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GARDENS,

PARKS

AND

GREEN

RESERVES

Dating well back into the colonial period, Singapore began to make a mark in the botanical, horticultural and wildlife worlds. This came by way of both its natural circumstances, including those that survived the onslaught of plantation and other less than discriminating agricultural practices and in the form of its magnificent Botanic Gardens and other related curatorial activities. Biodiversity is also a hallmark of Singapore's environment, although it was significantly depleted during the colonial era of land exploitation. In the shift that has occurred towards a 'city with or in nature', significant aspects of Singapore's plant and wildlife attributes have been pushed further into service. This shift also appears to expert opinion to be closer to a truer natural state of existence than earlier garden-like interpretations, even though the appropriation of whole-hearted public support might be more difficult to secure. Depending upon the eye of the beholder, it certainly seems true that butterflies are more beautiful than caterpillars, but, of course, without the latter you will not have the former. More prosaically, the greening of roadway verges, public parks and so on, thrive better under mixed rather than mono-cultural species conditions. Also the scale of vegetation involved can be and often is very mature and large, more in keeping with the primeval tropical antecedent conditions and so-called 'nature' of Singapore. For this to be sustained successfully, risks from events like falling branches and uprooted trees must be avoided almost at all costs in Singapore's current socio-cultural environment. Consequently

the National Parks Board has begun engaging in high-tech data applications to these environments. Finite element analysis, for example, usually deployed on building structures is now routinely applied to large trees to help predict branch failures and to monitor trimming and other maintenance functions. Similar data rich scrutiny of ways of improving biodiversity and wildlife habitat are under way, including fluid dynamic modeling of water ways, especially in vulnerable coastal areas. The PUB's ABC Waters approach to public parks, like the Kallang River at Bishan-Ang Mo Kio Park, and to drainage canals, like the Alexandra Canal, are aimed squarely at closer integration of a more 'natural' agenda of greening and conservation than the earlier strictly structural solutions to conditions like storm water management. A more complete embrace of local tropical landscapes, however, remains to come. Other significant projects, like 'Gardens by the Bay,' while attracting substantial local and tourist attention, also thrusts the curatorial program of botanical activities into the twenty-first century. The remarkable hybridization and DNA protocols of researchers at the Singapore Botanic Gardens also extends Singapore's reach into the forefront of tropical plant life and ecology, as does the literal greening of buildings that has sprouted forth in the last decade or so. These mergers of science, technology and active urban environmental management are unique and, again, appear to be potentially transferable elsewhere. Over time, Singapore appears to be moving towards a distinctly biophilic outcome.

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## BOTANIC AND HORTICULTURAL GARDENS

Specific types of gardens have existed in human history for many years. In the western ecumen, for instance, this interest by the ancient Romans first started to focus on the medicinal properties and later, around the eighth century, monks brought this interest forth in their monastic gardens.<sup>1</sup> The rise of the botanic garden, however, began with the sixteenth-century Italian university gardens, such as the very first in Europe at the Università di Pisa, founded in 1543 by Luca Ghini both a physician and a botanist. By the mid-eighteenth century and later, the botanic garden was essentially a museum of living plants. Like other kinds of museums it had a double function.<sup>2</sup> It was a place where plants could be studied by experts for the furtherance of scientific knowledge and a place where exhibits could be arranged for the education and recreation and enjoyment of non-experts. At much the same time international trade propelled imperial powers to bring newly discovered tropical species to Europe and to cultivate them both in the homeland and in their natural environment. Established in 1859, Singapore Botanic Gardens served as a park for Singaporeans and visitors, a scientific institution and as a testing ground for tropical plantation crops. The first of these functions was mainly for the Singaporean elite at the time. In the 1800s it was a centre for research and plant conservation with a focus on economic botany that had direct repercussions, as pointed out earlier, on Malaya and Singapore. Also, among other characteristics, the Botanic Gardens was the largest intact historically-designed landscape in Singapore. It is also among the most visited botanic gardens in the world, hosting

as many as four million visitors in 2013. Then, the Singapore Botanic Gardens was inscribed as a UNESCO World Heritage Site on 4 July 2015 at the 39th session of the World Heritage Committee, the very first of its kind in the island nation.

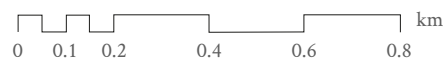


### 59. SINGAPORE BOTANIC GARDENS

Historically, after being founded in 1859 on a site at Tanglin, at least partly under the banner of the Gardens of the Agri-Horticultural Society of Singapore, Lawrence Niven was engaged in 1860 to develop the 23 or so hectare property as a garden.<sup>3</sup> This he did in the manner of the English Landscape Movement and of 'Capability' Lancelot Brown, and by 1864 a system of roads and footpaths was in place. Then, in 1866, the Society's finances permitted expansion to the northwest, including the Swan Lake. However, having suffered substantial cost overruns during the construction of a Superintendent's house, the Agri-Horticultural Society appealed in 1874 to the government for relief. Henry James Murton was then appointed in 1875 as the Gardens Superintendent, with the assistance of

the Royal Botanic Gardens at Kew in Great Britain. Collecting plant materials from Malaya and Sri-Lanka, among other places, he turned the gardens into a more typical botanic garden with a focus on plants of economic interest. In 1879, for instance, he oversaw the construction of the spectacular 'Palm Valley'. He also established a zoological collection that

was terminated in 1904. Nathaniel Cantley succeeded Murton in 1880 and who set about to rationalize buildings within the gardens. A herbarium was built, for instance, in 1882 and nurseries for plant trees was established. Both Murton and Cantley were trained at Kew. An avid botanist Cantley also placed the Gardens on a firm systematic footing.



- |                     |                  |                      |
|---------------------|------------------|----------------------|
| 1. Raffles Building | 5. Swan Lake     | 9. Rochor River      |
| 2. Bukit Timah Gate | 6. Symphony Lake | 10. Bukit Timah Road |
| 3. Tanglin Gate     | 7. Eco Lake      | 11. Holland Road     |
| 4. Botany Centre    | 8. Forested Area |                      |

## 60. PLAN OF THE SINGAPORE BOTANIC GARDENS

Henry Nicholas Ridley took over from Cantley in 1897, becoming the Garden's first 'Director' and making it a regional centre for understanding the flora of Southeast Asia, a position it retains today.<sup>4</sup> Ridley's interests were broad, encompassing zoology, geology and botany with a special interest in the latter category for orchids. Coming from the National History Museum in London, he launched the first scientific agricultural journal in the region – The Bulletin of the Malay Peninsula – and became involved, as noted earlier, in rubber plant development and cultivation. Issac Henry Bukhill took over from Ridley in 1912 and saw the Gardens through a critical transition period from British rule to part of Malaya. Much later during the Fourth World Orchid Conference in 1963 held for the first time in Singapore, he delivered a paper on Singapore's role in hybrid propagation. Richard Eric Holttum succeeded Bukhill in 1925. He was a

scientist and emphasized horticulture with orchids as a focus.<sup>5</sup> As early as 1928 he set up an *in vitro* propagation unit, which from the 1930s onwards began to see the merits of this approach, resulting in 1956 with the beginnings of the Gardens VIP Orchid Nursery Program. Certainly by the mid -1950s the Gardens was known globally for orchid propagation. Today staff's interest and work in genetic aspects of plants and DNA sequencing for plant identification are prominent areas of expertise.<sup>6</sup>

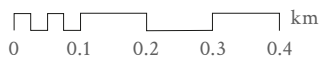
During the Japanese occupation from 1942 to 1945, Hidezo Tamakadate and Kwan Koriba were Directors of the Gardens. After the war Murray Hudson Ross, curator of the herbarium before the war, took over. Eventually the Gardens then played an important role during the greening of Singapore described earlier, and being taken over by the National Parks Board in 1986. During the 1970s the Botanic Gardens



61. SINGAPORE BOTANIC GARDENS

also assumed the role of a public park, now 65 hectares in area.<sup>7</sup> Today's Gardens are divided into three main cores: Tanglin, Central and Bukit Timah. The heritage portions are located in Tanglin; the tourist belt is located in the central area, including the Orchid Garden, the Healing Garden and the Fragrance Garden. The Eco-Lake and Foliage Garden are at Bukit Timah, which is an educational and discovery zone. One of

the most, if not the most, important centres of taxonomic and biodiversity research in the region, in 2014 the Gardens had 36,400 living plant accessions, 6,500 species and 44 heritage trees, a herbarium of 750,000 species of which 8,000 are typical specimens. In addition there is a library of over 28,500 books, journals and unpublished data.<sup>8</sup>



- |                   |                         |                     |   |
|-------------------|-------------------------|---------------------|---|
| 1. Flower Dome    | 6. Colonial Garden      | 11. Web of Life     | 15. Bay East Garden:<br>Planned Location of<br>the Founder's Garden |
| 2. Cloud Forest   | 7. Secret Life of Trees | 12. Discovery       | 16. Marina Barrage  |
| 3. Malay Garden   | 8. World of Palms       | 13. Supertree Grove | 17. Marina Bay Sands  |
| 4. Chinese Garden | 9. Understorey          | 14. Golden Garden   |   |
| 5. Indian Garden  | 10. Fruits and Flowers  |                     |   |

## 6.2. PLAN OF GARDENS BY THE BAY

The second extraordinary botanical and horticultural contribution by Singapore is the Gardens by the Bay project, first announced in 2005 by then Prime Minister Lee Hsien Loong on its 101 hectare site adjacent to the Marina Reservoir in central Singapore. It was the subject of an international competition in 2006 won by Grant Associates for the Bay South Garden and Dominic White for the Bay East Garden. The third garden – the Bay Central Garden – is a link between the other two gardens. A central and prominent feature of the Gardens by the Bay is the two conservatories beside the Marina Reservoir.<sup>9</sup> Both were designed by William Eyre to be energy efficient. The Flower Dome is the larger of the two and sits on a 1.2 hectare site and rises 38 meters. It is the largest column-less greenhouse in the world and maintains an interior atmosphere of between 23 and 25 degrees centigrade, replicating a mild dry climate and featuring plants found in

the Mediterranean area, as well as in semi-arid and tropical regions like Australia, South America and South Africa. It is comprised of seven different gardens which also merge together in unique ways as a singular display across a sloping topography.<sup>10</sup> The Cloud Forest is the second conservatory. It occupies a 0.8 hectare site and rises to enclose a 42 meter tall cloud mountain, accessible by elevator and covered in epiphytes such as: orchids, ferns, mosses and ormeleads. An exterior catwalk allows visitors to descend around the mountain's edge to the lower entry level. In addition, another prominent constructed feature is the super-trees that are from 25 to 50 meters in height.<sup>11</sup> They are outfitted with environmental technologies, like photo-voltaic cell and rainwater devices, which allow them to mimic ecological functions. They are also environmental engines for the gardens, having hot air evacuation units and methods of cooling water.



63. THE FLOWER DOME OF GARDENS BY THE BAY



64. THE CLOUD FOREST OF GARDENS BY THE BAY



65. THE SUPERTREES OF GARDENS BY THE BAY

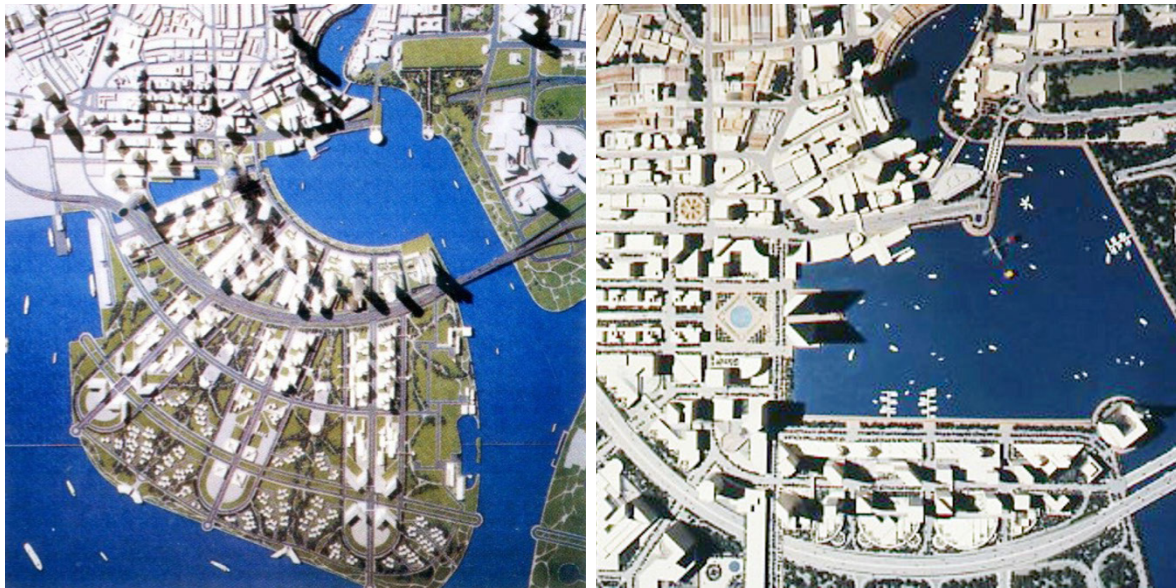




66. GENERAL VIEWS OF GARDENS BY THE BAY

The overall site is further comprised of roads and pathways defining varying horticultural domains, ranging from open meadows to dense forested areas. Part of this arrangement are the heritage gardens under the 'Plants and People' theme, representing plants from Chinese, Malay and Indian circumstances. The other larger part is under the 'Plants to Plant' theme and displays connections and relationships involving plant diversity. The entire ensemble is replete with rocks and other materials gathered on periodic overseas trips by the garden's curatorial staff, as well as several striking sculptures interspersed among the plants and accompanying water bodies. Another area is undergoing development on the eastern side of the Marina Reservoir and across the Barrage emplacement, which will house a Founders' Memorial Garden.<sup>12</sup> The entire complex occupies reclaimed land that lay fallow for 35 or so years. There were early plans for its development. In fact, in 1984 Kenzo Tange and

I.M. Pei were commissioned to propose layouts and designs for a new downtown on 266 hectares of the Marina South site. Tange, taking up the greening vision of Singapore proposed a radial scheme of intense development separated by swaths of green areas, drawing on the character of Singapore as a tropical island. Pei proposed a grid model that was integrated with the existing Central Business District. This facilitated the sales of land parcels incrementally. Commissioned at the behest of Lee Kuan Yew, the government adopted Pei's model which shaped the subsequent concepts of Marina Bay development.<sup>13</sup> Finally, the Gardens by the Bay was opened in 2012, attracting some 6.4 million visitors in 2014. It was built with budget and operations for around \$58 million per year. It is without doubt one of the most extraordinary botanical installations in the world and chiefly the brainchild of the congenial and brilliant Dr. Tan Wee Kiat, an eminent plant expert, especially with regard to orchids.



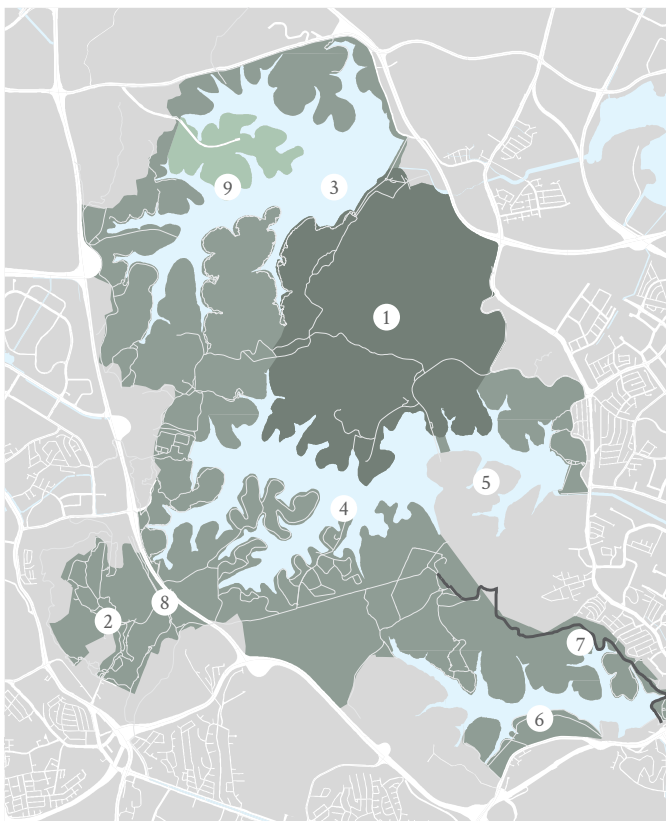
67. MARINA SOUTH STUDY 1983, BY KENZO TANGE (LEFT) AND I.M. PEI (RIGHT)

b.

## NATURE RESERVES

As described earlier, during the last third of the nineteenth century, following on the heels of extensive deforestation for agricultural purposes, the extent and scope of mature species and forest trees came under scrutiny with the McNair Report of 1879. This was followed in 1884 with the creation of the Forestry Department in order to conserve remaining forested assets on the island, totaling, as noted earlier, around eight percent of Singapore's total area. The Municipal Catchment Reserve was established in 1900, along

with several other reserves at Bukit Timah and some mangrove reserves, especially the Pandan Forest Reserve. Within reserves, reservoirs were constructed as noted in order to serve expanding population growth. MacRitchie was created in 1867, Kallang in 1911, and Sungei Seletar in 1922 with expansions in 1967 and 1969. Generally, early colonial administration of Singapore had little land management. Unfortunately, in the end, natural reserves of dryland primary forest amounts to only 0.5 percent of its original area.<sup>14</sup>



1. Nee Soon Swamp Forest
2. Bukit Timah
3. Upper Seletar Reservoir
4. Upper Pierce Reservoir
5. Lower Pierce Reservoir
6. Macritchie Reservoir
7. Treetop Walk (suspension bridge)
8. Eco-Link
9. Zoo

0 0.6 1.2 1.8 2.4 km

### 68. THE CENTRAL CATCHMENT AND THE BUKIT TIMAH NATURE RESERVES

Among Singapore's four major nature reserves there is the Central Catchment Nature Reserve, the Bukit Timah Nature Reserve, the Sungei Buloh Wetland Reserve and the Labrador Nature Reserve.<sup>15</sup> The Central Catchment Nature Reserve is the largest, spanning 2800 hectares in area and acting as a large green lung in the centre of Singapore. Indeed, it is an area ringed by the 1971 Concept Plan and is home to patches of dipterocarp forests, the species of rich primary lowland forest that was once characteristic of the island. It also hosts the rarer primary freshwater swamp forest, such as the Nee Soon Swamp Forest. The Central Catchment is the major one of only two such catchments, earning its name from housing the MacRitchie, Upper Seletar, Upper Pierce and Lower Pierce Reservoirs. A primary site for hunting, bird and nature watching, the MacRitchie Reservoir area, for instance, comprises

20 kilometers of trails and boardwalks. There is also the spectacular 250 meter long suspension bridge and observation tower, offering unrivaled high-level views of the forested area. These days the Central Catchment Nature Reserve is linked across the Bukit Timah Expressway by the Eco-Link@BKE to Bukit Timah.<sup>16</sup> This link is the first of its kind in Southeast Asia and aims to restore ecological connection between the two adjacent nature reserves, allowing some wildlife to expand their natural genetic pool and survival chances. The two reserves combined comprise some 840 or more species of flowering plants and some 500 species of fauna. The eco-link is hour-shaped in plan with trees and shrubs planted on the bridge. A wire mesh fence across the Central Catchment side of the link discourages larger animal species access to the much smaller habitat of the Bukit Timah Nature Reserve.<sup>17</sup>



69. THE ECO-LINK @ BUKIT TIMAH EXPRESSWAY



#### 70. THE TREETOP WALK AND SUSPENSION BRIDGE IN THE CENTRAL CATCHMENT NATURE RESERVE

The Bukit Timah Nature Reserve is located 12 kilometers from the centre of urban Singapore and is a very rich and diverse ecological system.<sup>18</sup> It is about 164 hectares in area and the highest point in Singapore at 163.63 meters above sea level. Originally established in 1883 it is one of the very few areas of primary rainforest in the country. It has also been a botanical collection area for over 100 years and is reputed to have approximately 40 percent of the nation's flora and fauna.<sup>19</sup> 1951 saw island-wide enactment of a Nature Reserves Ordinance, along with establishment of a Nature Reserves Board to manage these areas. In 1990 both the Central Catchment Nature Reserve and the Bukit Timah Nature Reserve were gazetted for propagation, protection, and preservation of Singapore's flora and fauna. This was also reinforced by the Parks and Trees Act of 2005. Then, Sungei Buloh Wetland Reserve was declared an ASEAN Heritage Park in

2003, followed by Bukit Timah Nature Reserve which was declared in 2011. They both became part of the prestigious network of 35 protected areas within the ASEAN member states. Like the Central Catchment Nature Reserve, Bukit Timah Nature Reserve plays host to trekking, mountain biking and, consequently, falls under Singapore's rules of trail etiquette.

The two smaller reserves are the Sungei Buloh Wetland Reserve at 130 hectares in area and the Labrador Nature Reserve at ten hectares in area.<sup>20</sup> The Sungei Buloh Wetland Reserve is located in the northwest of the island and was gazetted as a nature reserve in 2002. As mentioned earlier, it is replete with a rich ecology of plant and animal life. The Labrador Nature Reserve, by contrast, is located on the southern edge of the island, facing out to sea and is part of the Southern Ridges built on the edge

of a secondary forest with cliff-side vegetation and picturesque views. It was also gazetted in 2002 as a nature reserve. The Southern Ridges is a topographically interesting area of Singapore comprising Mount Faber Park, Telok Blangah Hill Park, and Kent Ridge Park. Collectively, the four

nature reserves make up most of the natural vegetated landscape in Singapore, along with the most numerous and diverse species of flora and fauna. When the metaphor of a 'City in Nature' is used it generally refers to this kind of landscape and aesthetic.



71. THE SUNGEI BULOH WETLAND RESERVE



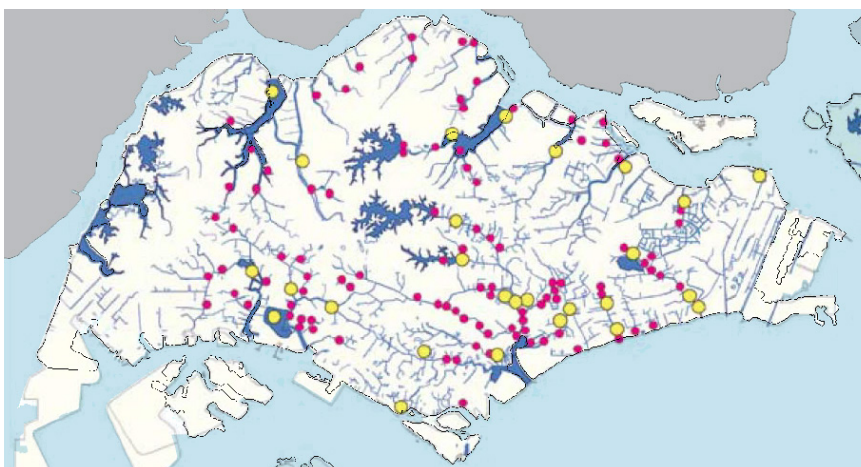
72. LABRADOR NATURE RESERVE

C .

## THE ACTIVE, BEAUTIFUL, CLEAN WATERS PROGRAMME

The Active, Beautiful, Clean Waters (ABC Waters) Program was implemented in 2006 as a part of Singapore's storm-water management strategy and reflects the nation's move towards 'blue-green' sensitive urbanization through the adoption of a low-impact development ideology and practices.<sup>21</sup> In this manner the ABC Waters Programme seeks to transform the utilitarian drains, canals and reservoirs, which have served the island from colonial days onwards into beautiful and clean waterscapes which are seamlessly integrated into adjacent developments and provide a host of recreational activities. Part of the PUB Singapore's National Water Agency's larger strategy is also to bring people close to the water so that they can better appreciate it. The city's blue map comprises seventeen reservoirs, 32 major rivers and more than 8,000 kilometers of canals and drains. Over 100 locations have been identified for ABC Waters projects to be implemented in phases by 2030. By

2017, over 36 projects have been completed by PUB as well as another 62 projects by other public agencies and by developers. The accompanying map shows the location of many of the projects. First initiated by the Water-bodies Design Panel led by the URA in 1989, and later formalised by PUB, the blue plan has been eventually incorporated into Singapore's Masterplan, forming an environmental overlay called the Parks and Waterbodies Plan. The Parks and Waterbodies Plan features a pervasive network of parks, open spaces, water bodies and connectors among them. With approximately two-thirds of Singapore's surface area designated as water catchment, it is important to ensure that runoff draining into its canals and reservoirs is well managed with regard to quantity and quality. On the other hand, besides water catchment and conservation *per se*. The PUB's ABC Waters Programme is a strong component of their effort to have Singaporeans take ownership and become stewards of the nation's water resources.



73. MAP OF THE ABC WATERS PROGRAMME PROJECTS

More technically, the PUB's ABC Waters Programme's approach to storm-water management embraces three broad conceptual domains. The first is the treatment of storm-water runoff using low-impact development approaches.<sup>22</sup> There, the underlying principle is to return the pre-development flow regime to an urban site and to remove storm-water pollutants by adopting ideas of catching storm-water at its origin, using simple methods, creating multi-functional landscapes and returning to natural hydrologic processes. In so doing the aim is to integrate waterways with the urban landscape and to provide a more livable and sustainable environment. This also includes accommodating flash floods adequately such as those that occurred in 2010 and 2011. In Singapore with around 2,400 mm of rainfall per annum and something like 178 rain days per year, rainfall and storm-water management is a non-trivial undertaking. Moreover, as stated throughout this book, water is also regarded as something of a precious resource. Absent this attitude Singapore would be classified as being water scarce, and ranked 140th out of 170 nations in one account of this scarcity. The second conceptual domain is the use of a source-pathway-receptor approach to storm-water management, whereby treatment starts at the origin of storm-water. The pathway component involves the traditional array of parks, canals, and

drainage ditches, and receptors are comprised of flood basins and outflows where the aim is to cope with rainfall events that exceed general drainage network expectations. The third and final domain is the implementation of the ABC Waters Programme. For the ABC Waters Programme the Active (A) aspect involves new community spaces around water bodies. The Beautiful (B) part is for vibrant and aesthetically pleasing spaces, and the Clean (C) component is to improve water quality and to educate the public about the need to reduce water pollution. Drawing heavily on the Australian 'Water Sensitive Urban Design Framework', the Board's 'Engineering Procedures for ABC Waters Design Features', published in 2009 and 2011, for instance, provides extensive documentation about best management practices, local performance results and other forms of technical data. It covers, for example, at least six kinds of practices. They are: sedimentation basins, swales, bio-retention swales, bio-retention basins and rain gardens, constructed wetlands, and infiltration systems. It also deals with various aspects of such practices concerned with sizing, location, media and plant selection. Indeed, one summary account and evaluation gave high praise for the use of low-impact development practices in the ABC Waters Programme, with regard to the 'Active' and 'Beautiful' components, but less clearly with regard to the 'Clean' component.



74. KALLANG RIVER AT BISHAN-ANG MO KIO PARK



Among completed projects, several stand out for their relative success or demonstration of the range of undertakings within the ABC Waters Programme. One of the largest and most ambitious was the Kallang River Project, which converted a concrete, structural storm-water conveyance into a scenic river by essentially making room for the river and use of low-impact development practices. Within this scheme of the Kallang channel, the Bishan-Ang Mo Kio Park deserves particular attention and comment.<sup>23</sup> Carried out by the Atelier Dreisetl, the Bishan-Ang Mo Kio Park is one of the most popular parks in the heartland of Singapore. It occupies a 62 hectare site that once incorporated concrete-lined Kallang channel, running beside the Bishan Township. Remodeling of the landscape involved converting the 2.7 kilometer long straight channel into a 3.2 kilometer long sinuous river, with natural characteristics and planting, meandering through the overall space with fluctuating water levels and ample spaces and facilities for park users. These include three playgrounds, restaurants and a new vantage point constructed from the material of the old channel. Ecological treatment of the water's edge and inclusion of appropriate planting also help to cleanse the storm-water. The return of wildlife and birdlife to the park also adds to its success. One disappointment might be found in the planting scheme which does not resonate as much as it might with tropical vegetation and general milieu. Another prominent project, also concerned with channel drainage is the Alexandra Canal, a 1.2 kilometer stretch through a dense urban area. Transformed in 2011, with CH2M Hill as the consultant, the canal now has softened banks, with a stretch decked over to create an interesting cascade and water play area.<sup>24</sup> Located in conjunction with the deck are a series of wetlands that engage in public learning regarding water cleansing and bio-remediation.



#### 75. ALEXANDRA CANAL

Improvement has also been made to the venerable MacRitchie Reservoir within the Central Catchment area of Singapore. Primarily these improvements arising from the ABC Waters Programme have focused on the visitor experience and use of the reservoir. An amenity centre and structured car park have been added, along with floating pontoons for kayakers. There is also now a food and beverage outlet, prominently located on one of the hills, as well as a submerged boardwalk along which visitors can experience walking in and on water. Allowance of visitors and recreational uses within the reservoir preserve itself is a break with the past and a testament to the viability of Singapore's closed loop and treatment of its water system. A relatively

new reservoir of water area is the Punggol Reservoir and particularly its Sengkang Floating Wetland installation. A primary feature at Punggol is the 'My Waterway at Punggol' that traverses the site through its town centre. The floating wetland helps to improve water quality and provides a good natural habitat for birds and fish. A boardwalk brings people close to the water so that they can observe and learn about wetland ecosystems. The wetland also provides a seamless connection between and among the clubs, sports places and parks of this new development. Some issues have emerged in the context of the ABC Waters Programme projects, critical of its operations and management. These include a certain rigidity in mindset within a comfort zone of practice and something of a fear to try even more unconventional ideas, as well as a lack of co-ordination between

agencies and projects.<sup>25</sup> Transferability to other locales in tropical and semi-tropical regions seems feasible for several reasons. First, the current ABC Waters Guidelines are more adaptable and applicable than guidelines taken from temperate areas where low-impact development practices first started due to similarities in climate. Second, bio-retention systems and rain gardens are the most suitable low-impact features to use, that may also be adaptable and appropriate to other tropical urban areas which are hemmed in by topography or urbanization. Third, the clarity and extensiveness of low-impact development guidelines can be a boon to followers in other tropical and semi-topical settings.<sup>26</sup> Finally, Singapore's experience with the public in the success of the ABC Waters Programme merits careful consideration and adoption by others.



76. MACRITCHIE RESERVOIR



77. NATURE WAY ALONG PASIR RIS DRIVE 3

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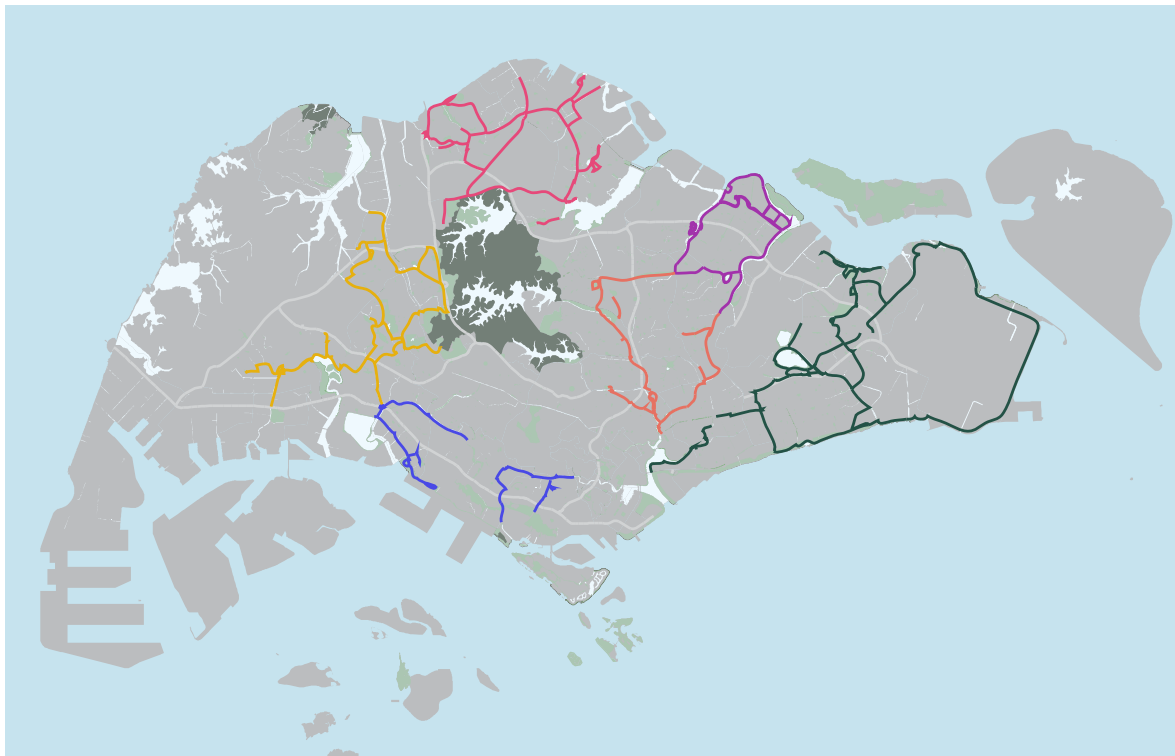
## PARK AND OTHER CONNECTORS

In 2002 Singapore launched its 'Streetscape Greenery Masterplan', emphasizing greater variety and improved scenic quality as well as identity for roadway landscapes.<sup>27</sup> In all there were five specific landscape treatments. They were: parkway treatments, gateway treatments, coastal treatments, forest treatments, and rural treatments. These were guided, in turn, by four design principles. They were: connectivity and convenience, luxuriousness of landscaping, landscapes enriched with elements of nature, and emphasis on quality, variety and creating

a local identity from nearby circumstances or those on hand. In addition Singapore's heritage in trees and landscapes were also safeguarded as a part of the program, with heritage trees woven into the street landscapes. In fact, heritage trees became landmarked in 2001. Earlier on Singapore's 'Park Connector Network' started on the heels of the 'Park Linkage Program' of 1989. This Program aimed to use canals and open spaces of residential estates to link major parks like, for instance, the five kilometer-long Kallang River park connector. Then in 1991 the 'Park

Connector Program' was approved by the venerable Garden City Action Committee that had been in place since the late 1960s within the Ministry of National Development to ensure Garden City policies and implementation was coordinated appropriately across agencies involved. The park connector idea was also incorporated in the 1991 Concept Plan for Singapore. Materially, the park connector network optimized public open space and created value in several ways. These included: double use of road reserves;

covered drains; conversion of drains into landscaped pathways; and the use of wider linear parks and green corridors and separators, like Bishan Park. Quickly park connectors became integral to creation of a 'City in a Garden' concept, communicated in, for instance, the 'Parks and Waterbodies Plan' of the Urban Development Authority and National Parks of 2002. By the end of 2009, fully 103 kilometers of park connectors had been completed, on the way to an eventual 350, or so, kilometers.<sup>28</sup>



- Central Urban Loop
- Eastern Coastal Loop
- Northern Explorer Loop
- North Eastern Riverine Loop
- Southern Ridges Loop
- Western Adventure Loop



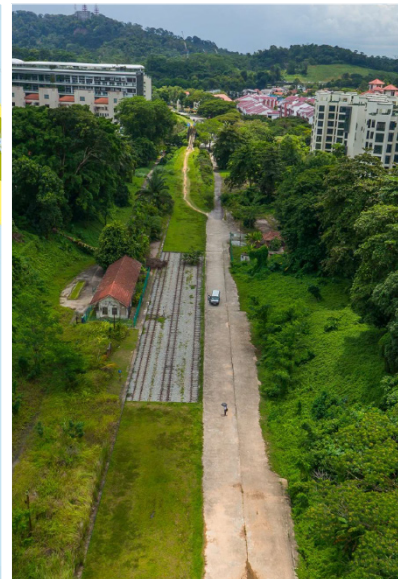
## 78. THE GREEN PARKWAY CORRIDOR PLAN

One of the most prominent green connector projects is the 'Rail Corridor' to be developed over the former railway line connecting Singapore to Malaysia. The railway which was operated by Keretapi Tanah Melayu (KTM) was originally constructed between 1903 and 1932 to transport rubber and tin from

the Malay Peninsula for export through the port in Singapore. On 1 July 2011 the railway ceased operations and the railway lands reverted back to the Singapore Government.<sup>29</sup> For most of its life the railway corridor was a barrier running through the centre of Singapore Island. In re-purposing

it as a green corridor it was now to be seen as a connector and much more of an inclusive and shared space, as well as a platform for community development and shared experience. In fact, within a one kilometer reach to either side of the corridor some one million Singaporean inhabitants reside, along with a plethora of community facilities, parks and heritage sites, some 58 schools as well as various places of work nearby. Recently, in 2016, a concept masterplan for the 24 kilometers Rail Corridor was awarded to a design team led by Nikken Sekkei following the launch of a Request for Proposal (RFP) internationally. A separate team led by MKPL and Turenscape won the award for re-purposing the former Tanjong Pagar Railway Station, the memorable art deco terminus built in 1932, into a multi-purpose community building. The Tanjong Pagar Railway Station is now a National Monument.<sup>30</sup> Prior to the RFP, an ideas competition called the “Journey of Possibilities” was held to engage members of the general public, students and professionals that resulted in many other wonderfully provocative ideas. Throughout the period of community engagement, the Urban

Redevelopment Authority placed emphasis on co-visioning and co-creating the future of the Rail Corridor with the public. As far as precedents, the corridor draws inspiration from the Promenade Plantée in Paris, constructed in the 1980s and 90s, as well as the Highline in New York City as former railway lines that have been re-purposed into well-loved public spaces. History and conservation of the memory of the rail line will also be incorporated, especially with regard to the re-purposing of the railway stations at Bukit Timah and Tanjong Pagar into community buildings. Also other remaining artifacts, like the cast-iron bridges, will also be conserved and protected during the project. To be eventually developed in segments, the project has a total area of about 100 hectares over a length of about 24km, which is substantial for a connector and community space.<sup>31</sup> The Rail Corridor when completed will be connected to the network of island-wide park connectors and the round-island route, hence ensuring that this centrally located Rail Corridor will be easily accessible from all corners of the island.



## 79. THE RAILWAY CORRIDOR PROJECT

e.

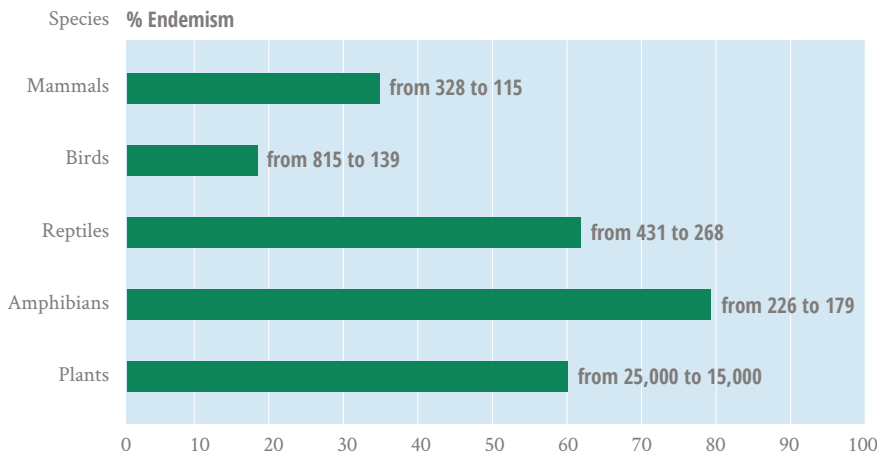
## THEMES AND MANAGEMENT CONSIDERATIONS

Urban greenery has recently gained popularity as an adaption and mitigation measure. Many city governments have adopted policies promoting tree-planting, preservation of urban green spaces and, more recently, green architecture. The potential benefits and services provided by greenery to the urban ecosystem include: reduction of greenhouse gas emissions, thermal comfort, improved air quality, energy-use reduction, and so on. From a social perspective

greenery promotes health and a range of recreational and psychological benefits. In the case of Singapore, several themes arise with regard to the island state's greening programs. They include: biodiversity, carbon sequestration, tree modeling and management, green building installation and development, alongside sundry ecosystem studies. What follows is a summary of these activities, contributions and services, as well as an appraisal of Singapore's relative performance.



80A. SUNDALAND



### 80B. ENDEMISM WITHIN SUNDALAND

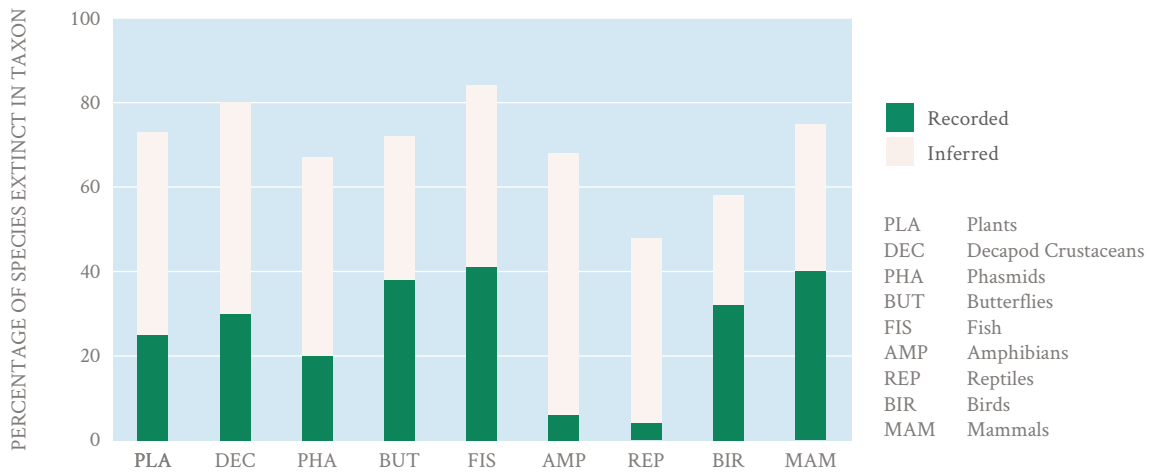
Tropical ecosystems are exceptionally rich and exclusive reservoirs of much of the earth's biodiversity and Singapore is no exception, except for the historically high rate of deforestation that occurred from 1819, as described earlier. Of 25 hotspots of biodiversity in the world, four are in Southeast Asia, although like Singapore, the region could lose as much as 75 percent of its original forests by 2100 and 42 percent of its biodiversity.<sup>32</sup> These four hotspots have been produced over time by the conversion of mountains into islands, producing ideal condition for speciation and with the migration of biota from the mainland of Asia to the archipelago. Of the hotspots Singapore is part of Sundaland, otherwise comprised of a lower part of the Malaysian Peninsular, Sumatra, Java and Borneo. As elsewhere, the rate of extinction is fixed to the endism of the hotspot or to its specific location and place. Recent study showed that endemism in Sundaland was around 35 percent for mammals, eighteen percent for birds, 61 percent for reptiles, 80 percent for amphibians and 60 percent for plants. These numbers are comparable to the other three Southeast Asian hotspots and indicate the precariousness of the resource. Threats to biodiversity, as described here, are largely anthropogenic and made up of forest conversion, forest fires, hunting for bush meat and wildlife trade. Conservation challenges include:

social, scientific and logistical elements. Social aspects are population growth, poverty, shortages of conservation resources and corruption.<sup>33</sup> Scientific elements are neglect of research, low levels of research and publication of results, and logistical elements encompass the diversity of habitat types and numbers and scope of protected areas.

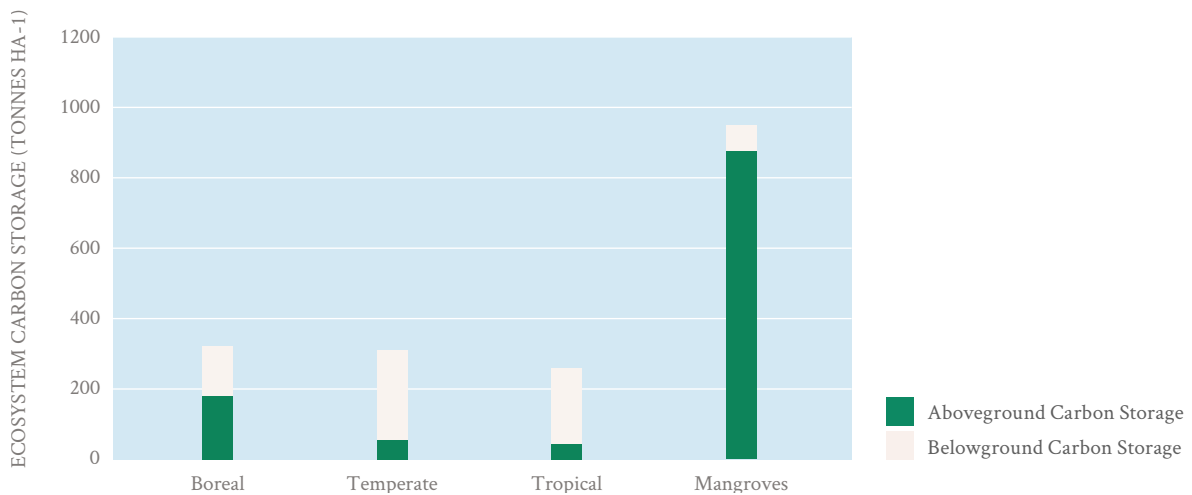
With regard specifically to Singapore, the first reliable species records date from the 1870s, from which inferences of the possible pristine species composition in 1819 have been made. From this exercise extinction rates were variable across taxonomic groups, with the overall loss of species diversity of around 28 percent, or 881 of 3,196 of recorded species.<sup>34</sup> This did not include species that were extinct prior to the 1870s records. In particular, extinction of well-listed taxa was high, at from 34 to 43 percent for butterflies, freshwater fish, birds and mammals. Based on these inferences of biodiversity loss in Singapore, losses in Malaysia, also part of Sundaland, could be as high as 73 percent with 60 percent of habitat. Differing magnitudes of extinction were due to what researchers described as "complex generational scaling effects on long-term population persistence". In other words, larger organisms have more habitat to support viable populations, but live longer. Most extinctions

appear to have occurred among biota related to forest habitats, with 33 percent rates of extinction, compared to seven percent for those species that preferred or tolerated open-forest edge habitats. The predominant cause of Singapore's extinctions were rapid and large-scale habitat destruction initially, followed by urban development. Habitat loss, fragmentation and modification caused extinction by wrecking breeding and feeding sites, increasing predation, soil erosion and thicket loss, as well as dispersal exclusionary edge effects. However, hunting and collecting was also involved. Large

vertebrates, like the Malaysian Tiger, were hunted as menaces to human life and livestock. As noted earlier the last tiger was shot in 1930, of a total of some 99 animals, with 125 losses of human life. Also the shelling of natural preserves during World War II probably had a detrimental effect on forest fauna. In fact, future prospects look bleak for Singapore's surviving biodiversity, according to some experts. Fully 77 percent of the island's species continue to be threatened, based on World Conservation Union regional listing criteria. In short, all existing pools and resources must be protected.



### 8.1. SPECIES EXTINCTION BY TAXONOMIC GROUPS



### 8.2. CARBON SEQUESTRATION BY FOREST TYPE



To date there is little empirical evidence showing the effectiveness of urban vegetation to reduce greenhouse gas emissions or concentrations of airborne pollutants.<sup>35</sup> This includes evidence demonstrating the direct removal of carbon dioxide from the atmosphere by urban vegetation. There are a number of reasons for this, but a complete assessment of the contribution to carbon sequestration by urban greenery needs to consider both the carbon accumulated by trees and by the soil respiration. In other words, contributions from above ground vegetation and underground soil processes. Many studies show, for instance, that recently disturbed ecosystems tend to lose carbon, unlike old-growth forests that usually act as carbon sinks. To date more studies have been made of these phenomena in temperate climatic circumstances, but far fewer in tropical and semi-tropical climes, such as Singapore's tropical rainforest climate. There trees are usually evergreen and, therefore, potential for carbon dioxide assimilation is larger than in boreal and temperate forests. A recent study was undertaken, including the Telok Kurau neighborhood of Singapore. There the major anthropogenic contribution of carbon dioxide came from vehicular traffic, followed by human metabolic respiration, especially given population pressures and density. Data from tests suggested that above ground vegetation sequestered 7.8 percent of the total emitted carbon dioxide. This occurred mainly by photosynthesis. However, the soil or below-ground efflux from the perennially warm and humid soil cancelled out much of the possible carbon uptake, making the biogenic component a net emission source. In other words, carbon dioxide was recycled into the atmosphere and not sequestered. It was further estimated that a forest area 30 to 50 times the area of the city state would be needed to offset the 38,790 Cg of carbon dioxide equivalent, or 97 percent of emissions. Over long

time scales carbon storage will depend on the amount of urban expansion, greenery management and carbon allocation to biomass and organic material. Each year biomass is transferred to the soil and removed from the urban ecosystem through pruning and debris collection. In Singapore, although large trees account for 36.8 percent of all trees they contain 95.3 percent of the biomass and, therefore, carbon. When taking vegetation and soil together the biogenic component was found to add 4.4 percent extra carbon dioxide in the Telok Kurau neighborhood of Singapore. Mangrove forests, however, also to be found in Singapore perform far better overall. In fact, the below-grade soil and dead root pools, which increase in size with age have a very high carbon to mass ratio, relatively speaking.

Part of NParks' conservation strategies is an extensive program of tree monitoring and research. Central to NParks' tree management program is a tree registry system, where trees are individually geocoded, tracked and managed. The tree registry system captures information such as tree height, girth and species, which allows finite-element structural analyses to be performed remotely to determine the stability of the trees. The results of the analyses are used to guide pruning decisions to strengthen the resilience of the trees against strong winds.<sup>36</sup> Finite-element models are more usually used to make computer simulations of buildings and other structures. Few, if any other cities, have deployed such techniques in order to protect the security of people and property around trees, as well as to guide pruning and trimming activities along with general plant management. In addition, all Singapore's trees managed by NParks are subject to regular inspection and pruning, as well as routine maintenance such as fertilizing and mulching. Indeed, Singapore's entire 'green and clean' campaign is supported by this intensity and style of monitoring, data keeping and research.



### 8.3. GREEN WALLS FROM THE SINGAPORE INSTITUTE OF TECHNICAL EDUCATION

The greening of roofs and walls as 'living' roofs and walls has become a relatively prominent feature of Singapore's urban landscape. In fact interest in such 'living' wall and roof installations dates back to the 1960s and 70s. Technically, there are several ways in which green living walls can be provided on buildings and other structures, such as bridges and flyovers.<sup>37</sup> Most common are wall mounted systems, where panels or similar components comprised of vegetation are attached to the outside of walls or structures. There are also free-standing systems, using trellises or frameworks that allow plants to grow up building facades. Then there are also impregnated systems of bio-soil, or similar concoctions, incorporated with conventional wall materials, like impregnated concrete. Wall-mounted systems and free-standing systems allow sufficient depth for deeply-rooted plants and also well-irrigated systems of plants growing up from ground level. The benefits of green living wall and roof systems are numerous. These include: reduced heating needs by adding mass and thermal resistance and

also the reverse with reduced cooling. Reducing or holding storm-water runoff can also occur, alongside of natural habitat creation and a certain capacity to filter air pollutants. Temperature fluctuation reductions can be as much as from 10 to 60 degrees centigrade to from 5 to 30 degrees centigrade.

As of 2017, Singapore had 100 hectares of vegetated roof space, with concerted policy efforts by the NParks and the URA to promote and advance green living walls and roofs in 2009 and 2011 respectively.<sup>38</sup> Introduction of the 'Landscape Replacement Policy' meant that new developments in certain areas were and are required to provide landscaped areas to make up for all greenery and landscape loss on the ground. Consequently a landscaped area equivalent to the area of a development site must be provided for in the form of landscaping at ground level, on sky terraces, mid-levels and roof-top gardens. In fact sky terraces have been encouraged in larger and loftier forms and as communal spaces. Through its 'Skyrise Greenery

Incentive Scheme', NParks agreed to cover 50 percent of installation costs. Prominent among living green buildings in Singapore are two hotels by the local architecture firm of WOHA.<sup>39</sup> One is the Parkroyal on Pickering, on the edge of Chinatown, replete with green roofs, wall elements and façade trellises. The other is the Oasia Hotel Downtown, which is fashioned as a high-rise tower in the form of a trellis wrapping of the overall building shell. Elegantly shaped this red-painted trellis hosts 21 species of

flowering plants, greening up the side elevations towards a partially-enclosed sky terrace with a large mid-level opening and mid-level terrace within the overall volume of the building. In recent years many other buildings have incorporated similar living wall and roof systems. In addition, considerable effort has been given to improve the overall resource demand and residual production efficiencies of buildings, commonly covered in LEED or similar rating systems.



84. PARKROYAL ON PICKERING HOTEL BY WOHA



85. OASIA HOTEL BY WOHA

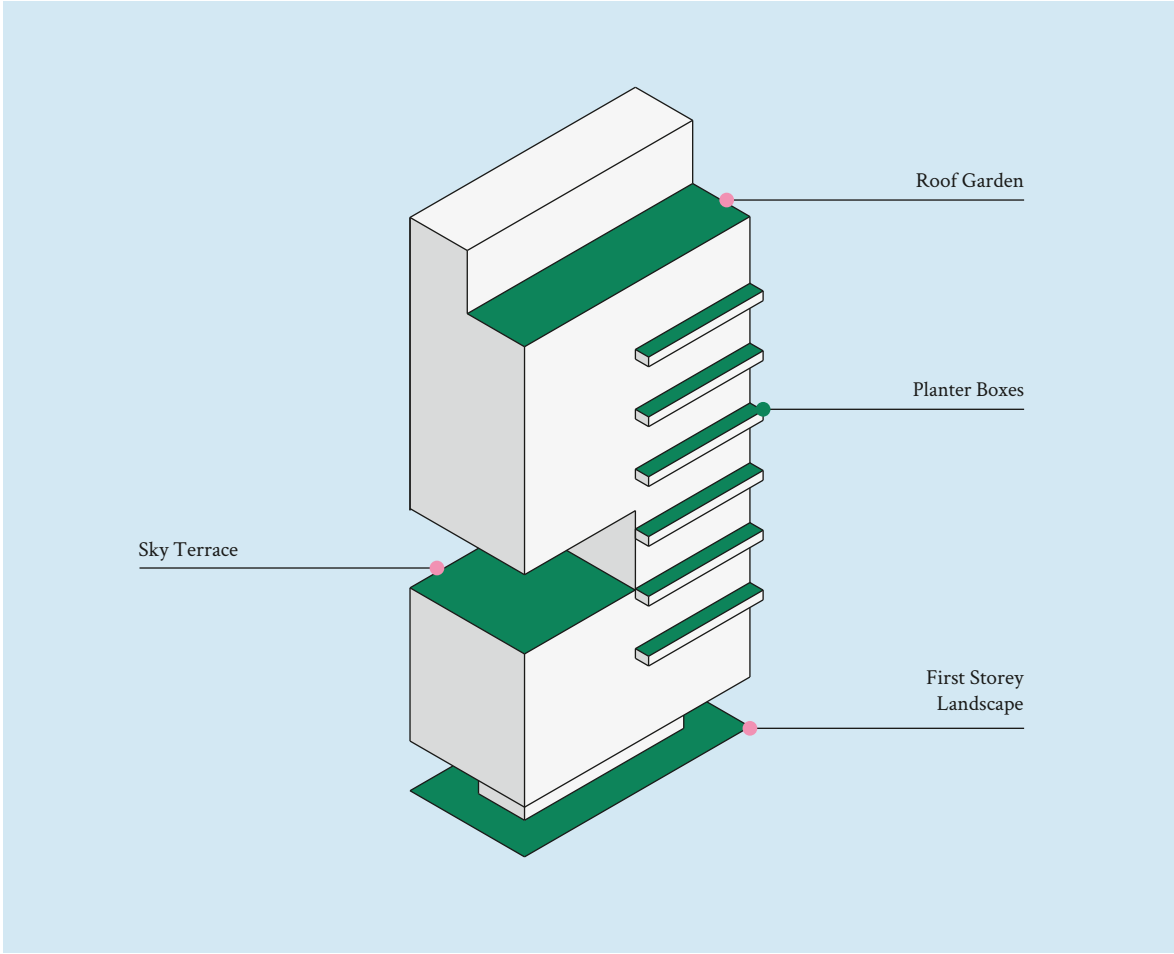
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## TOWARDS A BIOPHILIC OUTCOME

At a certain basic level there are two types of green landscapes in Singapore. The first belongs to its natural systems, catchments, native forests and so on. The second are artificial constructs of parks, gardens, streetscapes, canals and skyline terraces. From its inception and particularly during the trend from Singapore as a 'Garden City' to a 'City in a Garden' and on to a 'City in Nature', NParks, the authoritative oversight and driver, has been restoring ecosystems into artificial constructs and ecological processes with regard to the natural systems in place. The overall aim is to have Singapore functioning as a fully urban ecological system. Further, part of the aim is to connect and re-connect people with nature and to bring a more profound sense of being with nature into their lives. In so doing NParks is highly proactive, constantly searching for and identifying elements of the built environment that can be associated with greenery or all it portends. In fact, Singapore is unique among nations in the way it manages greenery. This derives from the scope of activities, the variety of activities, and the technical sophistication and scientific, botanical and other research backing up its greening efforts. The preceding sections have described these efforts and the almost inexorable trend and even obsession that has gripped the island

state in these regards and particularly over the last half century.

Lurking closely behind Singapore's efforts to connect its citizens with nature is that such association is beneficial and in fundamental ways. In a word, it is about becoming biophilic or certainly verging towards that condition. Simply put, biophilia suggests that humans possess an innate tendency to seek connections with nature and other forms of life. It is a state of being, popularized by luminaries like Edward O. Wilson in his book with a similar name of 1986.<sup>40</sup> More succinctly he describes biophilia "as the urge to affiliate with other forms of life". From this it closely follows that 'biophilic space' strengthens and supports social psychological capacities of life, spanning acts that unburden cognitive systems and further sensorial experience. More prosaically, biophilic undertakings, by creating strong connections between nature and man-made environments has benefits. To date there is evidence to suggest that this can include helping to make office workers more productive, encouraging children to learn and develop, as well as helping hospital patients to get better. There it is very much about natural light, views of nature, presences of plant life and the use of natural materials, textures and patterns.



86. DIAGRAM OF THE LANDSCAPE REPLACEMENT POLICY

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