



CASE STUDY

Singapore | Pulau Semakau

Growing the “Garbage of Eden”

As a fast-growing island city-state, Singapore has little space on its mainland for its rubbish. Its innovative solution was to build one of the world’s earliest and cleanest offshore landfills—an island that today harbours flourishing ecosystems from mangroves to reefs.

The Challenge

In 1992, one of Singapore’s last two landfill sites, a dumping ground in the western region of Lim Chu Kang, reached its maximum capacity and was closed. The other landfill, a 234-hectare site at Lorong Halus in the north-east, would run out of space in 1999.

Singapore, like any small country or city with a burgeoning economy, faced a trash problem. First, as it grew, it generated more and more waste. In 1970, about 1,300 tonnes of solid waste were disposed of each day; by 1992, this had ballooned to about 6,000 tonnes a day. Already, Singapore was incinerating its trash to generate some energy and minimise the space required for dumps. Yet more and more space was urgently needed for housing, industry and other uses. In fact, planners had already approved a new landfill site in the northern farming area of Punggol, and

government agencies had begun to engage local farmers to acquire their land when the area was abruptly earmarked for housing instead.

So Singapore had to find alternatives—quickly. An offshore landfill was one possibility. The island-state already had expertise in land reclamation, which it had carried out along its coastlines since the 1960s. But in order to deposit incinerated waste offshore, it would need to ensure that pollutants would not leach into the surrounding seawater. What’s more, the government was aware that converting islands to landfills encroached on precious natural space. So it aimed to find a solution that would not only fulfil the need for a landfill but also preserve the natural environment and enable the space to be open for public recreation.



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Rubbish truck of the Ministry of the Environment at a rubbish dump in the 1970s.





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The Solution

After feasibility studies, the Singapore government approved a proposal to construct an offshore landfill in 1994, one of the world's earliest. It would involve enclosing the space between two islands south of mainland Singapore, Pulau Semakau to the west and Pulau Sakeng to the east. The 350-hectare landfill would take the sludge and ash left over from incineration, as well as waste that could not be burned. Work began in 1995.

To contain pollution and protect nature, engineers, academics and contractors had to work together to come up with innovative solutions in the design, building, and operation of the landfill.

The seven-kilometre perimeter bund between the islands was lined with impermeable membrane, marine clay, and rock layers, to keep leachate in and the surrounding waters free of pollution. Any leachate generated would be treated at a plant on site.

The landfill's original design kept a narrow channel between Semakau and Sakeng, but experts determined that the channel's hydrodynamics meant all the mangroves on the east side of Semakau would not survive the resulting tidal changes. So engineers constructed the perimeter bund, and replanted 13.6 hectares of mangroves to replace those that had been removed to build it. The replanted mangroves would serve as biological indicators of leaking waste.

The replanting was an effort on an unprecedented scale—but that effort that was nearly scuppered after a 1997 oil spill released 28,000 tonnes of oil into the surrounding waters. The team of engineers, experts and contractors considered their options, including washing each leaf with detergent, but decided to let nature take its course, and more plants survived than expected.

During construction, screens were also installed to avoid smothering nearby seagrass and corals with silt. And after a study trip to the world's largest landfill, Fresh Kills Landfill in New York, it was decided that waste should be transported in an enclosed system to minimise dust and windblown waste.

At first, a container system was considered, but it would have cost too much. The team eventually decided on a 3,000-tonne covered barge—a method that was more costly upfront but cleaner and more efficient in the long run. The incinerator ash and non-incinerable waste are discharged in an enclosed building, and compacted in landfill cells pumped free of seawater. When filled, the cells are covered with a layer of earth, allowing grass and trees to take root naturally over time.

In all, the landfill cost some S\$630 million. In April 1999, it began operation, enabling the last mainland landfill at Lorong Halus to close after it was filled.

01 A barge like this transports incinerated ash and non-incinerable waste to Semakau every night.

02 Singapore's four waste-to-energy plants and the sea route connecting the network to Semakau Landfill.

“ Besides being a clean and odour-free landfill, Semakau also harbours flourishing natural ecosystems like mangroves, seagrass meadows, and coral reefs, as well as rich biodiversity...” ”





The Outcome

Today, more than 2,400 tonnes of incineration ash and non-incinerable waste are transported on barges to Semakau each night. In July 2015, a second phase of development was completed, comprising a single, 157-hectare landfill cell into which ash is directly discharged. Corals from the development site were transferred to a marine park at Sisters' Islands, while fish there were released into the open sea.

Besides being a clean and odour-free landfill, Semakau also harbours flourishing natural ecosystems like mangroves, seagrass meadows, and coral reefs, as well as rich biodiversity from sea stars to herons. Knobbly Sea Stars, large, colourful sea stars once common to Singapore waters but later decimated by habitat loss and the aquarium trade, are now a common sight again in Semakau. Meanwhile, the National Parks Board re-introduced fireflies—seldom seen on the mainland—to Semakau's wetlands.

Since 2005, Semakau has been open to the public for recreational activities such as guided nature walks, sport fishing tours, and stargazing. It is a test-bed for new innovations, such as a floating wastewater treatment plant, and in future, renewable energy solutions such as a micro-grid that integrates multiple energy sources. And it has received international acclaim—in a 2007 story for *New Scientist* magazine, journalist Eric Bland dubbed the landfill “Garbage of Eden”.

At current waste disposal rates, the landfill is expected to last till 2035 or beyond. But Singapore will not be resting on its laurels. Instead, it urges people to reduce and recycle, to extend the landfill's capacity as far as possible into the future. ●

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- 01 Healthy mangroves growing by the perimeter bund at Semakau testify to the safeguards installed to prevent waste in the cells from contaminating the sea.
 - 02 Knobbly Sea Stars, which can grow to 35 centimetres wide, are the main attraction for visitors to Semakau.
 - 03 Members of the public can explore the reefs at low tide in guided walks like this.
 - 04 Catching the sunrise at Semakau.

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