Water II: Water Management for the Future
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Bermuda's Freshwater Cycle: Capture, Conservation, and Water Quality Management

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BERMUDA: A porous limestone Island

Bermuda has high annual rainfall – but very limited freshwater resources due to highly porous limestone which absorbs rainfall. No surface water (other than flash floods on roadways).

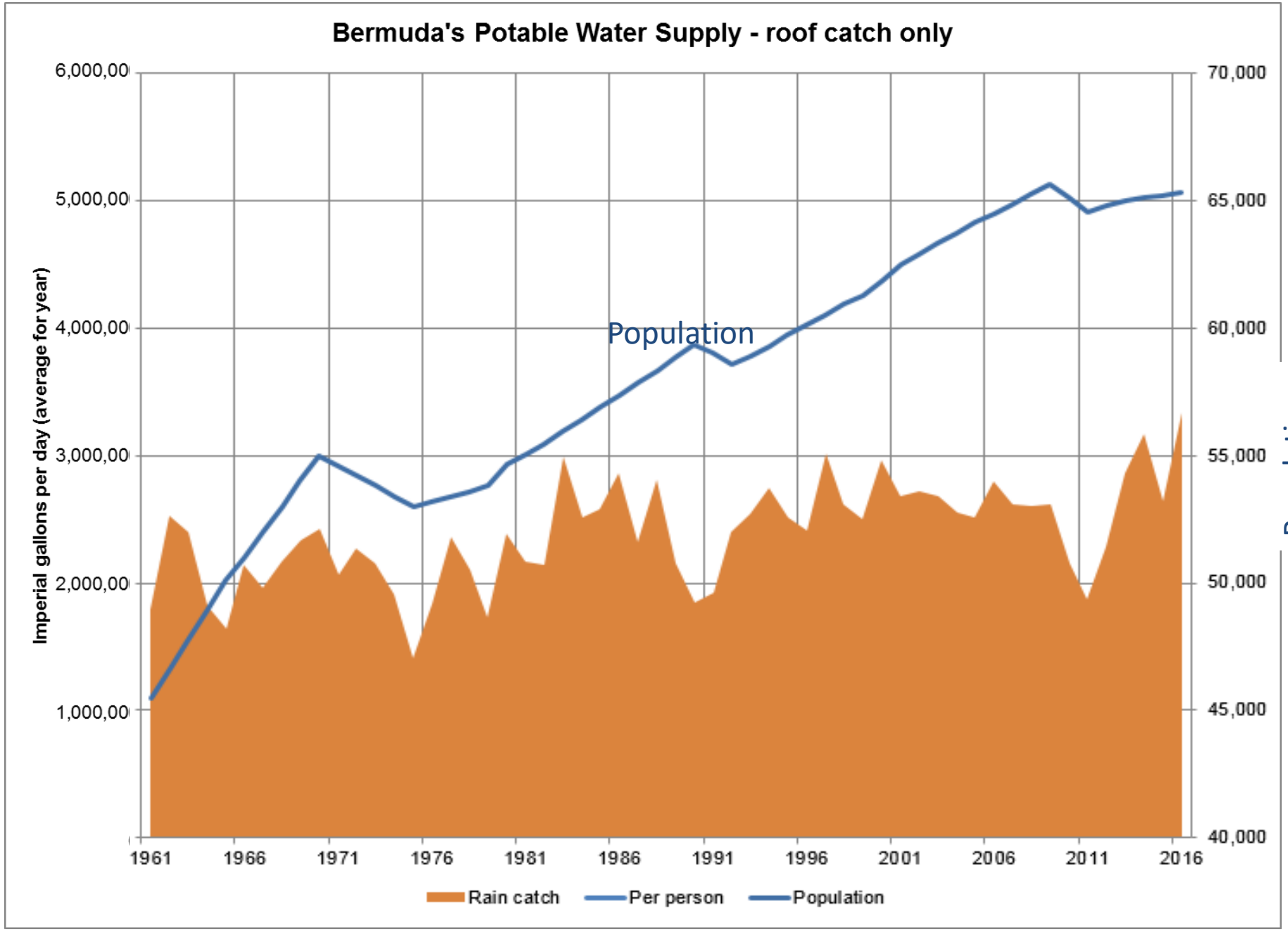
Roof catches and tanks

Early settlers collected rainwater from roof catches and used barrel-vaulted tanks.

Rainwater supply

Averaging ~40 lgpd/person, but note variability (and occasional droughts).

Population over this period rose from 45,000 to 65,000 pe



Legal Requirements:

PUBLIC HEALTH (WATER STORAGE) REGULATIONS 1951

Standard practice was eventually codified – the law requires 80% of the roof area to be a rain catch.

Legal Requirements:

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The law also requires a house tank to have a capacity of 10 gal/sq.ft. roof catch. This is equivalent to ~3 months' rainfall.

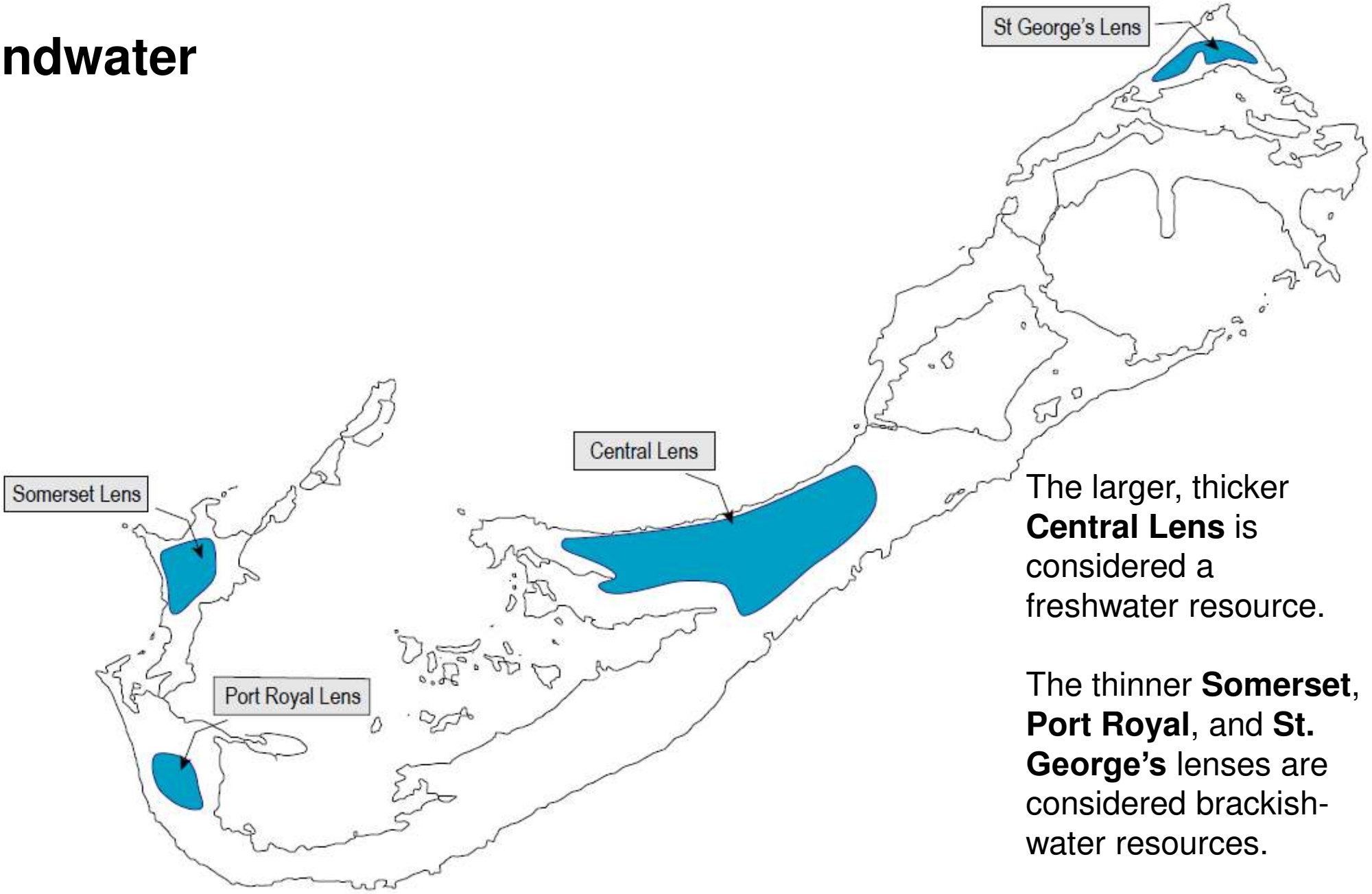
Are roof catches adequate?

On average the roof catch meets most Bermudians' needs in most years. However smaller homes with many occupants require a supplementary supply. More homes are affected during droughts. The island has ~30 water delivery companies a.k.a. "truckers".

Groundwater

Early settlers dug wells and found water at or close to sea level, ranging from saline to brackish to fresh. Watlington Waterworks started up in 1932 to provide an auxiliary water supply to hotels. Government started to develop groundwater for public supply in mid-1960s.

Fresh Groundwater

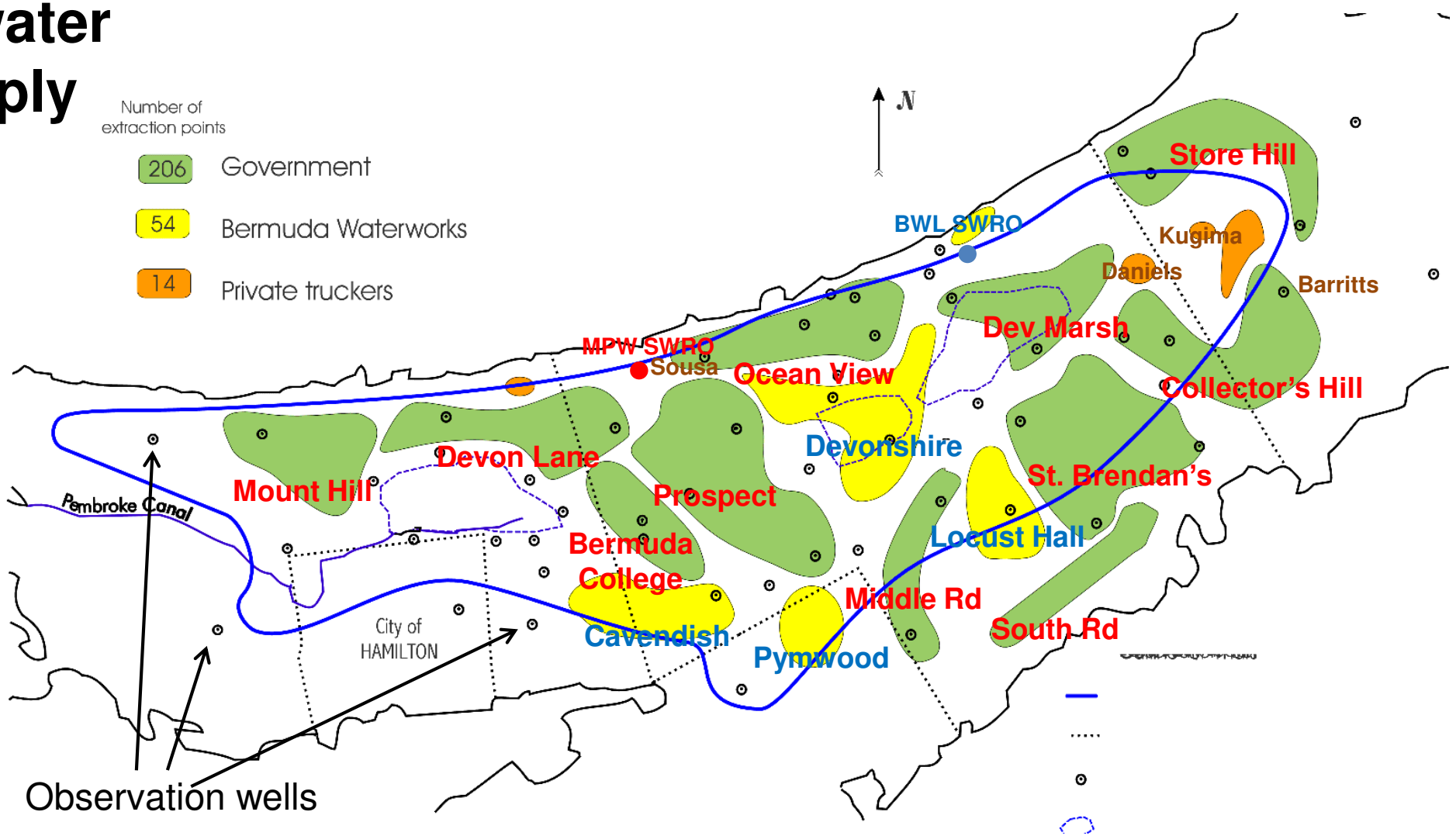


The larger, thicker **Central Lens** is considered a freshwater resource.

The thinner **Somerset**, **Port Royal**, and **St. George's** lenses are considered brackish-water resources.

In the 1970s the main areas of fresh water "lenses" were scientifically defined.

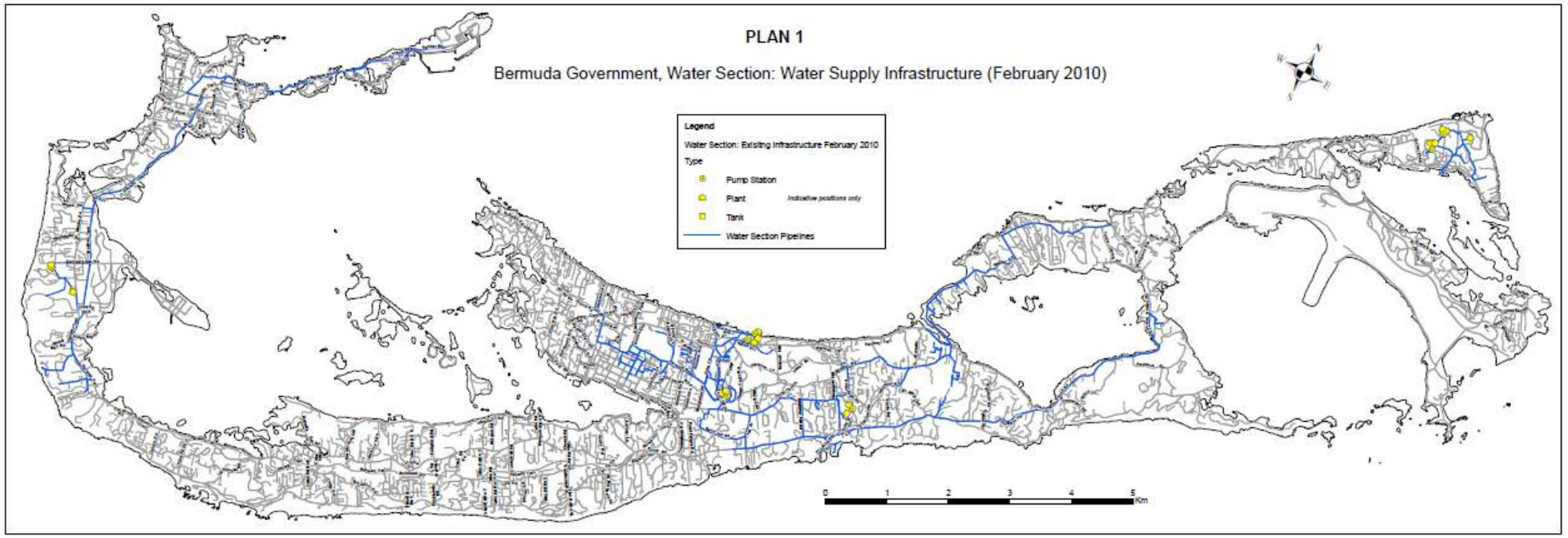
Fresh Groundwater for public supply

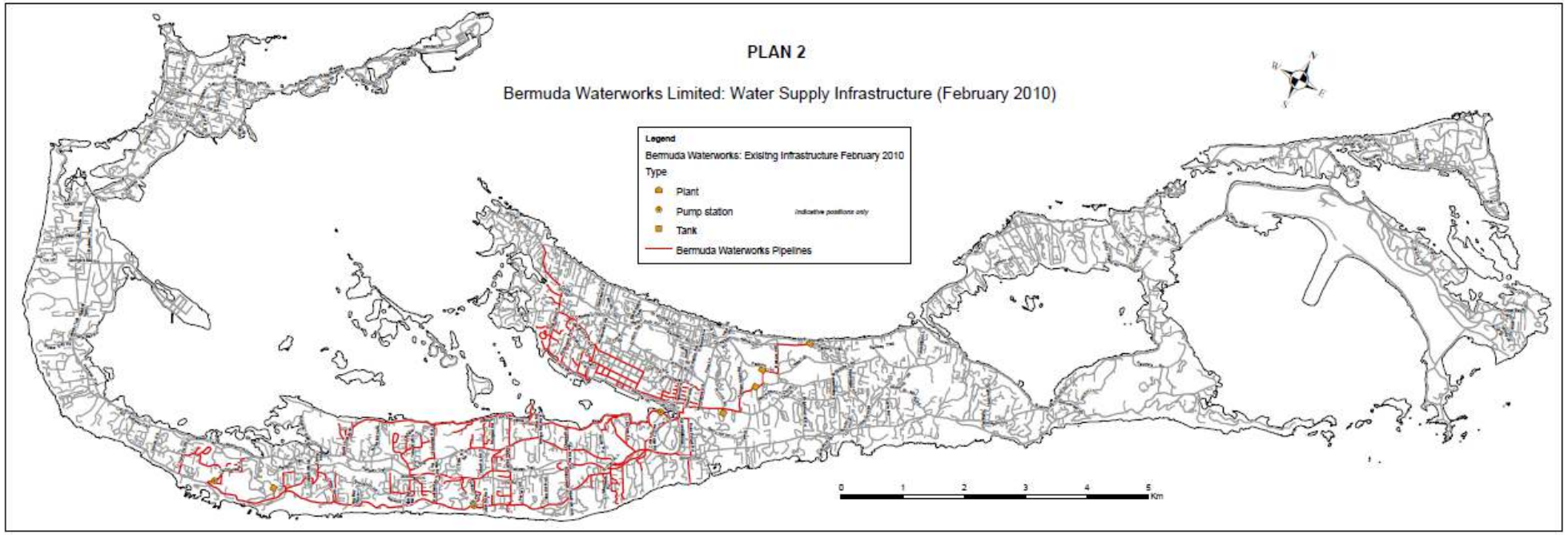


The Water Resources Act 1975 and Government-funded research led to limiting abstraction to the safe yield in each sector. Abstraction must stay within sustainable limits (based on annual recharge) to avoid the lens going saline. Therefore pumping for commercial supply is spread out via 274 abstraction points across 19 sectors – 11 Government and 8 private.

Potable water distribution

Government and Watlington Waterworks (now Bermuda Waterworks Limited) run separate systems to distribute water across the island.





Seawater Desalination

Dockyard (Wedco)
400,000 US gpd

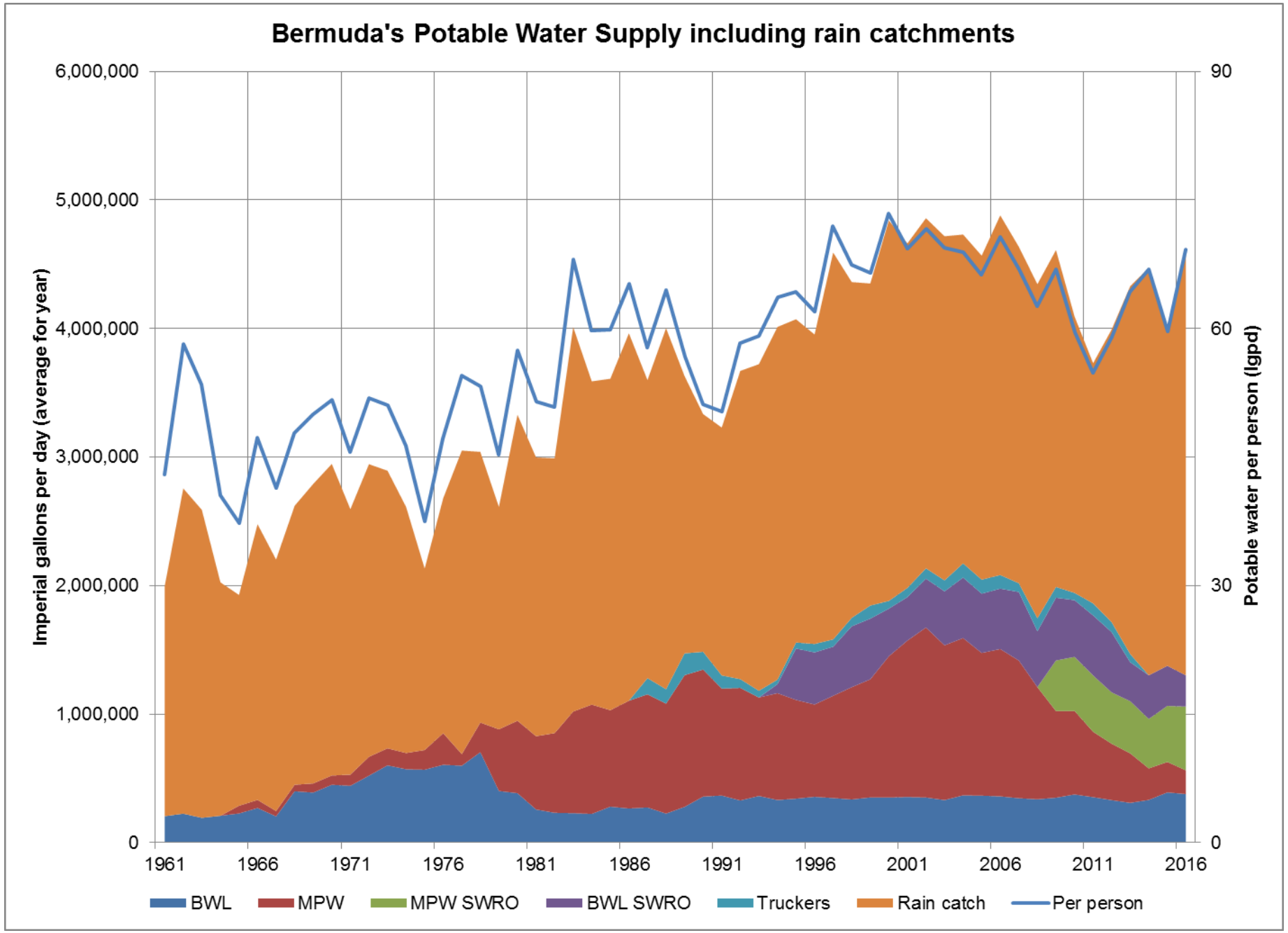
Devonshire
1,000,000 lgpd

St. George's
180,000 US gpd

Seawater RO became more cost-effective. BWL started SWRO supply in 1994 and Government in 2009. Government's principal SWRO plant is powered by power generated by the waste-to-energy facility (incinerator) that replaced a landfill north of Hamilton.

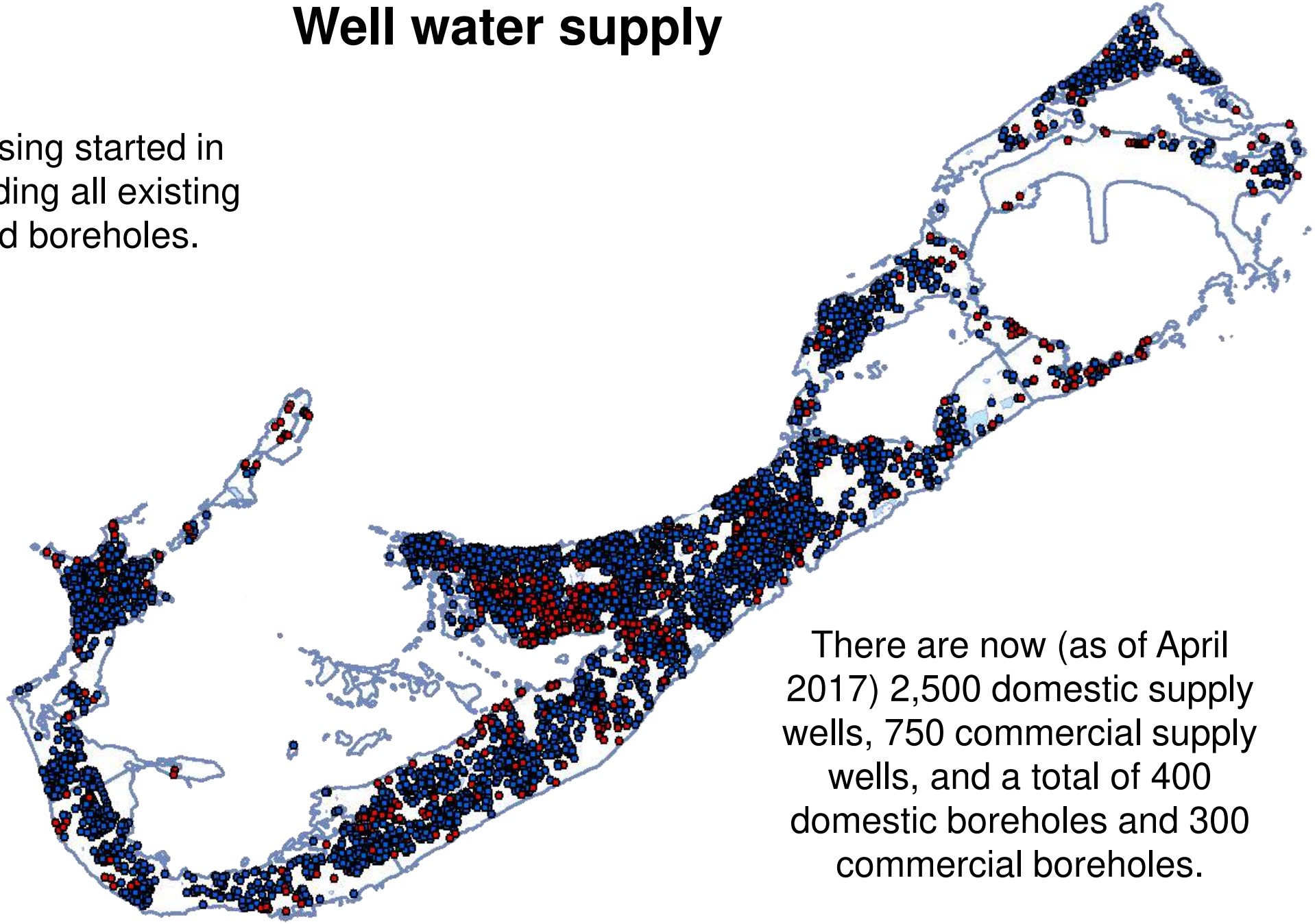
Growth in water supply

Public supply from groundwater and SWRO doubled the available water per person, from ~40 to ~60 lgpd.



Well water supply

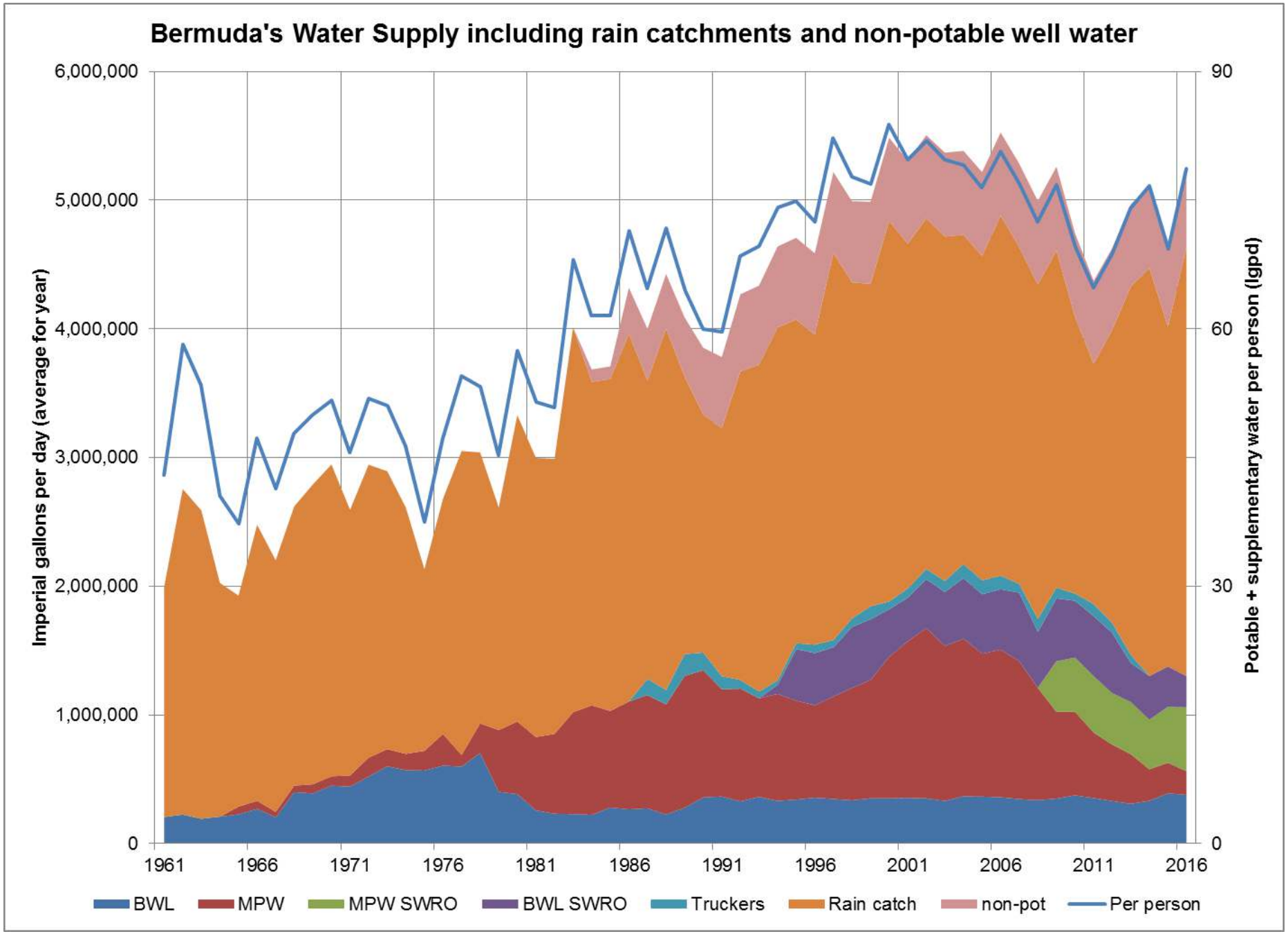
Well licensing started in 1984 including all existing wells and boreholes.



There are now (as of April 2017) 2,500 domestic supply wells, 750 commercial supply wells, and a total of 400 domestic boreholes and 300 commercial boreholes.

Benefit of domestic wells

Use of well water for non-potable purposes is equivalent to an extra 15 gpd per person.



Wastewater disposal

An estimated 90% of the island's population disposes of untreated domestic wastewater to unlined soakaway pits.

Delivery of a precast soakaway pit "liner"

Effect on groundwater recharge

Studies showed that sewage disposal and runoff from paved areas increases recharge to the lens from 25% of rainfall to 50% or more.

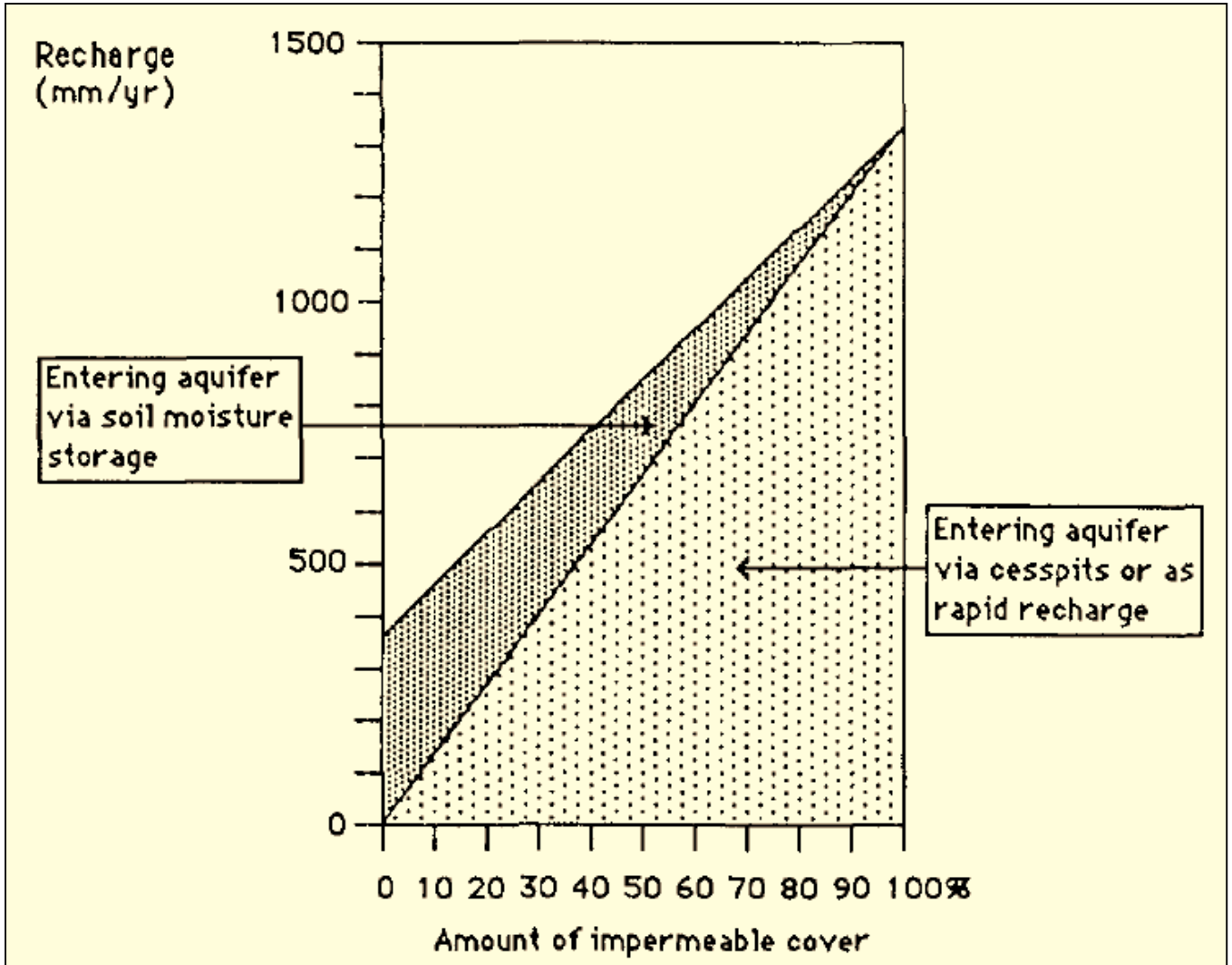


Fig. 2. The effect of increased urban cover on overall recharge. As the roofed and paved area grows, the contribution of cesspits and road drains to recharge increases markedly. Average rainfall is 1.5 m/yr.

SOURCE: Thomson (1989)

Nitrate and other indicators

Microbiological studies in the 1980s showed that, in general, sewage bacteria were not found in groundwater. However, nitrate levels exceeding WHO standards were present under densely-populated areas.

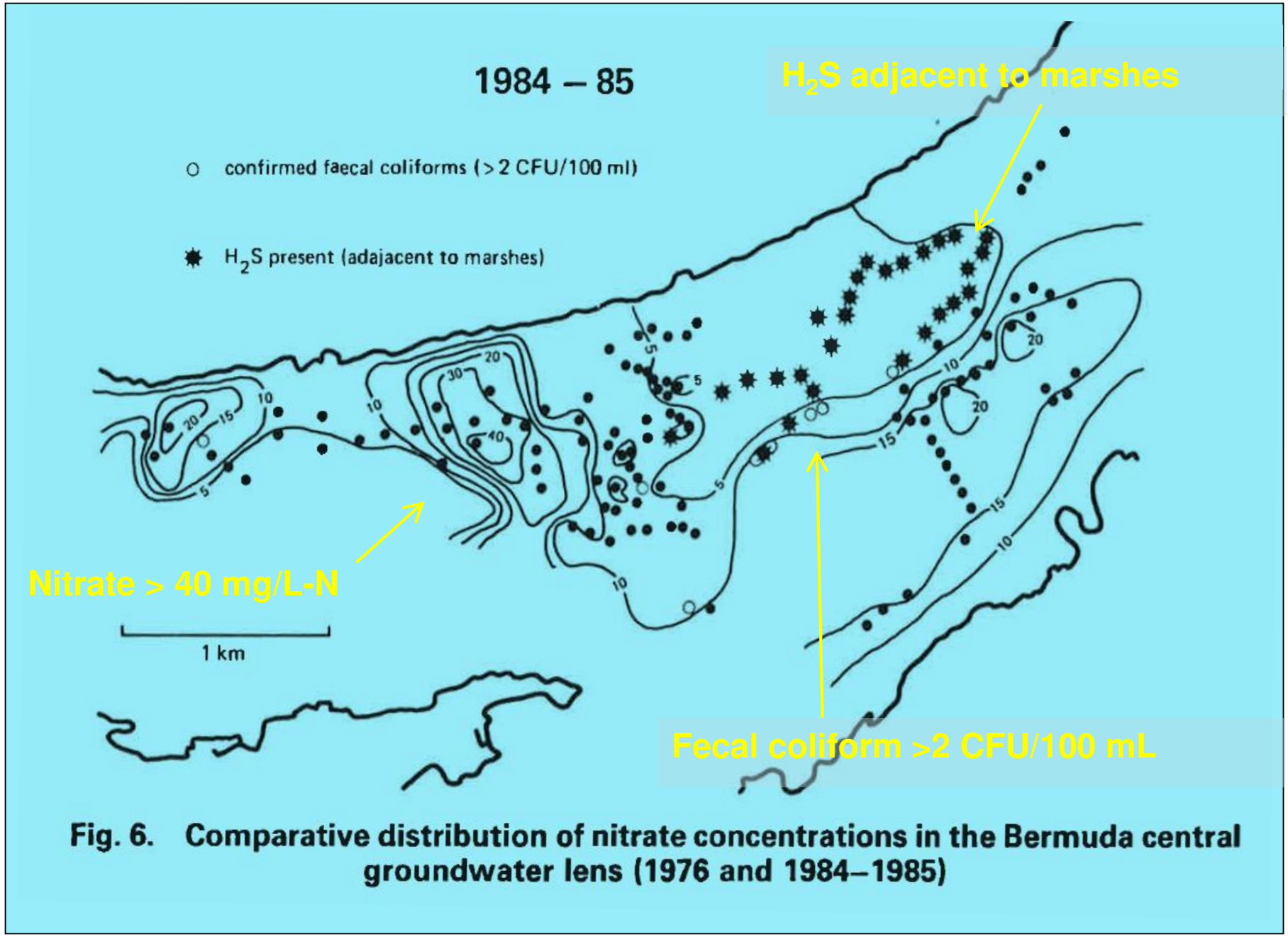


Fig. 6. Comparative distribution of nitrate concentrations in the Bermuda central groundwater lens (1976 and 1984–1985)

SOURCE: Thomson (1986)

Increase in nitrate

As the Central Lens wellfields expanded in the 1970s and 1980s, nitrate concentrations in the public water supply increased steadily, requiring a step-up in treatment from chlorination to ultrafiltration and RO.

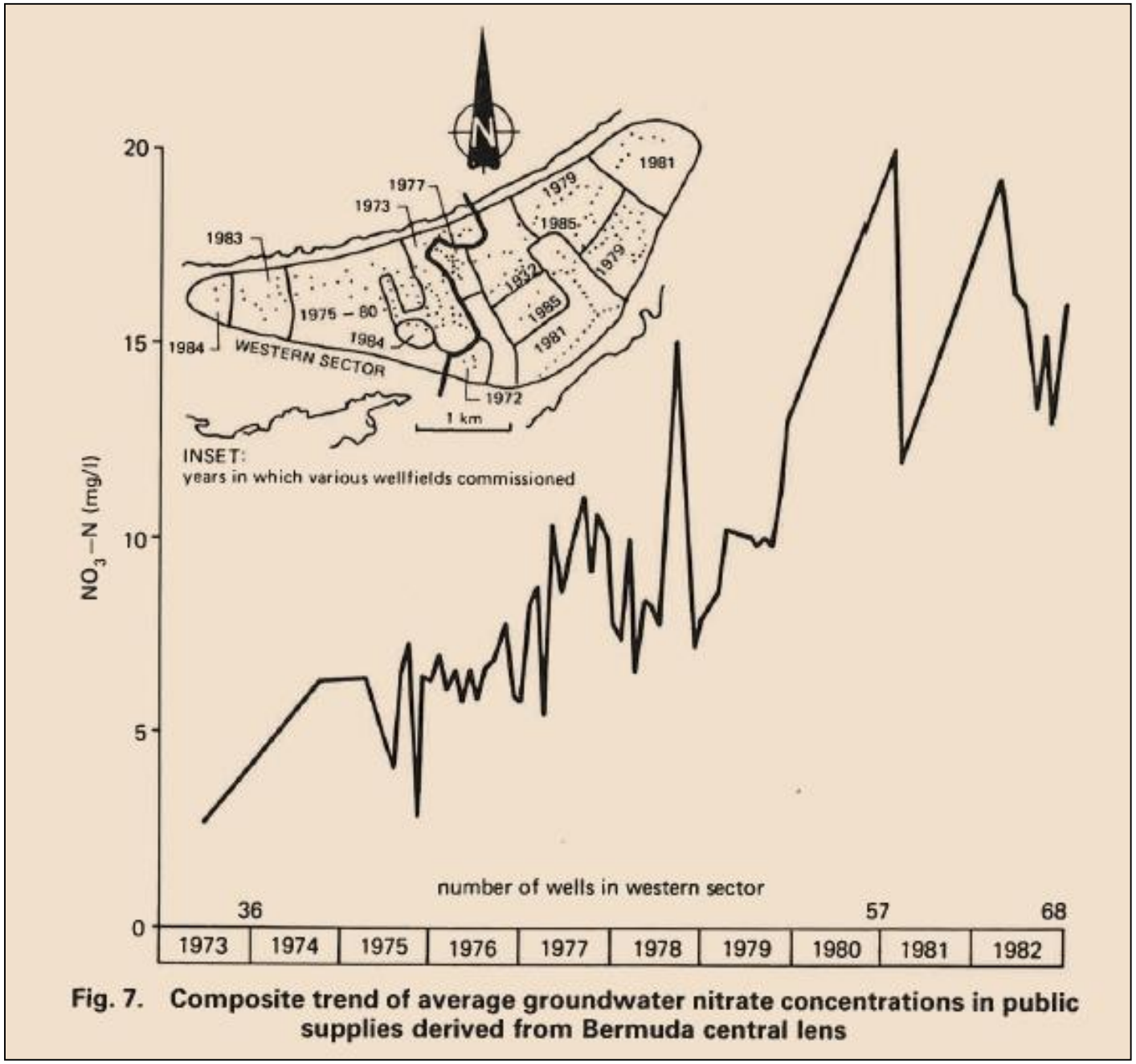
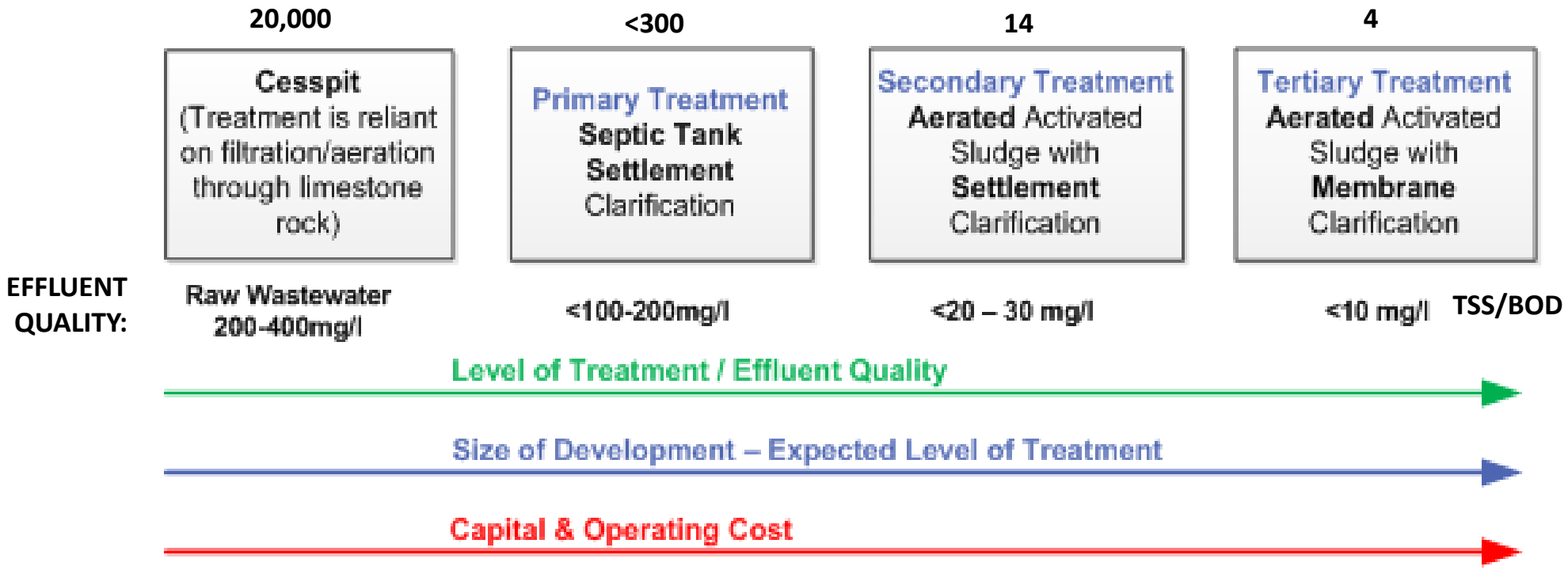


Fig. 7. Composite trend of average groundwater nitrate concentrations in public supplies derived from Bermuda central lens

SOURCE: Thomson (1986)

Sewage Wastewater Treatment

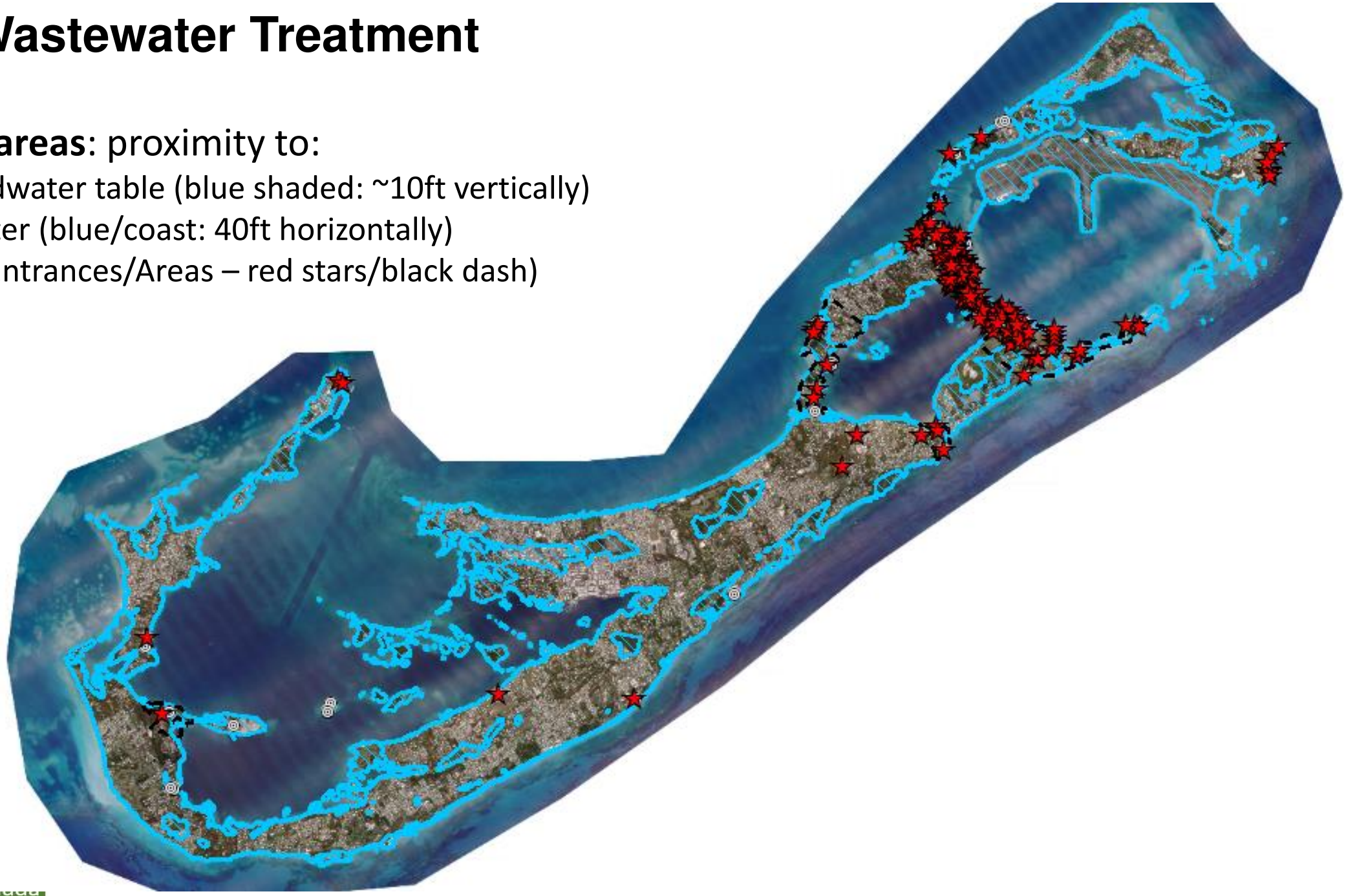
- A greater level of treatment is required for larger developments (50+ bed and 100+ bed) and when located in sensitive areas (*i.e.* close to the water table, the sea or over known cave systems).



- There are a total of 19 sewage treatment plants in Bermuda at the end of sewer mains belonging to corporations, hotels and condominiums.
- These include 4 ‘Tertiary-grade’ and 14 ‘Secondary-grade’ aerated sewage treatment plants.

Sewage Wastewater Treatment

- **Sensitive areas**: proximity to:
  - Groundwater table (blue shaded: ~10ft vertically)
  - Seawater (blue/coast: 40ft horizontally)
  - Cave (Entrances/Areas – red stars/black dash)



Sewage Wastewater Treatment

Secondary Treatment: x14 Plants

Tertiary Treatment: x4 Plants

Sewage treatment and disposal

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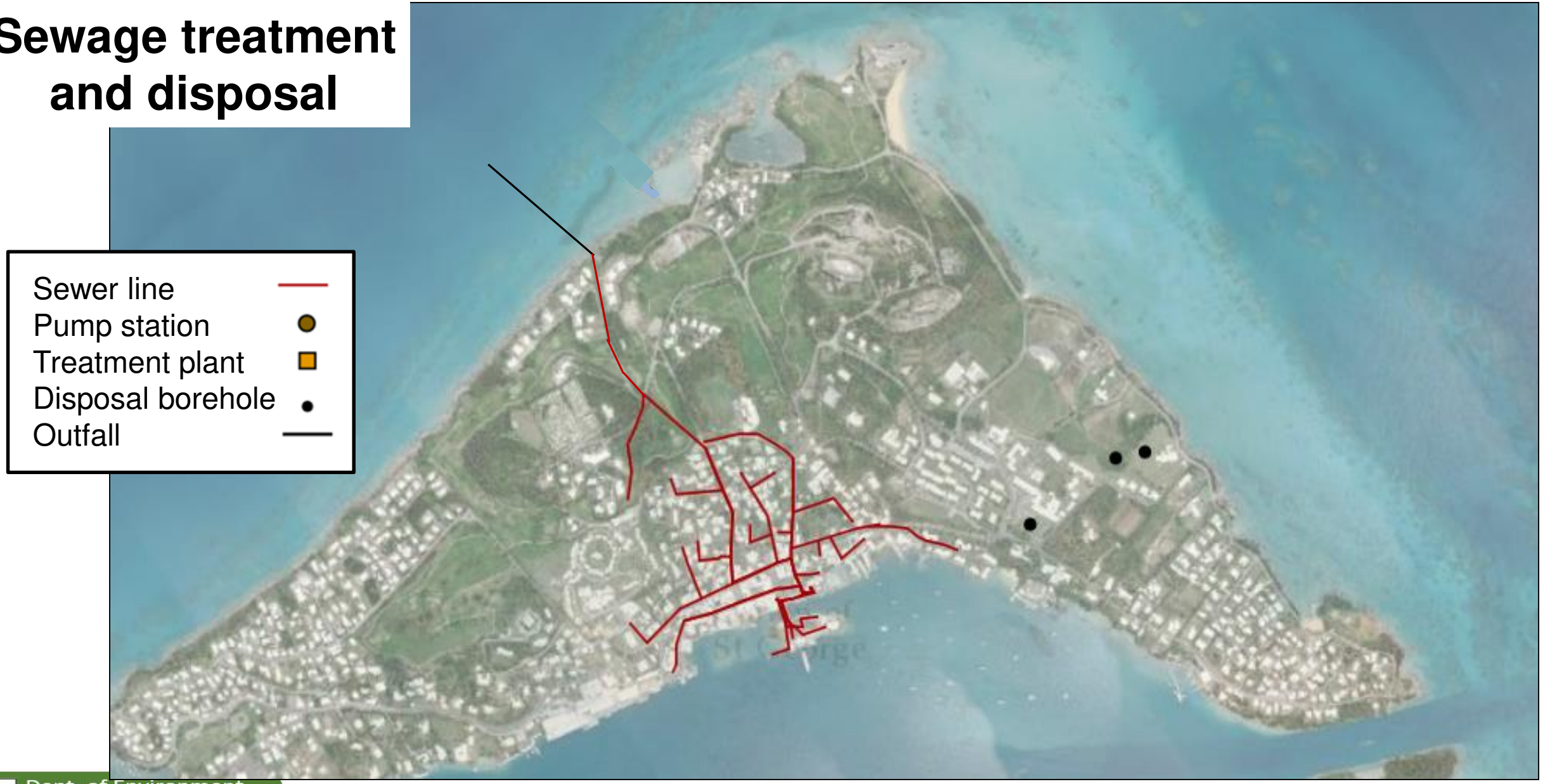
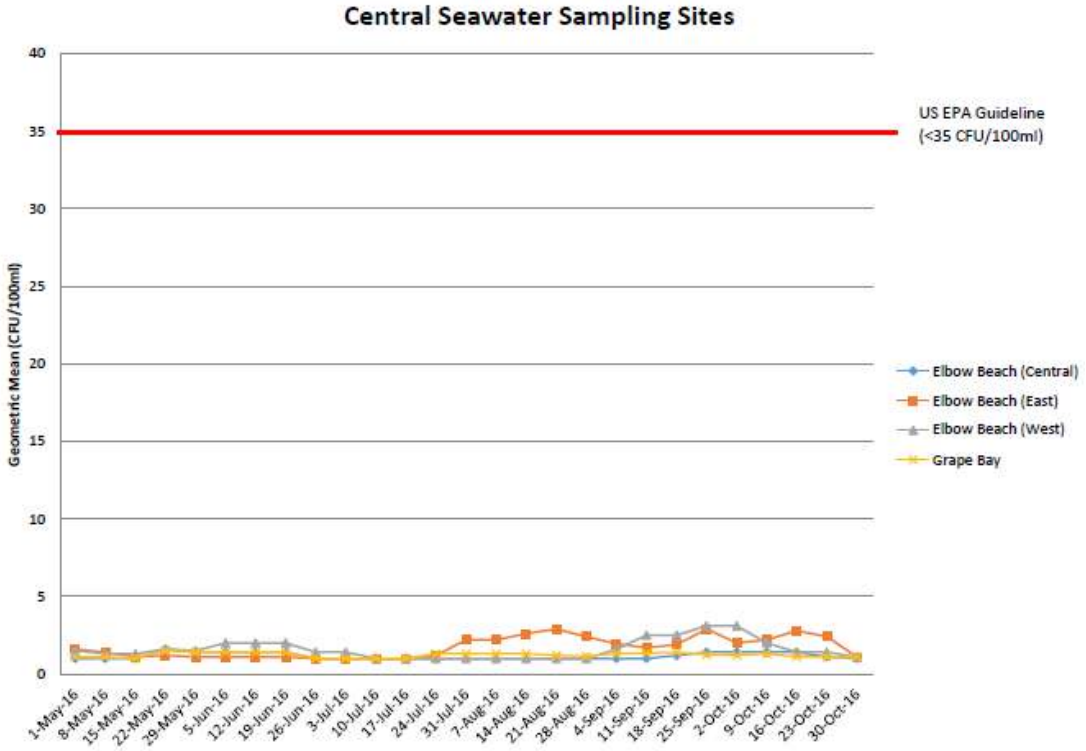
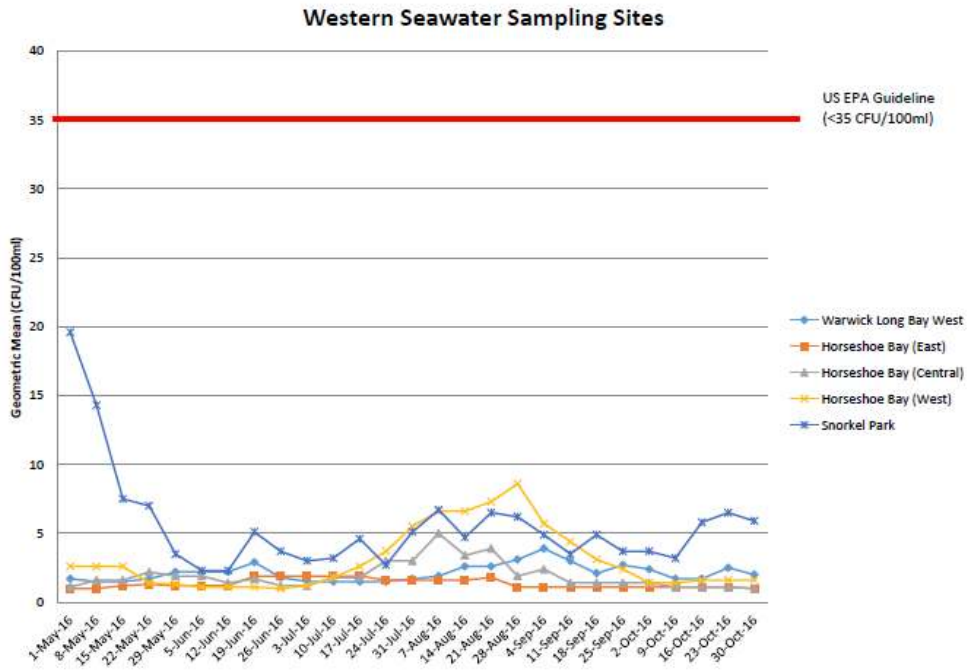


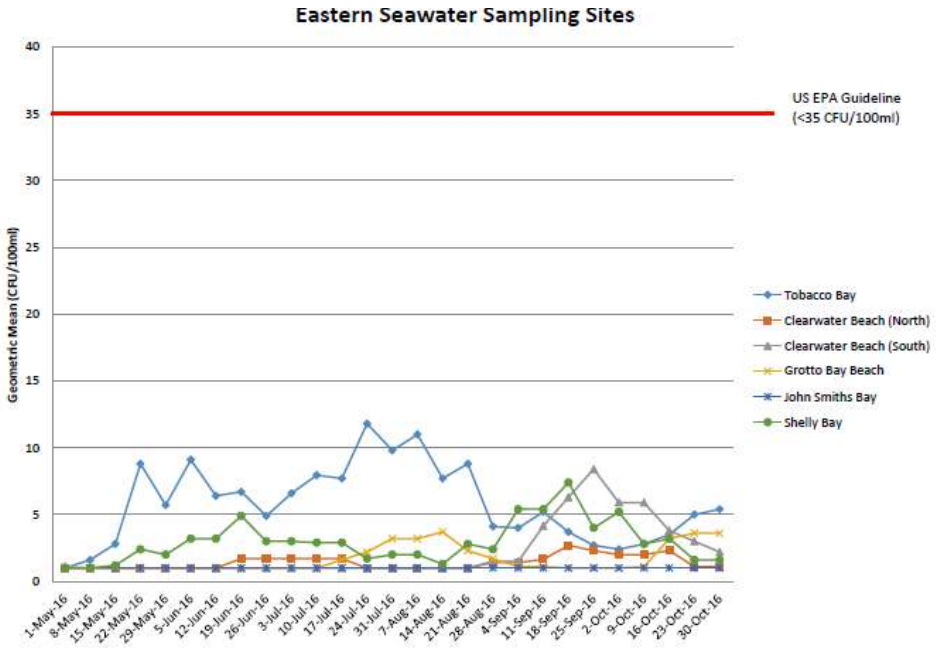
Monitoring Programs

Health Department routinely monitors bathing beaches for water quality. Extremely rare occurrences of microbial contamination.

Monitoring Programs







2016 data: Bathing water monitoring to the US EPA Recreational Water Guidelines (Red limit line) Department of Health