only does this facilitate the construction process, but enables the settlement to be moored at virtually any off-shore location. The floating ‘parent body’ at the heart of Marine City acts as a life support system for the settlement, not only providing services and utilities, but producing prefabricated units for the community’s growth . The concept of using the technology of floating structures, to support a city in the ocean, was revolutionary in 1958 and it was nearly two decades later before Kikutake was able to put his theory into practice at the Okinawa Ocean Exposition. Kikutake may not have changed the face of our oceans, but deserves credit for changing the way in which we view them. No longer should the sea be seen as a barrier, restricting mans domain, but as an opportunity for a new and exciting existence.Kikutake’s approach to oceanic settlements is in complete contrast to the traditional Dutch approach, referring to the process of extending the edge of the land as “reclaimed sprawl..... a violation of the stern and clean sea.”[39] It has taken a long time for the ‘floating solution’ to gain recognition, particularly in Europe, but Kikutake has at least demonstrated that it is a viable alternative.

Tokyo Bay City, 1960

The city of Tokyo has evolved as a result of "totally planless spontaneous growth on the basis of self-assertion of the inhabitants."[40] Unfortunately, there is no room to grow anymore and Tokyo's notorious land shortage has turned into a famine. The extortionate cost of land is deterring foreign investment and jeopardising Tokyo's position as one of the worlds prominent economic and cultural centres.

As early as the late 1950's options were being considered to address the problem, including several proposals for a new city to be built in Tokyo Bay. Considered futuristic at the time, the intervening years have seen considerable advances in the technology needed for such a project. One architect involved in those early proposals, was Kisho Kurokawa. In his 'New Tokyo Plan, 2025', Kurokawa proposes to remove some of the existing capital's functions to a new island to be built in Tokyo Bay and create a "completely new, twenty-first-century capital."[41]

Kurokawa believed that the capital city of the next century would consist of a string of urban centres, all combining to fulfil the traditional role. To this end, the new island will not be included in the existing district, but will become a "special city", which will include facilities and amenities such as central government ministries and agencies, foreign embassies, official residences, international facilities, business and commercial facilities, residential districts, resort and leisure districts and cultural facilities.[42]

Kurokawa was also an advocate of 'loop cities', whereby the focus of the city switches from the core to the edges. Consequently the centre of the island will consist of residential areas, with golf courses and cultural facilities, while the high buildings of the business and administrative districts will be on the outskirts (Fig.19).

19. The proposed new island in Tokyo Bay, 1960

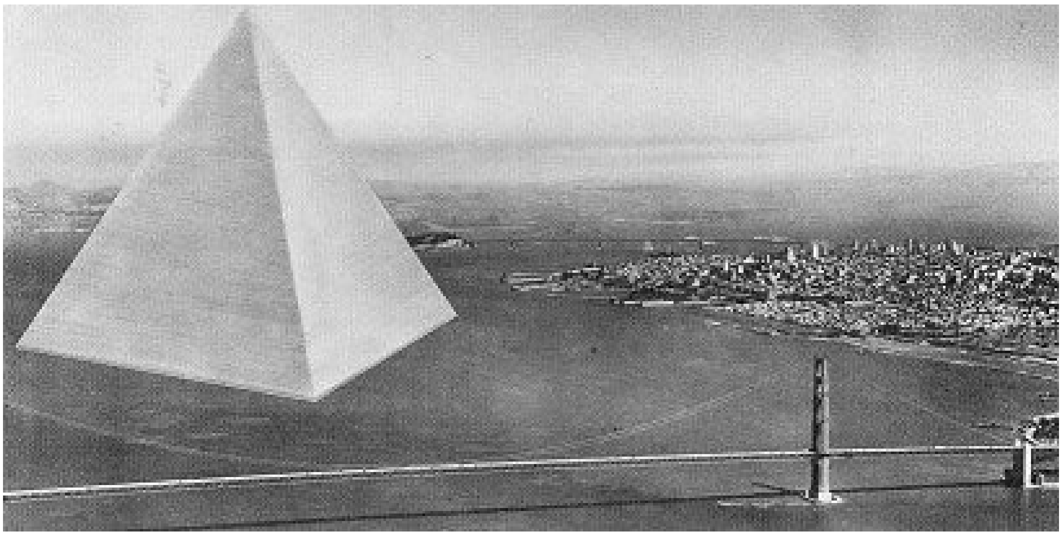
The new island would consist of 30,000 hectares of landfill in the centre of Tokyo Bay, and could support a population of up to 7 million people, at one fiftieth the cost of land in Tokyo.[43] The island would not only alleviate the pressing land shortage problem, but in doing so the value of land in central Tokyo would inevitably fall, making the city a more a affordable place to live. In addition, a new island in Tokyo Bay will provide the 'elbow room' for the much needed redevelopment of Tokyo itself.

The 'New Tokyo Plan, 2025' was an ambitious response to the pressing land shortage problem of the area. Although the project is appealing in terms of accommodation, business and leisure facilities it is a very traditional solution. The zoning, albeit in accordance with the 'loop' principal, is reminiscent of 1960's town planning and in complete contrast to the 'mixed use' strategies advocated by today's architects and planners. In addition, the 'land fill' approach to 'oceanic architecture' is not only dated in terms of technology, it is also of questionable environmental responsibility. The practice of reclaiming land, has been shown to affect the coastline far removed from the actual site.[44] Although Kurokawa has chosen to create an island in preference to extending the shore, this must still be a dubious solution in terms of the effect it will have on the rest of the bay, and perhaps a better solution would have been to create a 'floating island' in the spirit of Kikutake.

Tetrahedronal City & Triton City, 1965-68

Tetrahedronal City was intended as a vast floating pyramid, based on Buckminster Fuller's structural system of 'Tensegrity'. This system was developed from aircraft technology and incorporated wafer thin structural components constantly in a state of tension. His purpose in creating this structural system was "to bring the slenderness, lightness and strength of the suspension bridge cable into the realm previously dominated by the compression column concept of building."[45] The structural efficiency of this system enabled Fuller to make a variety of proposals for enclosing huge areas with extraordinary lightness:

"While the building of floating clouds is several decades hence, we may foresee that along with the floating tetrahedronal cities, air-deliverable skyscrapers, submarine islands, sub-dry surface dwellings, domed over cities, flyable dwelling machines, rentable autonomous living, black boxes, that man may be able to converge and deploy around earth without its depletion."[46]



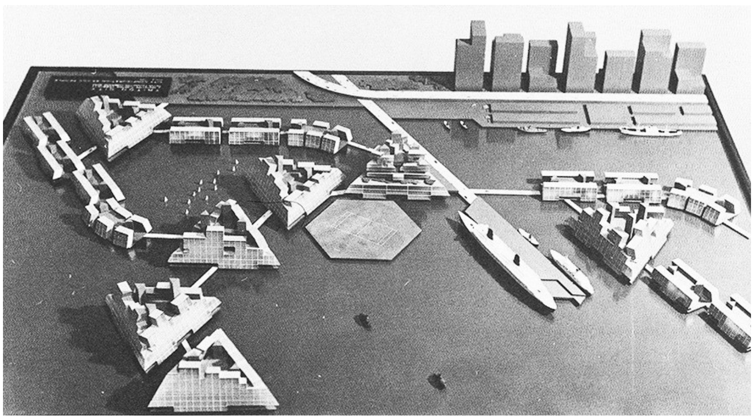
20. Tetrahedral City: photomontage showing scale of the project

Tetrahedronal City was to provide accommodation for one million people within its 3.2 km squared footprint. Moored adjacent to the Golden Gate bridge in San Francisco bay, Tetrahedronal City dwarfed the familiar landmark (Fig.20). Despite its size, however, the honeycomb concrete walls and hollow box sectioned reinforced concrete foundations would enable even a one million passenger tetrahedral city to float.

Contained within the base of the pyramid was to be a vast artificial harbour, providing refuge for the largest of ocean going vessels. The 5,000 apartments, contained within the walls of the tetrahedron, would consequently enjoy an external balcony with a ‘sea-view’, together with an internal balcony overlooking the harbour. In addition, the floating foundations around the perimeter provide an ideal landing strip for aircraft. Tetrahedronal city could grow according to demand, starting with a thousand occupants and building upwards towards its 2,500 metre peak. Self-sufficient through solar power and wave generated energy, Fuller envisaged Tetrahedronal cities of various sizes at offshore anchorage points throughout the world. This would permit cargo and passenger transfers in mid-ocean and vastly improve the worlds distribution and communication network.[47]

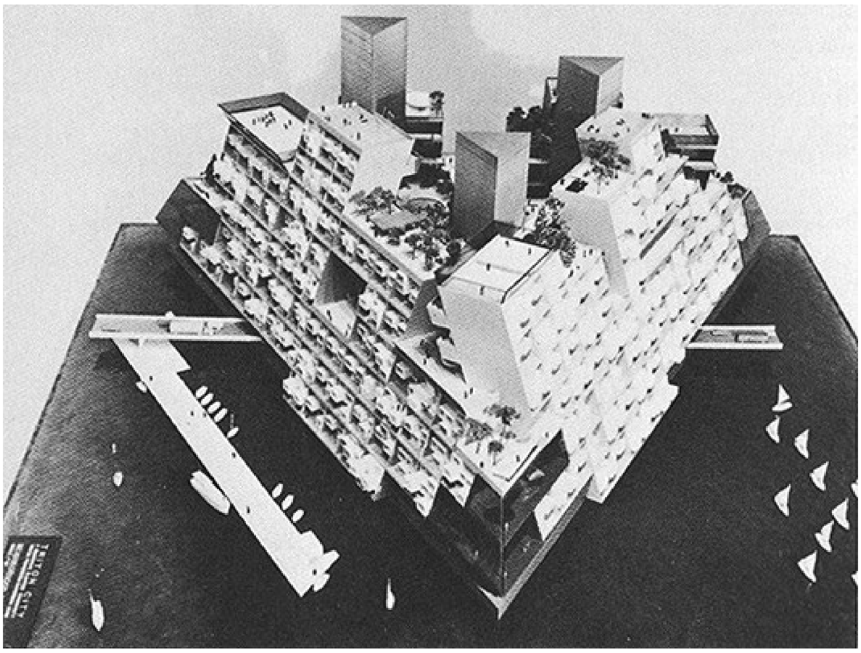
Tetrahedral City, although structurally advanced, was more akin to an Egyptian burial chamber than a city of the future. Superimposed adjacent to the Golden Gate Bridge the project might look impressive to an engineer, but is completely out of context. This speculative project does demonstrate however, what can be achieved with the technology at our disposal - a floating city for one million people!

Another floating city concept, by Buckminster Fuller, that owed much to the earlier Tetrahedronal city was ‘Triton City’(Fig.21). This proposal, financed by the United States Department of Housing and Urban Development, explored the technical and economic feasibility of developing areas of sheltered water adjacent to major cities, in order to alleviate problems of overcrowding. The study showed that over 80% of metropolitan areas, with a population of one million or more, are situated near bodies of water which are sufficient to accommodate floating cities.[48]



21. Triton City: floating modules moored adjacent to existing city

Triton City consisted of a complex of 'neighbourhood sized' communities, accommodating between 3,500 and 6,500 people (Fig.22). The larger platforms were triangular in shape and were expected to weigh somewhere in the region of 75,000 tonnes.[49] Three to six of these 'neighbourhoods' would form a town, and three to seven towns would constitute a city, with extra municipal modules being added as required. The framework superstructure would make for the flexible distribution of infilling components, such as apartments, classrooms, stores and offices. In addition outmoded units could be replaced or rearranged without disturbing the overall composition of the whole. Fuller intended to use the sea as a highway, with 'Triton' modules being produced at well equipped shipyards or dry docks and then towed into position. "Thus the economics of shop fabrication can be brought to bear on construction problems which are traditionally soluble only at the final site location."[50]



22. Triton City: model of neighbourhood-sized accommodation module

'Triton City' offered the best of both worlds; the dynamic quality of urban life associated with urban high density, together with the spectacular views and sense of openness previously the province of suburban and rural areas. Since the community is intended as a city complement, it would also benefit from the existing shore-based amenities such as the entertainment, educational and cultural activities that are available in all major conurbations.

In complete contrast to Kurokawa’s Tokyo Bay project, Buckminster Fuller’s approach to alleviating the over population of our cities is much more dynamic. As an engineer, Buckminster Fuller put his faith in technology as the solution to the worlds problems. Most of his projects were so advanced for their time and on such a large scale, that they stood very little chance of being realised. However, his contempt for the architectural profession, or “slave profession” as he referred to it, made him all the more determined to break the mould.[51]

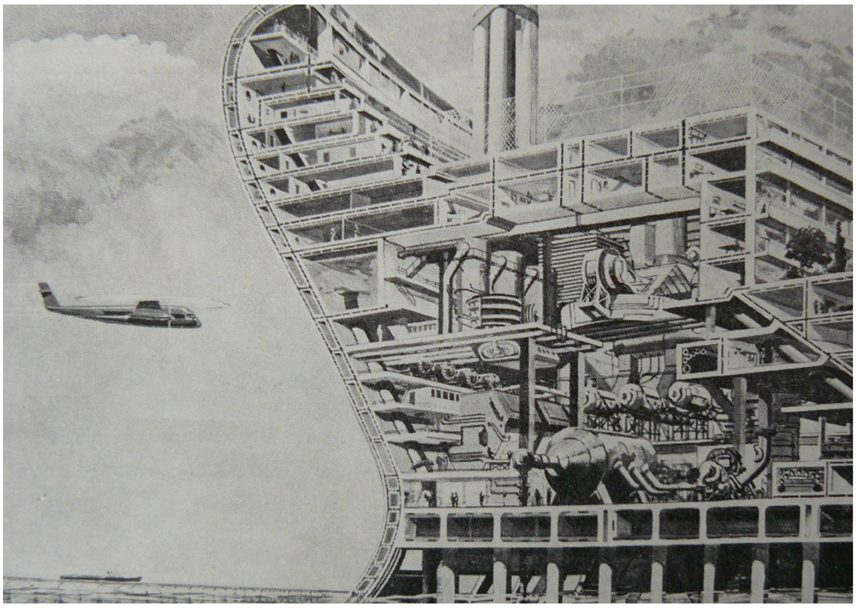
The Triton City project, is a much more realistic proposal. In a similar vein to Kikutake’s Marine City, designed ten years previously, the scheme provides all the amenities to support an independent off-shore community, whilst maintaining strong links with an established city on the mainland. It also reaffirms the importance of mobility and ‘metabolism’ in oceanic architecture.

Sea City, 1968

Sea City, by Hal Moggridge with John Martin and Ken Anthony, was the result of a theoretical exercise, initiated by the Pilkington Glass Age Committee. The idea was to explore possible solutions to the problem of overcrowding in Britain. In the optimistic euphoria of Post-war Britain, Pilkington Glass developed several ambitious projects aside from Sea City. The common cause behind each one was a brief to “design an imaginative project that could be realised within the next 50 years, the structural techniques for which are available at the present day”[52]

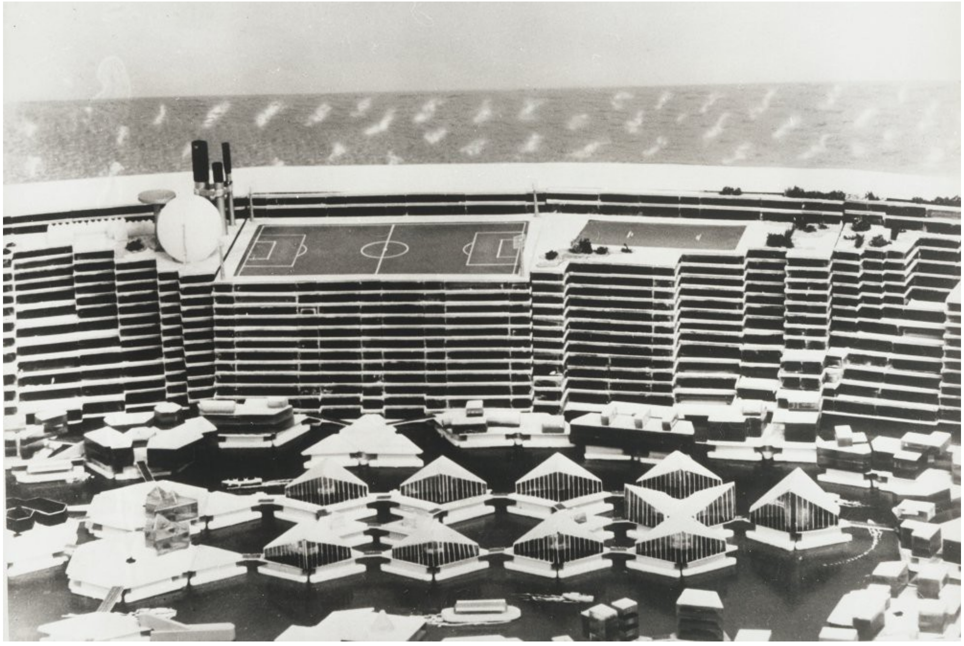
23. Sea City: model showing scale and complexity of project

Sea City was an offshore island, constructed from glass and concrete, designed to accommodate up to 30,000 citizens (Fig.23). The proposed location was the shallow shoal waters off the east coast of England, at the edge of the Hewett Gas Field, where the tidal range is relatively low.[53] The main structure of Sea City consists of a 16 storey 'amphitheatre' supported by piles driven into the sea bed. This terraced accommodation curves outwards to deflect wind up and over the city, whilst a floating breakwater also surrounds the city to create a 'moat' of calm water. The superstructure consists of concrete cells stacked on top of each other and joined together at the corners. Each cell was to be prefabricated on the mainland and assembled on site to form flats of varying sizes. Beneath the flats, on the outer edge of the perimeter terrace, provision has been made for offices, industry and power plants (Fig.24).



24. Sea City: section through outer wall

The flats overlook a central lagoon where floating islands, anchored to the sea bed, support lightweight buildings such as shops, cafes and pubs. Moored to the islands would be visiting sailing craft (no diesel or petrol propulsion would be allowed) that pass beneath elevated walkways (Fig.25).



25. Sea City: Lagoon

The city is designed to be self-sufficient in terms of services and entertainment, with schools, a 200 bed hospital, fire, police and local government services. Social and cultural facilities include community centres, theatres, libraries, cinemas, an art gallery and a museum, as well as a church for every religious denomination.[54] Sea City would be well equipped to maintain close contact with the mainland, with regular sorties by helibus and hovercraft, and at the same time be free from the noise, fumes and dangers of shore based society.

Sea City is probably the most detailed speculative proposal for an oceanic settlement to date. The project not only has a specific site, but the structural details and method of construction have also been anticipated. The project is unique in that it uses a combination of fixed and floating accommodation. The shallow shoal waters enable piles, brought from the mainland, to be driven into the sea-bed, providing a permanent superstructure. However, the pontoons within the lagoon are more versatile and will enable the city to adapt to future requirements. The rigid outer structure is able to support more accommodation than would otherwise be possible and also provides a protective environment for the more vulnerable floating structures. This is an important consideration for exposed sites like the North Sea where the environment can be particularly hostile.

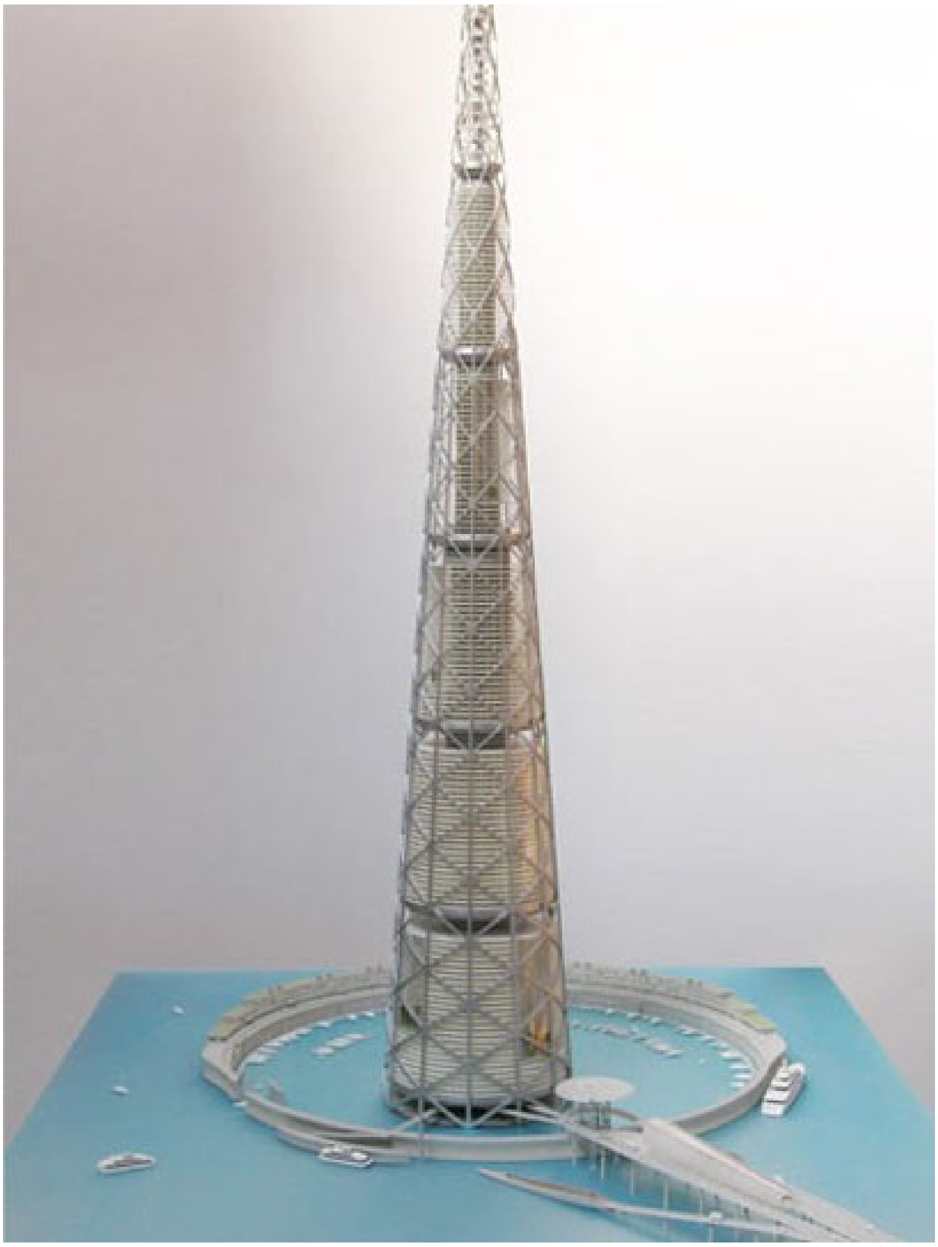
Sea City appears to be a natural progression from Kikutake's proposal ten years earlier. Both projects were inspired by the pressing concerns of land shortage and overpopulation. Although radical solutions, Marine City and Sea City could both have been realised at the time of their design. In the intermediate years, Buckminster Fuller's proposals, although technically plausible, were and probably still are at the limits of feasibility. Unlike these projects however, Hal Moggridge and his team were designing with a specific site in mind. As a consequence, the form of Sea City is not just a product of architectural speculation, but a direct response to the environmental and geographical conditions. The proposed location of Sea City makes it particularly important as a precedent for any future developments off the coast of Britain. Although Sea City was designed to be built using the technology of the day, even then it was conceded that such a project would probably not be realised for at least another 50 years.[55]

Millennium Tower, 1989

Foster's design for a Millennium Tower, commissioned by the Japanese company Ohbayashi, is the most recent proposal for Tokyo Bay (Fig.26). At 840m the tower would be the world's tallest building and provide mixed accommodation for 50,000 inhabitants. In the mix of uses the complex was to resemble any major city thoroughfare, such as New York's Fifth Avenue, or Tokyo's Ginza, with residential, commercial and professional activities.[56]

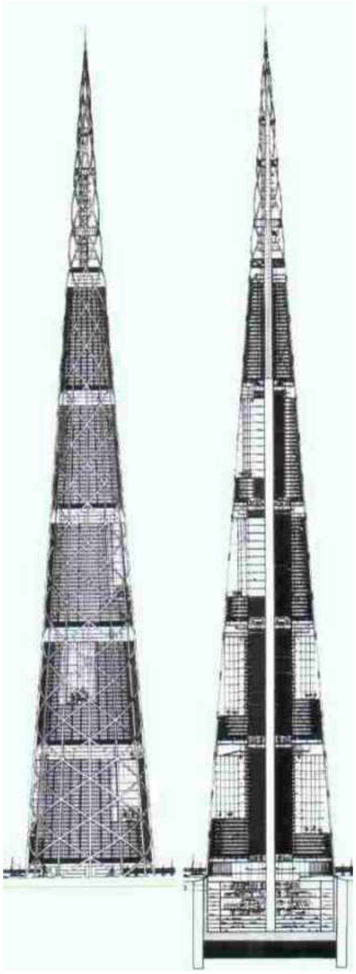
In contrast to Kurokawa's proposal, Foster took the opportunity to create a self-contained, independent, urban complex that re-addressed the concept of urban development:-

"The planners preoccupation with strict zoning of human activity has been perhaps the single most destructive social evil of contemporary urbanism. As we have evolved from working with our hands to working with our minds, the twentieth century office building has replaced the nineteenth century factory as the central villain of alienation and dehumanisation. The opportunity exists to return to a multi-functional existence, embracing endeavour and leisure, work and play, the making and spending of money, in a much richer diverse experience."[57]



26. Millennium Tower: model

The tower itself is conical in form rising from its 130m diameter base into the sky like a needle, whilst the helical external structure wraps itself around the building in a sinuous grasp (Fig.27). According to Foster, “its slim shape evokes the rocket, while the complexity of its structure echoes the radio telescope.”[58]



27. Millennium Tower: cross-section and view of facade

The tower is divided up into seven sections. The top two sections are designated for viewing platforms, restaurants, communications, and collectors for wind and solar energy. The remaining five sections consist of living accommodation on the upper levels and offices towards the bottom. A central service core contains high speed lifts that access each section, while slower local lifts provide connections within each sector. The first six storeys form the main public domain of the building while 'sky centres', located at every thirty floors, provide semi-public areas, with terraces, hotels, restaurants, sports centres and shopping facilities.[59] To the south of the building a plaza overlooking the water, welcomes visitors by road, rail or water. A marina encircles the base of the tower and provides an area for recreation and relaxation.

Foster’s Millennium Tower is as much a symbol of Japan’s economic success as a practical response to Tokyo’s land shortage. Although one of the most recent proposals for an ‘oceanic settlement’ its interaction with the water is limited to the marina that surrounds it. The ‘rocket’ and ‘telescope’ metaphors are more appropriate to land based communities than those of the ocean and the extraordinary height literally makes it a 'landmark' building.

In its proximity to the densely populated fabric of Tokyo, the Millennium Tower would undoubtedly serve to alleviate the overcrowding, but perhaps in the 21st century we should be looking for a new approach to solving our urban problems. The opportunities at sea are endless and in this respect Foster’s contribution to oceanic architecture is very limited.

Conclusion

"Beyond this world of vice and potential there is escape, the floating world criss-crossed by the ship of fools, where the relationship between the certainties of architecture and the possibilities of water is reversed"[60]

Why a City at Sea?

The projects outlined in the last chapter were not just the result of a futuristic flight of fantasy, but the response to specific problems - namely overcrowding and an increasingly short supply of land. The problem is most severe in small countries with high population densities, such as England, the Netherlands and Japan, however populations are continuing to expand throughout the world and many other countries could soon be faced with the same predicament.

Another problem that threatens countries on a global scale is that of rising sea levels. Although there is a diffence of opinion regarding the scale of the effects of global warming, experts generally agree that a change in the level of our oceans is inevitable. The consensus of opinion moved world leaders to address the problem at the Earth summit in Rio in 1992. Although the resulting 'Climate Treaty' committed participants to reducing carbon dioxide emissions, the main catalyst in global warming, it was clear by a follow up meeting in Berlin in 1995, that "many countries would fail to reach their commitments for the year 2000"[61]

Little progress has been made since 1992, with recent efforts being blocked by both developed and developing countries, on economic grounds. The failure to reach an agreement will inevitably lead to higher energy consumption and an inherent rise in CO_2 emissions, particularly given the ever increasing world population. The human race has a seemingly insatiable appetite for energy, particularly in the rich 'Westernised' countries, no matter what the cost. The resulting rise in sea level will put buildings, infrastructure and people throughout the world at risk from flooding, and undermine the commercial stability of many coastal cities. The loss of land and the devaluation of property, in high risk areas, will cost billions of pounds. Burdened by such devastating effects, coastal settlements, particularly in the developing world, may not be able to afford the luxuries of sea defences.

The so called 'rich countries' of the developed world however, will have to decide on their tactics in the war against the sea. The battle will commence in countries like the U.K and the Netherlands, where there are many sites that are already prone to flooding and coastal erosion. Coincidentally, both these countries also have relatively high population densities, with little room for manoeuvre. In Britain, the Humber Lowlands and the Norfolk Broads are particularly vulnerable, especially as this side of the country is still experiencing geological change as a result of the last ice age. Various options for sea defence and coastal protection are at our disposal, including raising existing sea walls, building storm surge barriers, building major estuarine barrages or even sacrificing whole sections of coast. However, all of these solutions carry an extremely high price.

A report on Climatic Change, commissioned by the United Nations, estimated that Great Britain would have to spend over £6.5 billion during the next century, just to maintain the status quo.[62] The enormous cost of defence, coupled with a move towards a policy of non-intervention, is likely to mean that even the comparatively rich countries will have to succumb to the sea.

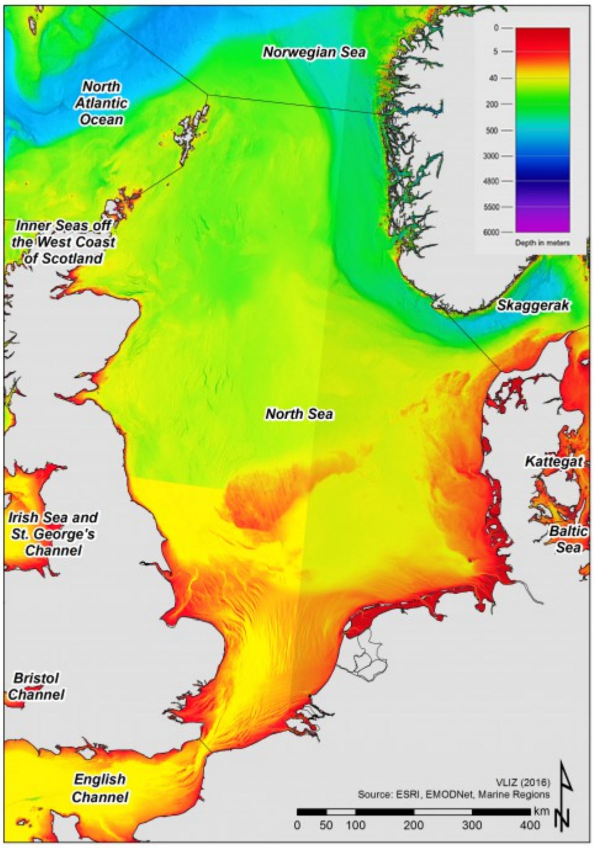
In the face of a seemingly hopeless situation, the solution may well lie with one of the problems - the sea. At present the oceans occupy around 75% of the earth's surface, but as yet remain largely unexplored and uninhabited. Although small populations exist on the oceans, projects on the scale of Marine City or Sea City have yet to be realised. However, it is precisely this kind of development that will be necessary in the not too distant future, if we are to cope with the predicted population rise and the effects of global warming.

Not only are we desperately short of land, but we are rapidly depleting the natural resources necessary to support the existing number of people, let alone any more. Apart from the finite sources of raw materials for fuel and manufacturing, the most pressing concern is the supply of fresh water and fresh air. Many experts are now looking to the sea as the source of a new reservoir of supplies in which the survival of mankind may lie:

"An incipient crisis of resources is already teaching man seriously to consider the problem of his ultimate survival and inevitably he is exploring the possibility of developing away from land into the sea"[63]

Location

There is now a strong stimulus to find suitable sites for a city at sea, that could alleviate the pressures on land. Shallow 'shoal waters' cover nearly 10% of the sea bed, providing many suitable sites across the world.[64] In Europe, large shallow areas are to be found in the northern half of the Adriatic and off the north coast of the Black Sea, however perhaps the greatest combination of advantages for siting and constructing a city at sea is offered by the North Sea (Fig.28).



28. Depth of Water in North Sea

The North Sea is scattered with shoals that can reduce the depth of the sea to less than 45 ft.[65] The tidal range also varies over the surface of the North Sea, from zero up to 21 ft.[66] From a construction point of view it is obviously preferable to position a sea settlement in relatively shallow water with a small tidal range. This combination can be found at various places within the North Sea and since shipping lanes tend to follow the deeper channels, the potential sites for a sea city would not impede sea going vessels.

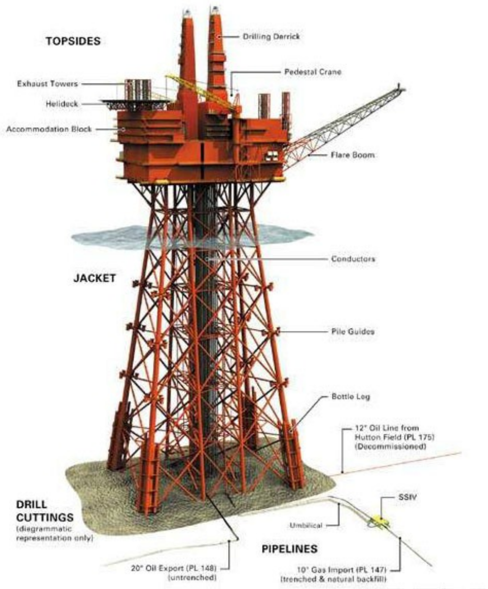
In the main the North Sea is protected from the prevailing South West wind by the land mass of Great Britain, and the short 'fetch' precludes the build up of extremely large waves. However, on rare occasions stronger winds blow from the North East quadrant and protection, in the form of some kind of barrier, will probably be necessary to minimise their effect. Sea City, by Hal Moggridge, demonstrated how a wind break could be incorporated into the design of a settlement in the North Sea, to create a more sheltered environment.

Communications and supplies for a city built in the North Sea could also hail from one of the many ports or towns along the east coast of Britain. Great Yarmouth, for example, already acts as a supply base to the drilling rigs in the North Sea gas fields, and has the necessary harbour facilities for handling large structural elements. A settlement off the Holderness Coast could also utilise the industrial assets of the ports within the Humber Estuary.

Construction

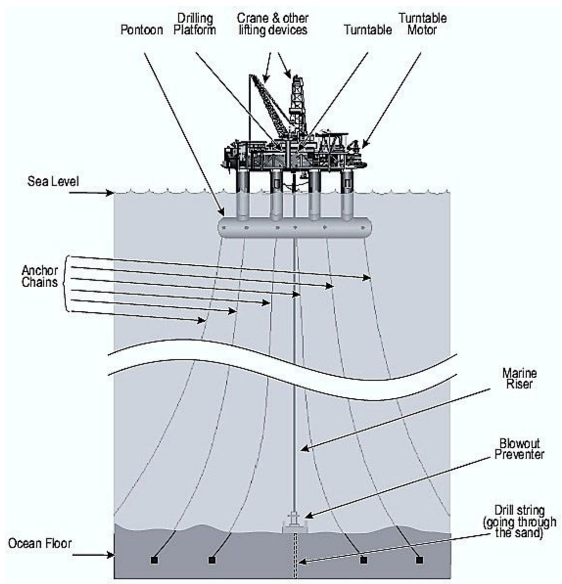
Having discovered a site that meets the requirements for establishing a settlement in the North Sea, both in terms of the physical features of the location and the proximity to a suitable 'shore base', the next question to be considered is the type of structure and method of construction. As we have seen, there are basically two types of substructure – fixed or floating.

A fixed structure has the advantage that it can support a more substantial superstructure, however it is limited by the depth. Given the nature of the sea bed in the North Sea, piling would be the only method of supporting a fixed structure. The length of piles would be determined by the depth of the water and distance to a suitable load-bearing stratum. These would then support deck sections above the sea, as typified in a traditional drilling platform (Fig.29).



29. Typical 'Fixed' Offshore Drilling Platform

The general nature of the North Sea varies from rock to areas of peat and post-glacial deposits.[67] Structures founded in the latter will not be stable and this is reflected in the design of modern drilling platforms in the North Sea, where the rigs are constructed on land and then floated out to the prospective reserves. Depending on the depth of the water, hollow members are then flooded to enable the structure to rest on the sea bed or remain semi-submerged. The platform is then secured with steel cables and anchors (Fig.30).



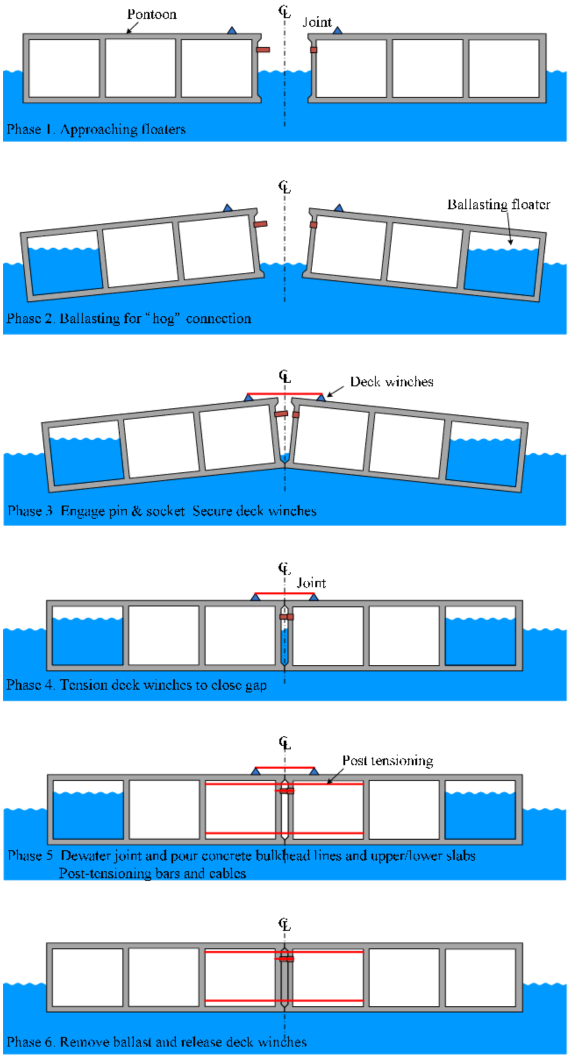
30. Typical 'Floating' Offshore Drilling Platform

The advantages of a floating or semi-submerged structure are three-fold: firstly they negate the difficulties involved in finding a firm footing, since they utilise the carrying capacity of the water; secondly they can be constructed on land and floated onto the site, greatly reducing the cost of construction and thirdly, the flexible nature of floating units means that the structure can be assembled in stages and in response to demand.

Materials

The majority of drilling platforms at present are constructed from structural steel. Steel has a high strength to weight ratio and can be protected against the effects of sea water by paint and electrolytic action. Reinforced concrete, however, offers an alternative solution, which is much less susceptible to corrosion. Concrete pontoons not only float on water, but a box type foundation can also accommodate rooms within the hull. In addition, concrete modules can be towed out to site and joined together to form much larger structures (Fig 31 & 32).

31. Towing Concrete Pontoons



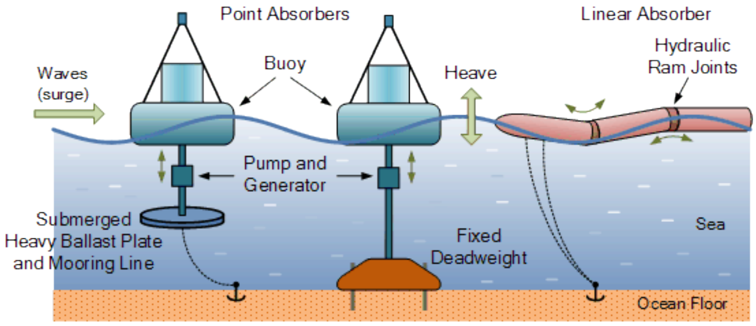
32. Joining Concrete Modules

Although at present, steel is the dominant material for existing oceanic architecture, reinforced concrete is probably a better alternative, particularly in the harsh environment of the North Sea. Concrete has a long history of use in marine environments - in 1944 a million tons of reinforced concrete was towed across to France to create shelter where none existed.[68] Aluminium, magnesium and plastics, although popular in other branches of marine technology have yet to make a significant impact in the field of oceanic architecture. However, just as synthetic materials have changed the face of the building industry on land, oceanic architecture will inevitably adapt and change, as the benefits of new materials are realised. These modern materials will probably be more suited to the superstructure of a sea based settlement, providing lighter and more flexible structures on top of the substructure.

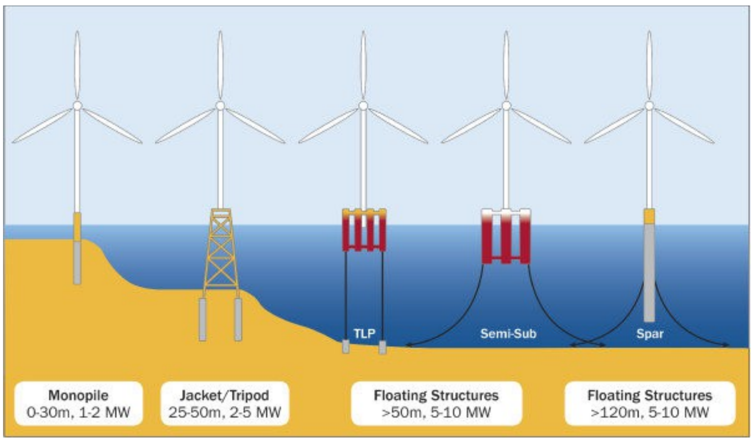
Energy

The North Sea, with its reserves of natural gas and oil, has hosted small settlements for many years. Sited near to deposits of fuel, a new settlement in the North Sea could take advantage of these resources, certainly initially. A combined heating and power plant (CHP) could not only produce electricity, but also provide a district heating system for the whole settlement, which is a much more efficient use of resources.

However, it is renewable sources of energy, which will guarantee the long term future of a sea-based settlement. Solar, wind and wave power offer a virtually unlimited supply of cheap and sustainable energy. These renewable sources of energy would eventually replace gas and oil, as fossil fuels are phased out (Fig 33 & 34).



33. Wave Energy Devices



34. Off-shore Wind Turbines

In addition, the sea acts as a 'heat battery', storing the energy from the sun. Consequently, an oceanic settlement would benefit from a comparatively mild environment in the winter, compared to the mainland. It is much easier to provide a warm environment in the North Sea than a cool one in the Red Sea.[69]

Utilities

A city at sea would be intrinsically linked to its new environment and it is clearly desirable to avoid the levels of pollution that have plagued urban life on the land. In particular sewage must be treated before release, so as not to contaminate the lagoon or host waters. Two processes have recently been developed that would enable a sea settlement to efficiently treat its soil-water; one produces chlorine from the electrolysis of water, whilst the other utilises ultra-violet light to render the discharge harmless.[70]

Pure fresh water can now be produced by desalination plant. As an ancillary to the power station, the desalination plant could operate using the heat emitted from the generators. The cost of desalination has decreased rapidly since its inception and it is now anticipated that fresh water extracted from the sea will be cheaper than that collected on land in the near future.[71]

Industry

A city at sea can only be a realistic proposition if it is a self-supporting community. It is not sufficient to be an attractive place to live or a 'floating hotel' for workers . In order to be economically viable the settlement must have an industrial base. The type of industries that would suit a sea settlement will be those that benefit most from the location, such as industries that require an abundant supply of cheap water and fuel. Presently located at isolated coastal sites, these primary industries would be the ideal basis for a sea city. Industries of this nature often attract other companies and suppliers that are dependent upon them. These primary industries therefore could be supplemented by secondary industries with similar requirements such as paper making, cloth processing and the production of fibres and fabrics. Consequently the industrial base would gradually expand and become more labour intensive.

In addition to those land based industries that would benefit from relocating to a sea settlement, new industries would evolve that could only exist at sea. The sea water itself is a source of trace elements such as magnesium, bromine, rubidium, nickel and cobalt which could be extracted as a side product of the desalination process.[72] It is also conceivable that fresh water produced by the desalination plant could be exported to the mainland, as this important commodity becomes increasingly valuable.

Fish farming could provide a variety of fish for human consumption, cultivated in the temperature controlled environment of a lagoon, with tremendous advantages over traditional fishing methods. Linked to fish farming would be the associated industries of canning and freezing, for distribution to the mainland. Another product of the ocean that could support an industry peculiar to a sea city is seaweed. Seaweed is not only a table delicacy, but a major ingredient in the manufacture of alternative fertilisers.[73]

Finally, a city in the sea will become part of the biggest industry in the world - tourism.[74] The tourist industry would be a healthy bonus for a sea settlement. As a holiday destination it could rival any other resort in Britain. Its controlled climate would extend the holiday season, whilst special attractions peculiar to its location could include an aquarium, deep-sea diving and other water sports facilities. A leisure centre, theatre and cinema could provide traditional entertainment and of course a toursit destination would require hotels, along with cafes and bars.

Transportation

Due to its isolated location, a city at sea will have to be a self-sufficient and independent community. As discussed earlier, however, it will still require a safe, convenient and rapid link with the mainland and efficient telecommunications. The North Sea poses particular problems in this respect, since the inclement weather conditions can delay and restrict the means of transport.

Traditional boats and ships are the most effective cargo carriers as they offer the greatest payload. The larger vessels can also operate in the most adverse weather conditions. However, compared to other means of transport they are slow and inefficient, wasting energy on the production of waves.[75] There is however, a new generation of high-speed ocean-going craft for small cargoes and passenger transportation. Based on ‘ground-effect’, aerofoil and multi-hull technology, various vessels are now capable of carrying over 600 people at speeds of upto 50 knots.[76] These new ships will drastically reduce the travelling time across the ocean and will probably form the basis of a passenger service between a sea settlement and the ports and harbours of the mainland. The fast freight carrying craft sector is also expected to grow in the near future.[77]

Helicopters currently fly regular sorties between North Sea platforms and the mainland. They offer the fastest service for people and small cargoes in the absence of a runway and would be essential for any sea settlement. The manoeuvrability and speed of helicopters makes them indispensable in emergency operations at sea and also enables them to work in conjunction with other modes of transport.

Harbour facilities, will therefore be a core element in the design of a sea settlement. An off-shore transportation terminal will not only cater for the residents of the settlement, but could benefit all ocean going traffic, providing a safe refuge. The exchange of goods at an off-shore harbour would reduce the congestion at shore-based ports, improving efficiency and also releasing valuable land for alternative uses.[78]

"We are now contending with a transportation crises which can only be relieved by turning to the sea. If we ignore the benefits of off-shore terminals and jet-ports, our highways and airways will slowly strangle and we will be forced to build such facilities on a crash basis, at high cost and with less regard for the environment."[79]

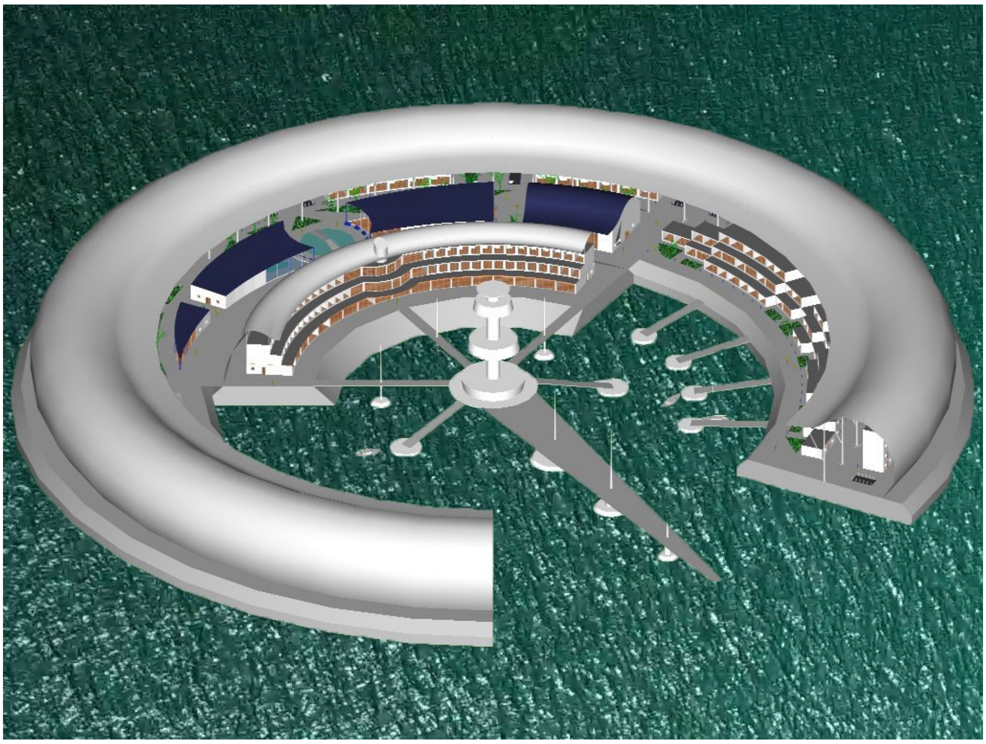
Realisation

A city in the sea will only become a reality, if there is sufficient funding. Building a city in the sea will obviously be a large scale development and would require enormous investment. However, the absence of any acquisition of land, coupled with the advantages of off-site production, could make it an economically viable alternative to building on land. In this country in particular, there is an increasing reluctance for governments to provide money for new large scale developments; however the alternative of building and maintaining coastal defences could be far more expensive in the long run.

There are also various industries that would benefit from having an operations base in the Noth Sea, especially one that incorporated accommodation for an insitu workforce. The success of oil and natural gas exploration in the North Sea depends upon efficient management and communications.[80] As a result, a large oil or gas company might be willing to invest in such a project. Alternatively, a consortium of private companies or investors could provide the necessary funding.

The right financial backing is the last piece of the jigsaw in the realisation of a city in the sea. There would of course be political, legal and administrative obstacles to overcome in making a city in the North Sea a reality. The first sea settlement would probably have to be a prototype or 'test town' to study the structural and social issues that result from establishing a community in this new environment (Fig.35). A successful prototype could, however, set a precedent for much larger settlements all around the coast of Britain and beyond - the sea **is** the building site of the future!

"Until recently, we regarded the sea primarily as an obstacle to reaching distant land masses, or as a glorious battlefield, but not as a place where one would want to live or do business. Now that we are feeling the pinch of intensive land usage, especially in coastal areas where population and industry are concentrated, we are beginning to take a hard look at the oceans around us, and there we find all the things we need to solve our immediate and foreseeable problems: natural resources in great abundance, food and water for all the world's peoples, and virtually limitless space."[81]



35. Sea City: A prototype sustainable oceanic settlement

[1] Moore, Charles, Water and Architecture, Thames and Hudson, 1994, p.175

[2] Kuroyanagi, Akio, Composition of Oceanic Architecture, Process Architecture Co., 1991, p.16

[3] Jones, Julian, Water-Designing for Plenty and Purity, Architecture and Water, Academy Group Ltd., 1995, p.17

[4] Glass Age News, Pilkington Brothers Ltd., 1968, p.4

[5] Government Actuary, National Population Projections, 1994, p.22

[6] Glass Age News, op.cit., p.4

[7] Pethick, John, and Burd, Fiona, Coastal Defence and the environment, Ministry of Agriculture, Fisheries and Food, 1993, p.1

[8] Stapleton, C.M, Humber Estuary and Coast, Humberside County Council, 1994, p.7

[9] Stapleton, C.M op.cit., p.2

[10] Pethick and Burd, op.cit., p.2

[11] Robin, Climatic Change, Rising Sea level and the British Coast, Institute of Terrestrial Ecology, 1989, p.3

[12] Pethick and Burd, op.cit., p.26

[13] Hoffman, Climatic Change Rising Sea Level and the British Coast, Institute of Terrestrial Ecology, 1989, p.3

[14] Pethick and Burd, op.cit., p.27

[15] Butler, Climatic Change, Rising Sea Level and the British Coast, Institute of Terrestrial Ecology, 1989, p.3

[16] Pethick and Burd, op.cit., p.27

[17] Stapleton, C.M, op.cit., p.4

[18] ibid., p.5

[19] Bertrand, Goldberg, Composition of Oceanic Architecture, Process Architecture Co. Ltd, Tokyo 1991, p.13

[20] Fletcher, Sir Banister, A History of Architecture, Architectural Press, Oxford, 1996, p.1246

[21] Parkes, Carl, South East Asia Handbook, Moon Publications Inc., U.S.A, 1994, p.62

[22] ibid., p.62

[23] The Contemporary Kampong, S.I.A.J, 1989, p.38

[24] Gazzard, Kubik, Price, Storey, Winch, North Sea Settlement, Northern Architect, 1966, p.634

[25] ibid., p.634

[26] Geuze, Adrian, Adrian Geuze/West 8: Landscape Architecture, Uitgeverij 010, Rotterdam, 1995, p.74

[27] Bertrand, Golberg, op.cit., p.104

[28] Ibid., p.104

[29] ibid., p.100

[30] ibid., p.106

[31] ibid., p.107

[32] ibid., p.82

[33] ibid., p.86

[34] Theme for the Lisbon Expo' 1998, Architecture and water, Academy Group Ltd., 1995, p.83

[35] ibid., p.27

[36] ibid., p.34

[37] ibid., p.34

[38] ibid., p.27

[39] ibid., p34

[40] Tange, Kenzo, A Plan for Tokyo, The Japan Architect, 1987, p.8

[41] ibid., p.49

[42] ibid., p.56

[43] ibid., p.51

[44] Stapleton, C.M, op.cit., p.41

[45] Pawley, Martin, Buckminster Fuller, Trefoil Publications Ltd, 1990, p.148

[46] ibid., p.156

[47] Fuller, Buckminster., Marks, Robert., The Dymaxion World of Buckminster Fuller, Anchor Books Edition, 1973, p.233

[48] ibid., p.231

[49] ibid., p.110

[50] ibid., p.231

[51] Pawley, Martin, op.cit., p.155

[52] Pilkington Glass Age Development Committee, Previous Projects, February 28, 1968, p.1

[53] Building A City in the Ocean (by a Pilkington Correspondent), The Futurist, Vol.3, 1969, p.66

[54] ibid., p.68

[55] ibid., p.66

[56] Foster, Norman, Architecture As Building, Sir Norman Foster and Partners Publications, 1993, p.79

[57] Foster, Norman, Norman Foster, E and FN Spon 1995, p.138

[58] ibid., p.138

[59] ibid., p.139

[60] Betsky, Aaron, Take Me to the Water, Architecture and Water, Academy Group Ltd., 1995, p.9

[61] Battle and McCarthy, op.cit., p.3

[62] Ince, Martin, The Rising Seas, Earthscan Publications Ltd., London, 1990, p.84

[63] Gazzard, Kubik, Price, Storey, Winch, North Sea Settlement, Northern Architect, 1966, p.632

[64] Building a City in the Ocean (by a Pilkington correspondent), The Futurist, Vol.3, No.3, 1969, p.66

[65] Glass Age News, op.cit., p.7

[66] ibid., p.7

[67] Gazzard, Kubik, Price, Storey, Winch, op.cit., p.640

[68] ibid., p.7

[69] ibid., p.639

[70] Glass Age News, op.cit., p.24

[71] Gazzard, Kubik, Price, Storey, Winch, op.cit., p.629

[72] Glass Age News, op.cit., p.18

[73] ibid., p18

[74] Nature Tourism: Managing for the Environment, Island Press, 1991

[75] Gazard, Kubik, Price, Storey, Winch, op.cit., p 641

[76] Jane's High Speed Marine Transportation (Edited by Stephen J. Phillips), Jane's Information Group, Surrey, 1997, p3

[77] ibid., p 4

[78] Marks, Wilbur., Skirkanich, Robert., Ocean Platforms: Extending Man's domain into the Seas, Habitats Tomorrow, World Future Society, U.S.A, 1984, p 156

[79] ibid., p 156

[80] Gazard, Kubik, Price, Storey, Winch, op.cit., p 643

[81] Marks, Wilbur., Skirkanich, Robert., op.cit., p 153

Bibliography

Fletcher, Sir Banister, A History of Architecture, Architectural Press, Oxford, 1996.

Foster, Norman, Architecture As Building, Sir Norman Foster and Partners Publications, 1993.

Fuller, Buckminster., Marks, Robert., The Dymaxion World of Buckminster Fuller, Anchor Books Edition, Illinois, 1973.

The Futurist, Vol. 3, No.3, 1969.

Gazzard, Kubik, Price, Storey, Winch, North Sea Settlement, Northern Architect, 1966.

Geuze, Adrian., Adrian Geuze/West 8: Landscape Architecture, Uitgeverij 010, Rotterdam, 1995.

Glass Age News, Pilkington Brothers Ltd., 1968.

Government Actuary, National population Projections, 1994.

Institute of Terrestrial Ecology, Climatic Change, Rising Sea Level and the British Coast, Department of the Environment, 1989.

Jane's High Speed Marine Transportation (Edited by S. J. Phillips), Jane's Information Group, Surrey, 1997.

The Japan Architect, A Plan for Tokyo, 1987.

Jellicoe, Susan and Geoffrey, Water: The Use of Water in Landscape Architecture, A & C Black Ltd. London, 1971.

Kuroyanagi, Akio, Composition of Oceanic Architecture, Process Architecture Co. Tokyo, 1991.

Marks, Wibur., Skirkanich, Robert., Ocean Platforms: Extending Man's Domain into the Seas, Habitats Tomorrow, World Future Society, U.S.A, 1984

Melling, David, Global Designers.....Guilt-ridden Regionalism, Architecture New Zealand, Jul./Aug., 1993, pp92-93.

Moore, Charles W. & Liz, Jane, Water and Architecture, Thames and Hudson, London, 1994.

Nature Tourism: Managing for the Environment, Island Press, 1991.

Parkes, Carl, South-east Asia Handbook, Moon Publications Inc., U.S.A, 1994.

Pawley, Martin, Buckminster Fuller, Trefoil Publications Ltd., London, 1990.

Pethick, John and Burd, Fiona, Coastal Defence and the Environment - a guide to good practice, Ministry of Agriculture Fisheries and Food, 1993

Russell, Delvin, A Tale of Two Conferences: 'A Celebration of Architecture' and 'Gone to Kiwi', Home and Building, Aug./Sept., 1983, pp48-50.

S.I.A.J, The Contemporary Kampong, 1989.

Stapleton, C.M, Humber Estuary & Coast, Humberside County Council, 1994.

Stoilov, Georgi and Stanishev, Kiyonori Kikutake, World Architecture, Cheerman Ltd. 1993, pp26-48.

Submarine Odyssey, Architecture Today, June 9, 1990, pp38-43.

Tange, Kenzo (and others), Tokyo Transformation, Japan Architect, Nov./Dec., 1987.

Toy, Maggie (and others), Architecture & Water, Architectural Design: Academy Group Ltd. London, 1994.

Treiber, Daniel, Norman Foster, E and FN Spon, London, 1995.

Whyte, Ian D, Climatic Change and Human Society, Hodder Headline P.L.C, London, 1995.

Wylson, Anthony, Aquatecture: Architecture and Water, Architectural Press Ltd., London, 1986.