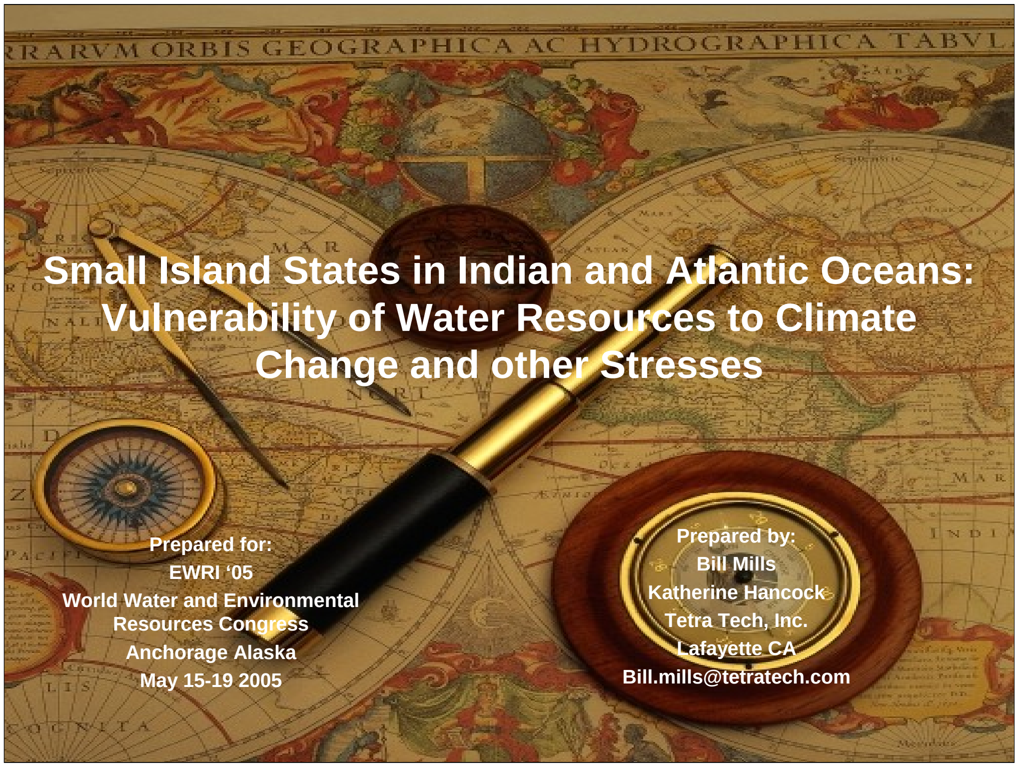
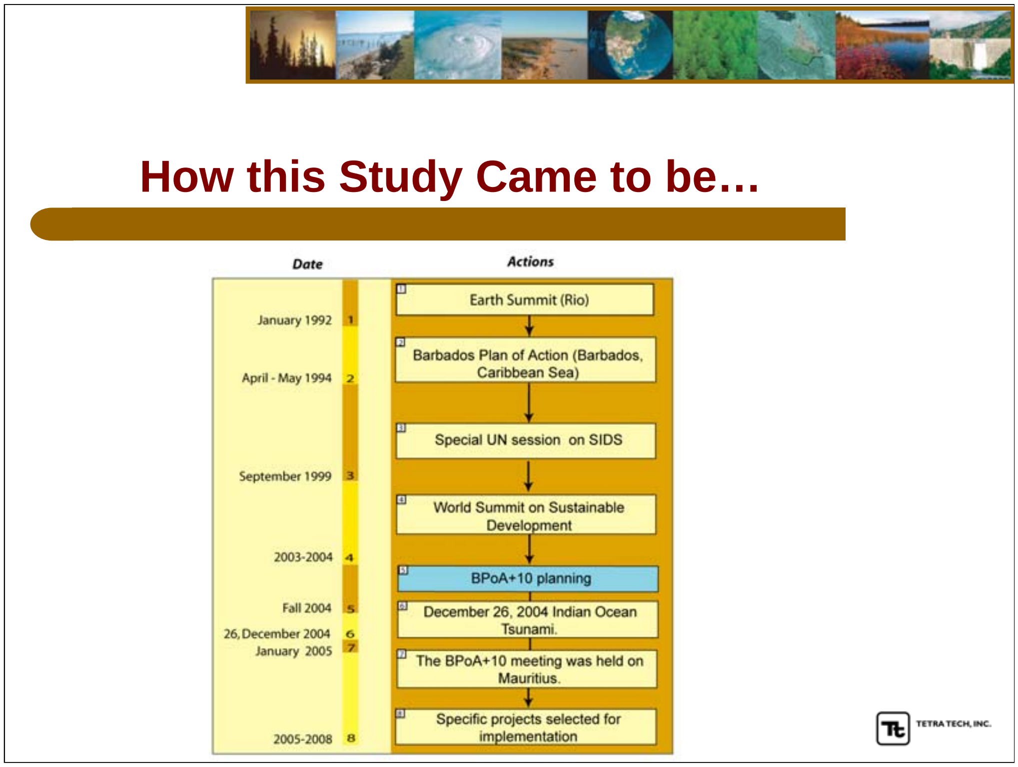


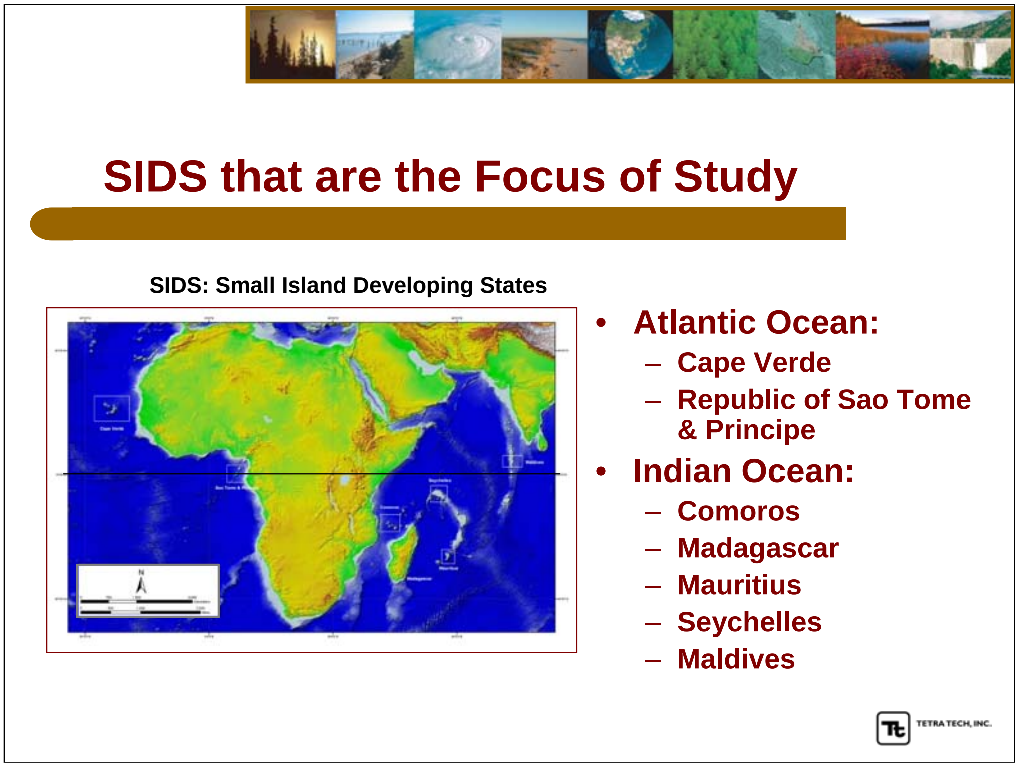
This work has been an overview study conducted during the past year of a group of island countries in the Indian and Atlantic Oceans, the objective has been to examine stresses on water resources on those islands.

Overview of Presentation

- What are SIDS, and why this study?
- Water resources on the SIDS: reasons for vulnerability
- Overview of adaptation strategies



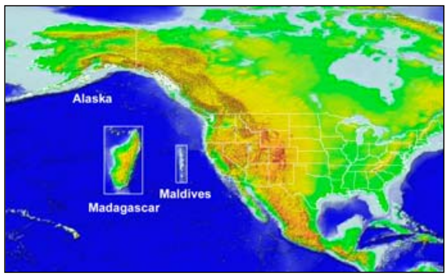
a. Seeds sown in Earth Summit 92 in Brazil: attainment of sustainability for all the earth's people
b. In 1994 focal meeting on SIDS in Barbados
c. Next 10 years: little progress
d. Spawned BPoA+10 in Mauritius, which was delayed due to December 2004 tsunami
e. This study was primarily done to support that meeting, and provide information to subsequent planning.
f. This particular study emphasized the least studied SIDS. Those in the tropical Pacific and Carabean Sea have been much more studied.



a. SIDS is an acronym that means Small Island Developing State
b. Cape Verde: Northern hemisphere and off the coast of West Africa, and west of Sahara Desert
c. Sao Tome and Principe:right at equator and in Gulf of Guinea
d. Comoros: In southern hemisphere between Madagascar and Africa and in Mozambique Channel
e. Madagascar: a large island, but included in study due to regional proximity and similar needs as others
f. Mauritius: west of Madagascar in Indian Ocean
g. Seychelles: near equator in southern hemisphere
h. Maldives: southwest of India and mostly in northern hemisphere.

Basic SIDS Data

- **Number of islands: Over 1300**
- **Land area per SIDS: 6%- 76% of Anchorage's area** **(expect Madagascar)**
- **Population density: 60%-1700% of Anchorage's density**
- **Total shoreline length: 7700 km**



TETRA TECH, INC.

8 island nations but more than 1300 islands. Maldives has more than 1000.

With the exception of Madagascar, area of each SIDS is less than area of Anchorage (5000 km**2). Area of Madagascar (shown) is greater than the area of California.

Population density ranges from 60 % (Madagascar) to 1700 %(Maldives) of Anchorage (51 per km**2)

Sum of population is about 20 M, most of which live on Madagascar

Shoreline length is 7700 km, about the distance from SF to NY, and back to Denver

Representative Scenes From Several SIDS

Cape Verde: The driest of the islands with annual precipitation equivalent to NV

Madagascar: island known for its diversity and uniqueness of flora and fauna.

Republic of Sao Tome and Principe: fishing boats for subsistence fishing

Mauritius: one of many streams on island; not all SIDS have streams

Seychelles: Unique beauty of one of the low-lying islands

Comoros: Volcano (Karthala) that recently erupted and displaced 10,000 people

Cape Verde Islands: enduring a dust storm that originates from Africa's Sahara Desert

Victoria on Mahe Island Seychelles, showing damage to infrastructure caused by December 2004 tsunami

Maldives: solid waste disposal

Madagascar: erosion of red soil into Mozambique Channel due to deforestation in the Betsiboka Estuary.

Maldives (January 2, 2005)

Image of City of Male and the International Airport in Maldives a week after the tsunami. As seen from space (Starbird)

Airport has returned to normal, and jets can be seen on runway and in terminals

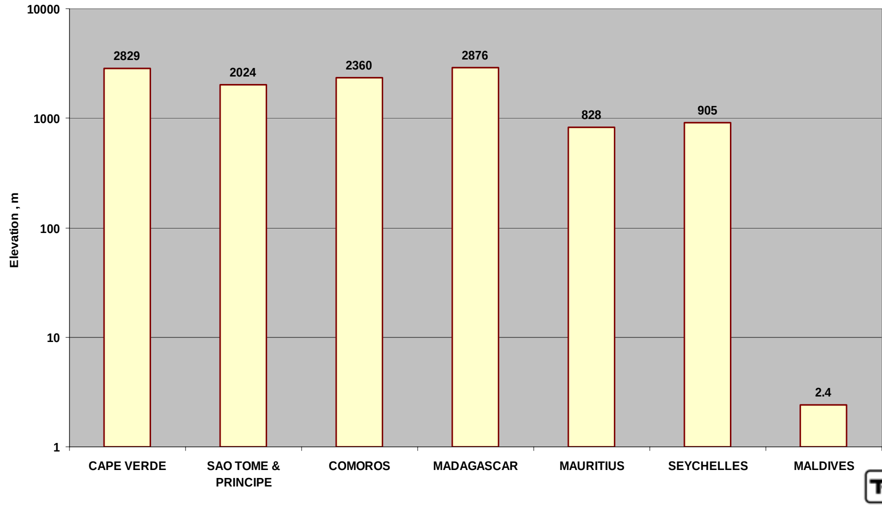
Small boats appear to show flights have been arriving

City of Male’ contains about 25 percent of population and has a density of 30000 people per km**2

The very small islands are resorts, where maybe 100 or so tourists can stay, per island

These slides illustrate that water resources would be very precious on these islands, and that the opportunity for contaminating the fresh water lens beneath Male’ is great.

Maximum Elevation on each SIDS

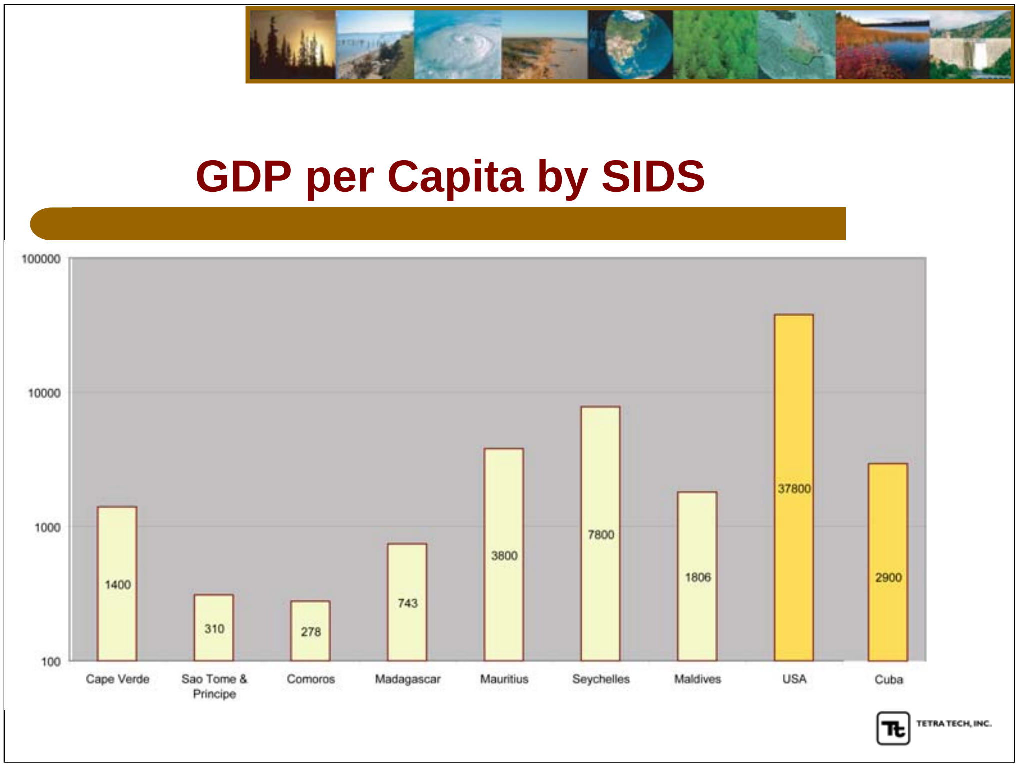


TETRA TECH, INC.

Seven of the eight SIDS have mountains, with three (Comoros, Cape Verde, and Sao Tome/Principe) having volcanoes.

Note the maximum elevation of the Maldives: only 2.4 m above msl

The islands with the highest mountains limit areas for agriculture and enhance runoff of rainfall, limiting freshwater availability

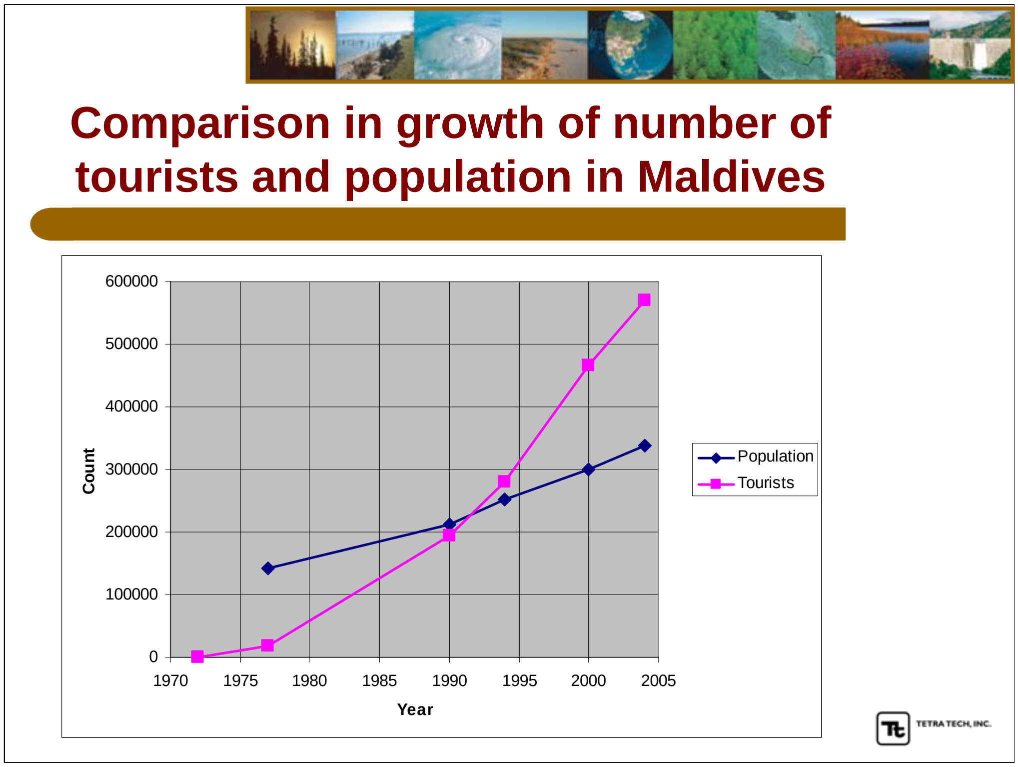


This slide is intended to provide an idea of the economic status of the SIDS.This slide shows the gross domestic product per capita for each SID , and for comparison also shows USA and Cuba.

Compared to the USA the GDP per capita for each SIDS is typically 20 to 100 times less.

The largest is the Seychelles, which has a low population and a thriving tourist industry.

These countries are all poor.

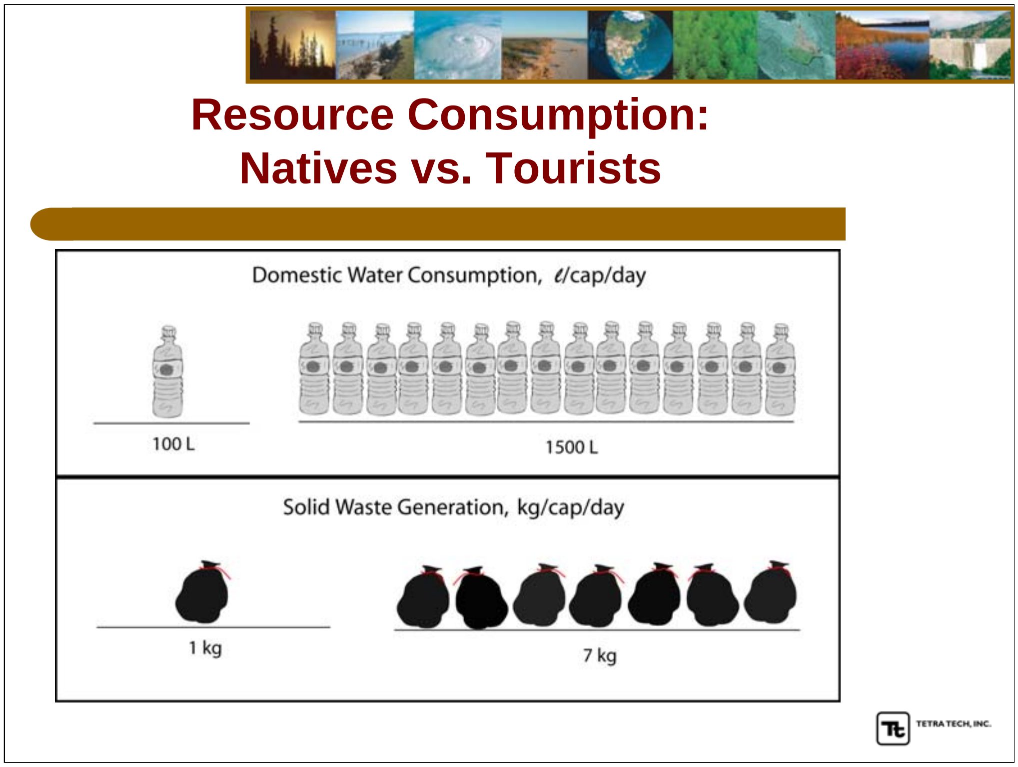


Population has been growing on all the SIDs. An example for the Maldives is shown above.

It is instructive to examine tourism and its impact on water resources. Tourism has dramatically increased during this time period as well, particularly on the Maldives and the Seychelles.

About 30 years ago, practically no tourists came to the Maldives. Today, on an annual basis there are nearly 600,000 tourists landing, compared to a population of about 300,000. Typically, there are 10000-20000 tourists in the Maldives at any given time.

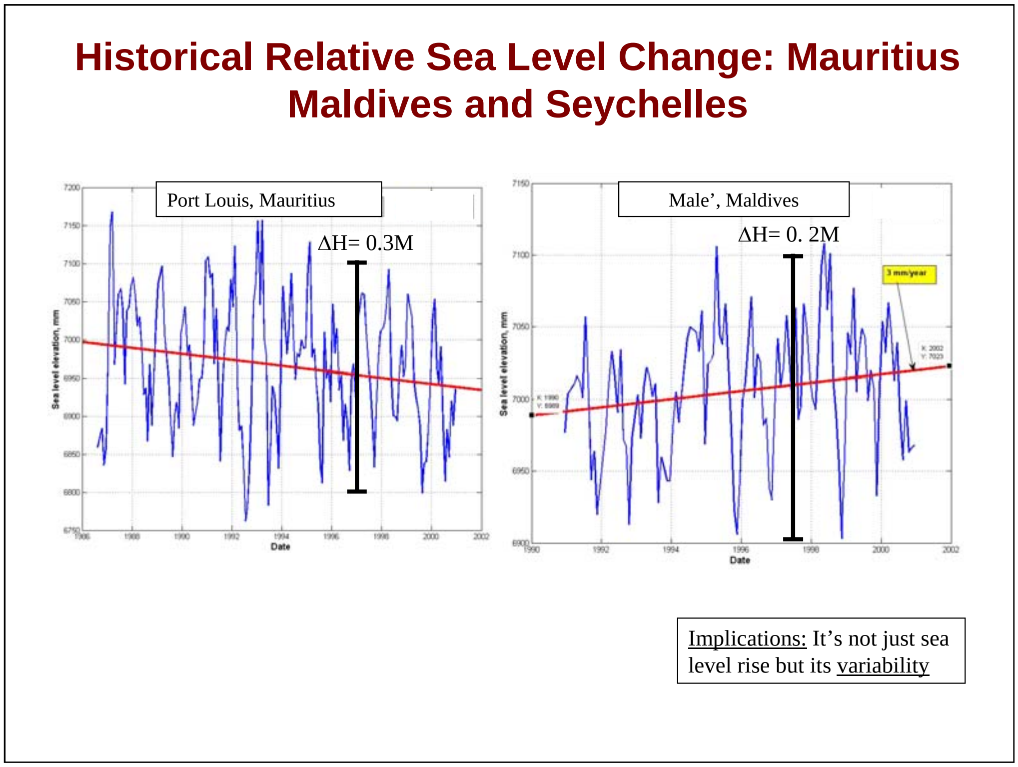
What effect does this have on water resources? The next slide illustrates.



Tourists can consume up to 15 times the water, on a per capita basis, as do the native population. On the Maldives, due to the large numbers of tourists, on an annual basis, the tourists can consume approximately the same amount as the entire native population.

Most of us use more than 100 liters each time we shower. The average person in the USA spends approximately 8 to 10 minutes per shower.

Tourists also generate much more solid wastes. Such wastes, if not properly managed, can contaminate surface water and groundwater, and further stress the available supplies. On the Maldives, the tourist industry increases the solid wastes about 50 % above that generated by the native population.



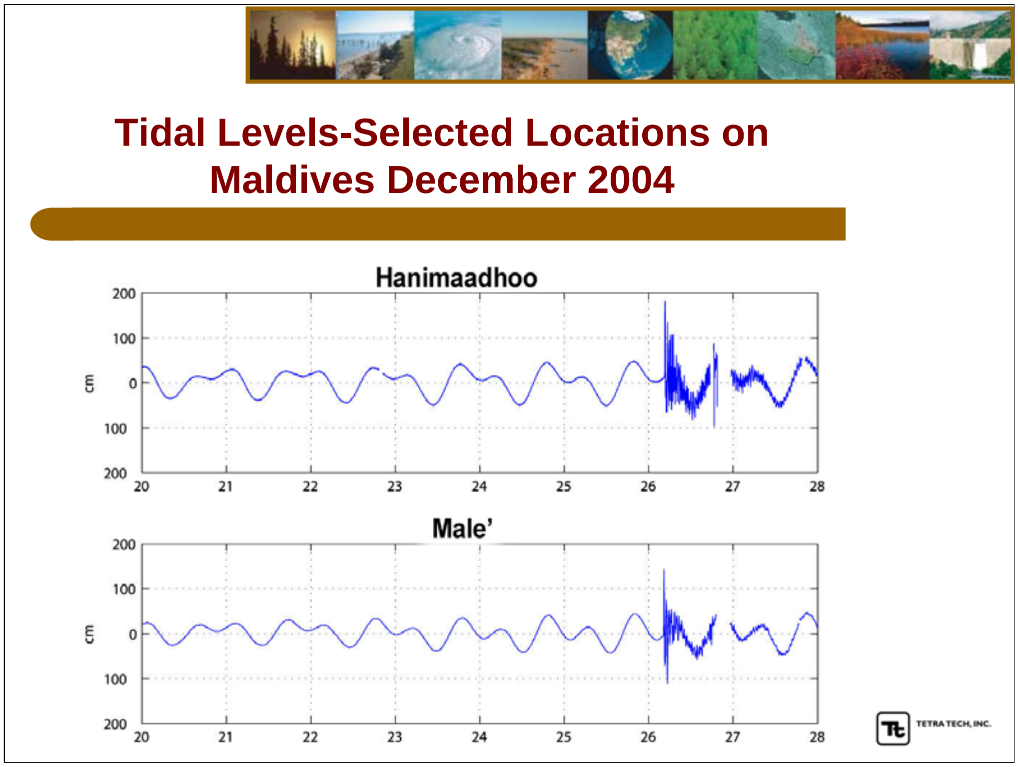
What appears to be happening to the SIDS with respect to sea level change? Well, there seem to be differences, but there are uncertainties, too. This figure shows time trends for two tide gages. One is Port Louis, Mauritius and the second is Male, Maldives

One record appears to show relative sea level is dropping, while the other shows relative sea level is rising at about 3 mm/year, which is slightly higher than the global average.

In general such time trends need to be interpreted carefully, since the period of record is short (10-15 years), and the results each represent only a point.Typically, 40 or more years of data are needed to establish long term trends.None of the SIDS had such long periods of record.

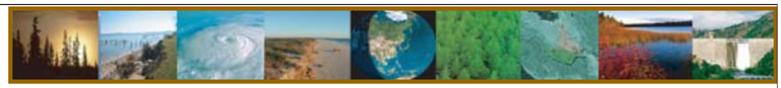
Nevertheless, they do show the seasonal variability that occurs at each location, due both to seasonal temperature and monsoonal changes.

The trend at Male is particular disturbing since those islands are so low lying.



On top of long term relative sea level changes and seasonal changes, tidal levels that produce intra-daily variations are important. Daily tidal levels can vary by about 0.5 m. These plots are tidal time series at two locations on the Maldives just before and during the December tsunami.

At Male the amplitude of the tsunami produced water levels about 1.5 m above the level of the sea at the time of impact. A crest occurred before the first trough.



Projected Relative Sea Level Change

Island	Predicted RSL change During 21st Century
Global	+200 to +800 mm
Mauritius	-150 to +460 mm
Maldives	+300 to + 900 mm
Cape Verde	-1200 to –540 mm

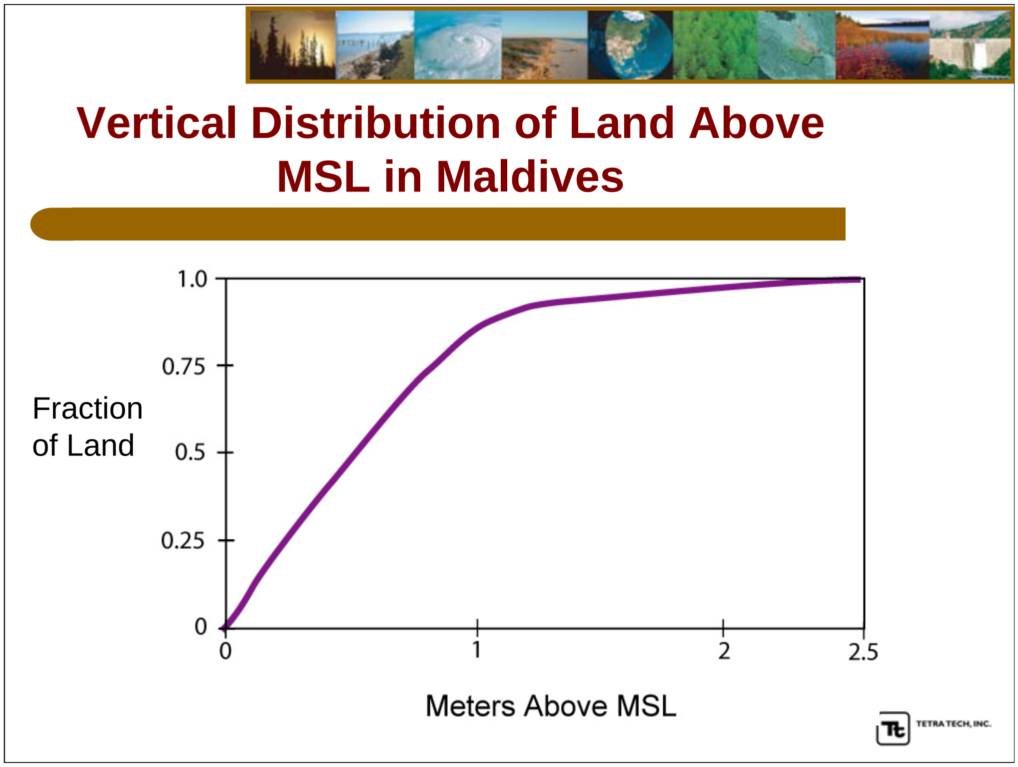
Present global rate of sea level rise: 1.8 mm/yr

TETRA TECH, INC.

What are the projected relative sea level changes on the SIDS?

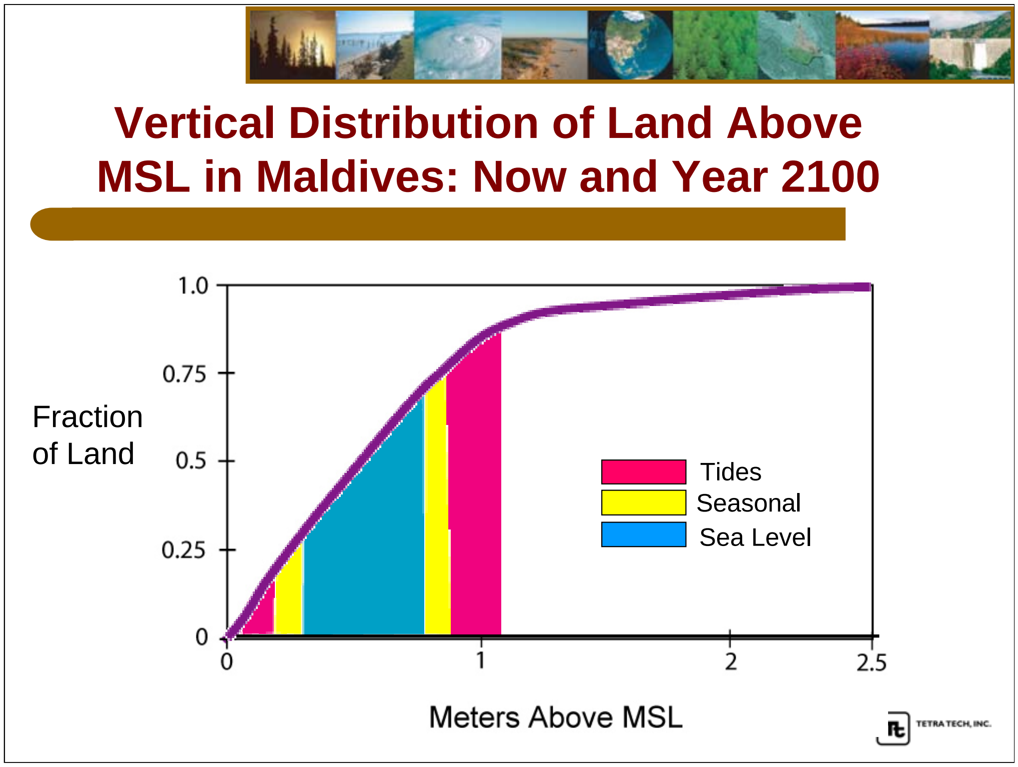
Over the next century, global sea level is projected to rise, but at uncertain rates (200 mm to 800 mm)

However, the local relative mean sea levels will likely change at different rates.



What does this mean with respect to water resources? Lets look at the most extreme example: the Maldives. This slide illustrates the significance of relative sea level rise on the Maldives.

100 % of the land is within 2.4 m of msl, and 80 percent is within 1 m of msl.

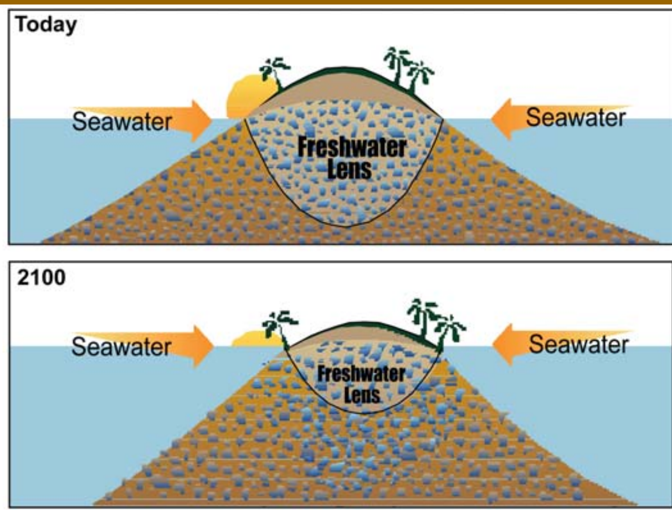


Showing the effects of the range of long term sea level, seasonal sea level, and tidal elevations, we see that it is possible that by the end of the 21st century the land near 1 m above msl today will be submerged.

But the submergence would be only for a portion of the time: when seasonal sea levels are high and tidal levels are high simultaneously.

Possible Reduction in Volume of Freshwater Lens on Maldives by 2100

.



Here is an example for the Maldives to illustrate impacts on the freshwater lens.

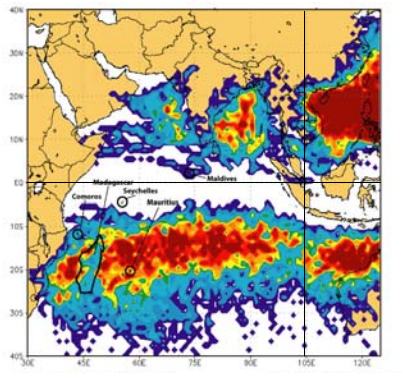
It is assumed that the radius of the island has been reduced by half, which is plausible for year 2100.

The volume of the fresh water lens could shrink by 88 percent.

Of course, other issues would arise as well.

Tropical Cyclones in Indian Ocean

(Storms with sustained wind > 63 km/hr or 38 mph)



Year 2004:

At or below climatological averages in Indian Ocean, Arabian Sea and Bay of Bengal.

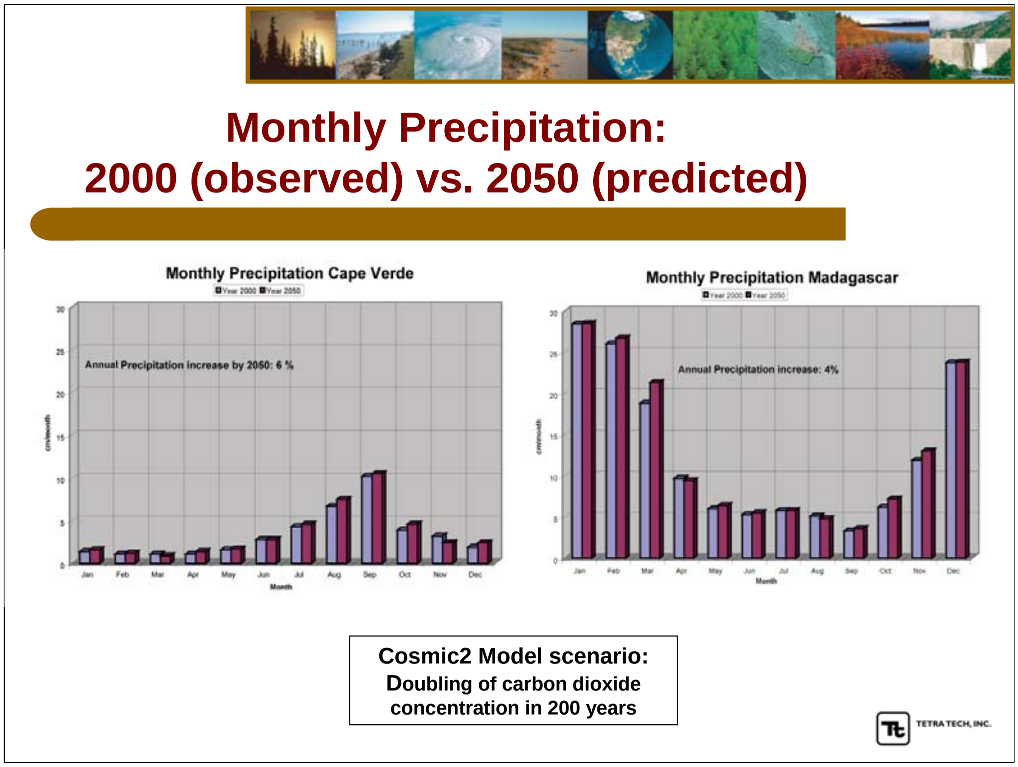
TETRA TECH, INC.

Tropical cyclones can cause great destruction on the islands, while at the same time provide large amounts of precipitation.

The graph summaries the storm tracks for tropical cyclones over the past 25-30 years.The activity is typically greater in the southern Indian Ocean. Note that Mauritius, Madagascar, and Comoros are within the typical storm tracks. The Seychelles are outside, and the Maldives are on the edge.

The numbers of tropical cyclones in the Indian Ocean were examined for both 2004 and for longer term records (back to the 1970s). The year 2004 was a typical year in the Indian Ocean with 12 cyclones in the southern Indian Ocean and 5 in the Northern Ocean (Compared to longer term averages of 13 and 5, respectively). There did not appear to be a trend toward increases numbers of storms. Severity was not examined.

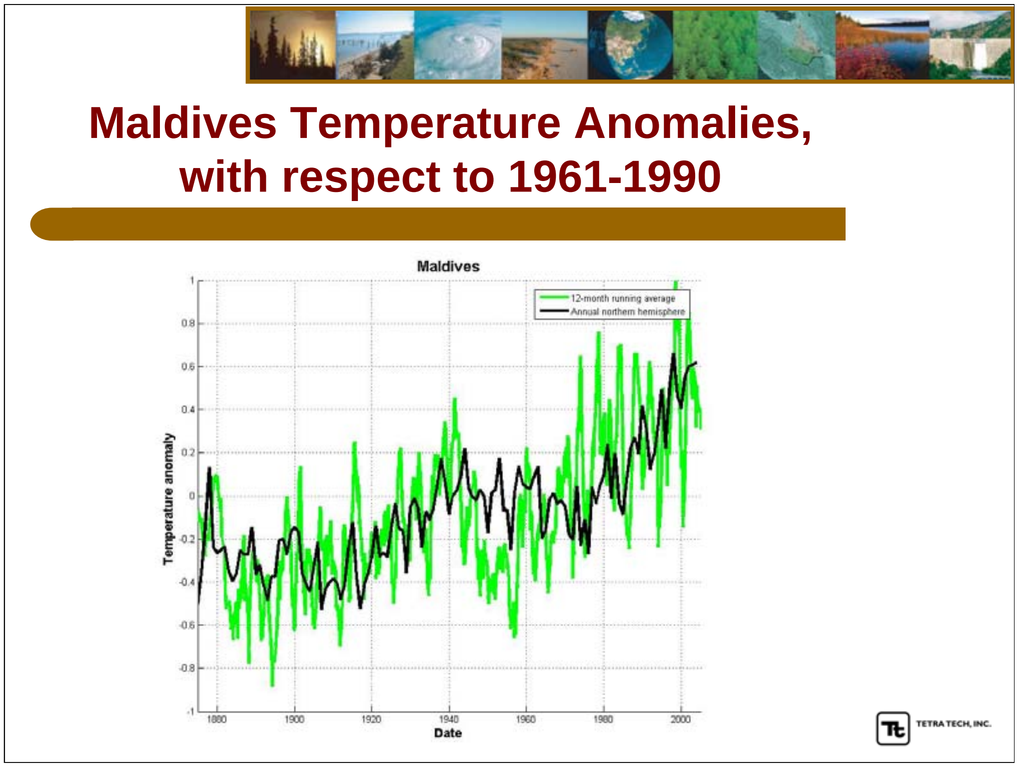
Regarding changing tracks, while this may occur, those islands near the equator typically do not get the cyclones, perhaps due to effects such as coriolis acceleration.



Using a model called Cosmic2, which is based on results of GCMs such as the GISS model, predictions were made of monthly precipitation for each of the SIDS. Above results are shown for Cape Verde in the Atlantic and Madagascar in the Indian Ocean.

Understanding that there is large uncertainties in estimations of predicted precipitation, both show a slight increase in annual precipitation (4% to 6%) , with most of the increase coming during the wet season. Other models gave somewhat different predictions, which is not unexpected.

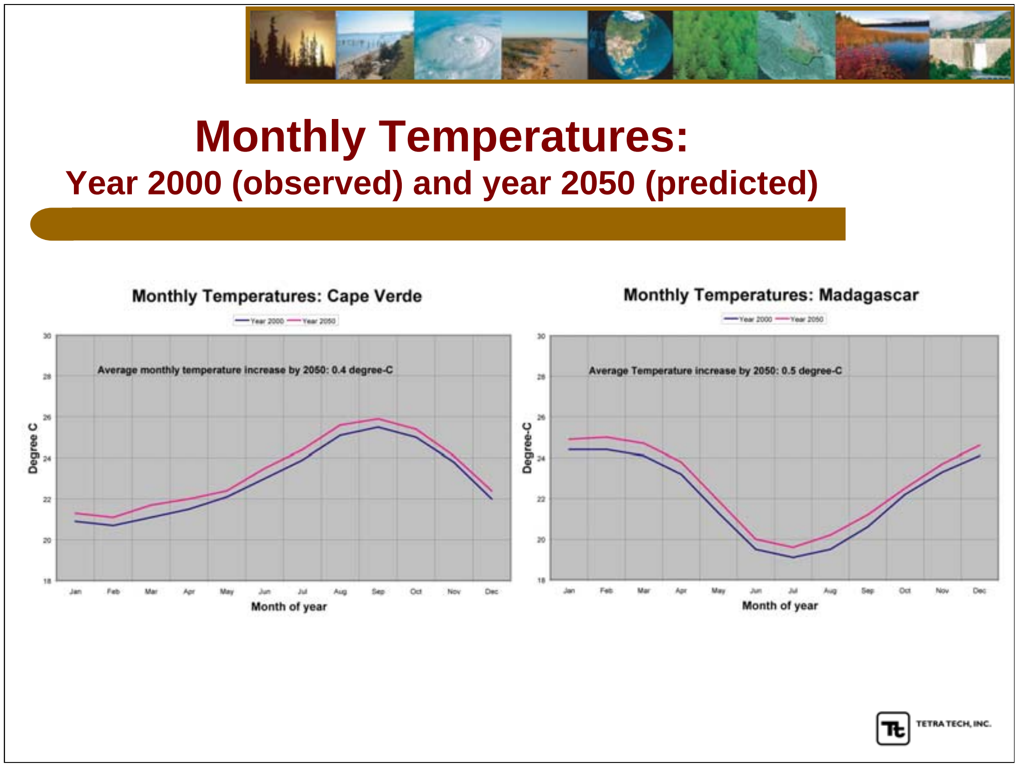
Dry season precipitation appears to be either unchanged, or slightly reduced-. This tells us that with increased population, and the same or less precipitation during the dry season, stresses on water resources should increase.



The next climatic factor we examine is temperature.Temperature increases can cause impacts on water resources by , for example, increasing evaporation, making for less available water.

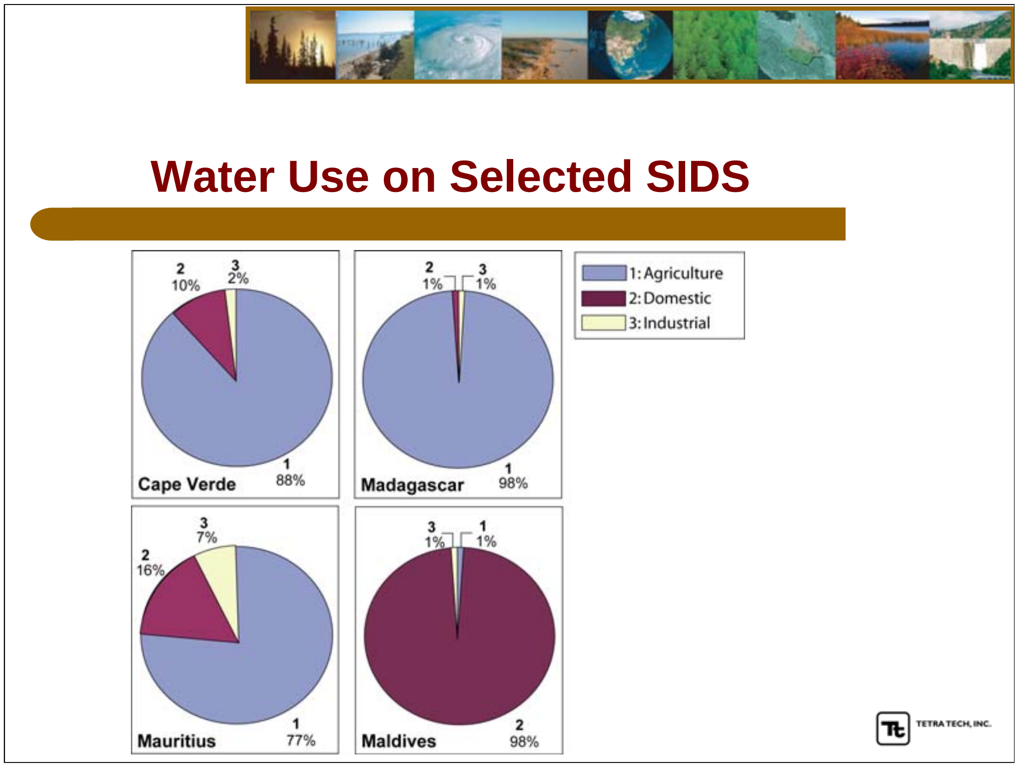
Here an example of northern hemisphere temperature increases is compared to temperature increases in the Maldives.

They both show similar trends, while the temperature variability on the Maldives is much greater, as expected.



Examples of monthly temperatures in 2050 on Cape Verde and Madagascar are shown. We again used Cosmic2 and show results from GISS GCM.

While the seasonal temperature patterns differ greatly on the two islands, the temperature increase is approximately the same on both : 0.5 deg-C by 2050. There are uncertainties in these predictions, depending on the scenario simulated, and model uncertainties.

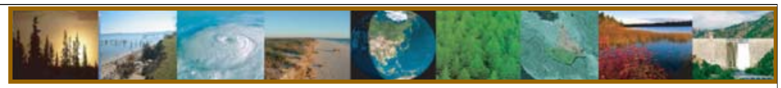


Here are four pie charts that show water use by sector on four SIDS. We were not able to find even this basic information on all the SIDS, providing an example of the limited data.

Note that on three of them (Cape Verde, Madagascar, and Mauritius) most of the water use is for agriculture. Not too surprising, as Madagascar and Mauritius are the two largest SIDS.

On the Maldives, there is very little room to develop agriculture (recall from the space shot of Male).

Based on FAO data, the total amount of water withdrawals (3.3 million cubic meters per year) exceeds the amount of precipitation (1.0 M). Most of the withdrawn water is from the groundwater, and appears to be beyond sustainable yields. On Male specifically, the thickness of the freshwater lens has decreased from 30 m to 1 m, and it is contaminated. The volume of water originally in the aquifer was about 30 M cubic meters, which would be about a 15 year supply for 100 liters/day/capita. Nationwide, there might be 3000 M cubic meters available fresh water in pristine state, or enough for more than 100 years supply.



Estimated Freshwater availability: 1980-2050 (gal/(cap-day)

SIDS	(P-E)/Population		
	Year 1980	Present	Year 2050
Madagascar	25,000	14000	4600
Maldives	480	280	110
USA (Alaska)	-	5500(>1M)	-

TETRA TECH, INC.

This graph provides one metric of the relative importance of climate change(precipitation, temperature, evaporation) and other stressors(population growth) on availability of water resources on the SIDS.

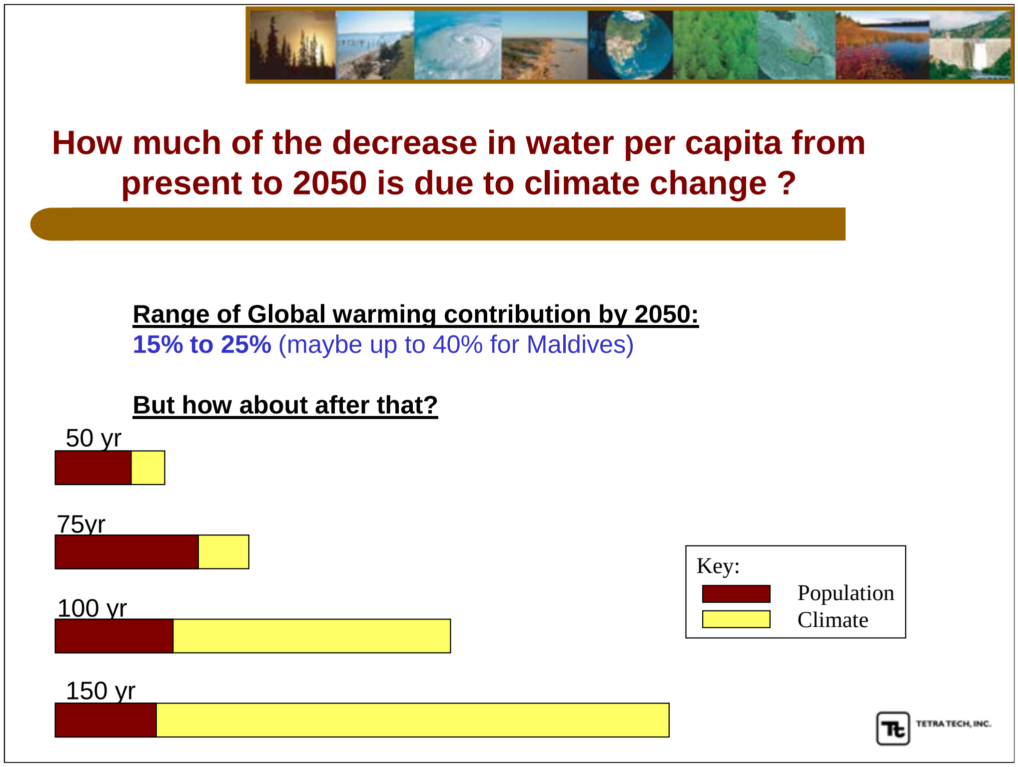
Climate change is reflected in both P and E. Population is the other variable. Size of the island, while fixed, is also considered. We do not include sources of water other than precipitation, such as desalinated water.

The two examples (Madagascar and Maldives) show the range of this metric on the SIDS.

Compare to USA

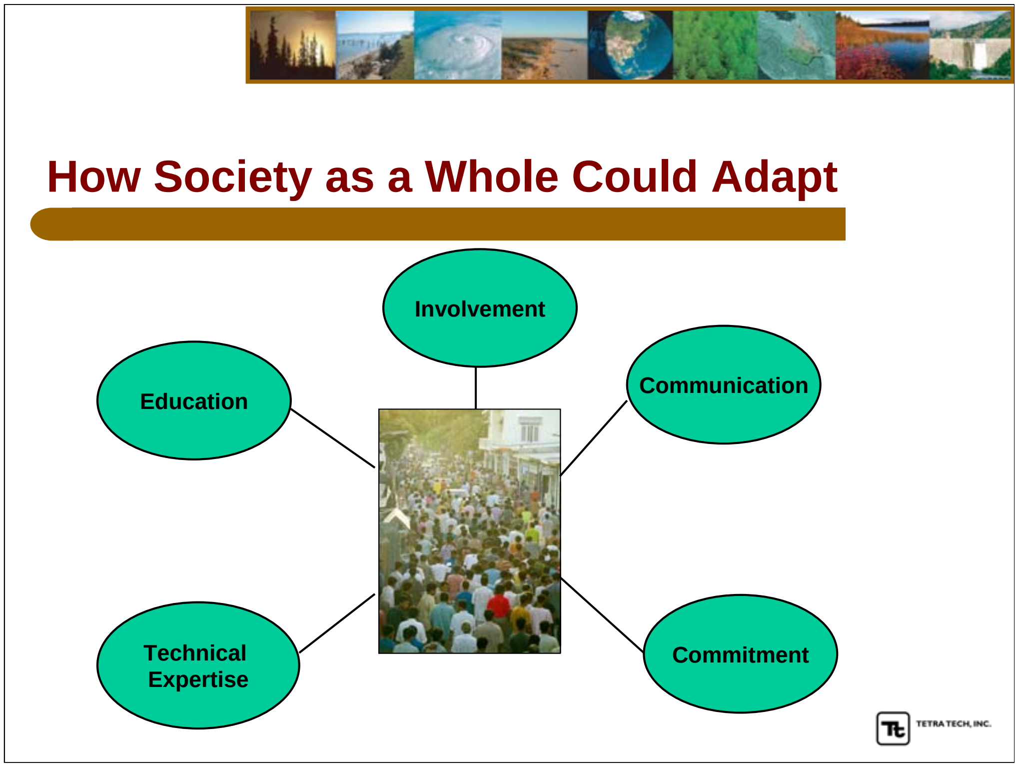
In the Maldives, for example, by year 2050 the available water is predicted to approach 110 gal/cap-day. Or 440 liters/cap-day. Note this is between the rate consumed by natives and tourists, implying that most of the rainwater needs to be captured to maintain a supply. It is apparent that additional sources of freshwater will be needed (such as through desalination. (In 1991 , desalination plants produced 1000 cu m/day).

In a period of less than 100 years, this metric of water resource availability would have decreased by 75%



It is predicted that only about 20 percent in the decrease in the water availability metric is due to projected climate change by 2050.

However beyond that time, the effects of climate change is expected to increase.



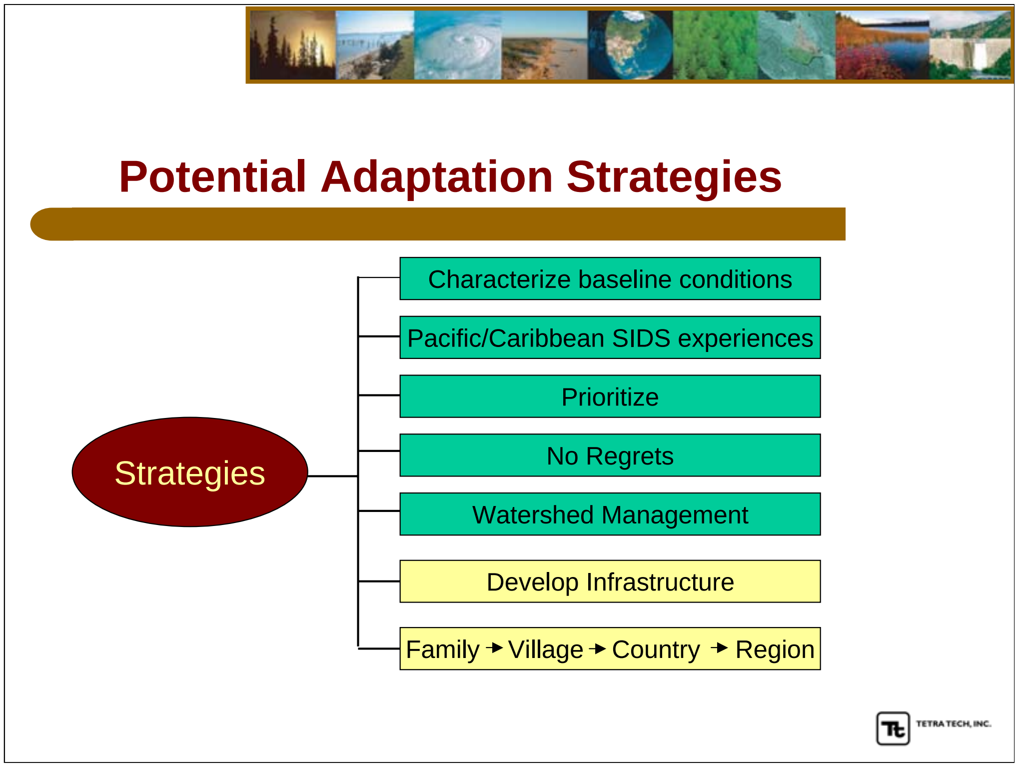
Society as a whole will play an important role in adapting to changing water resources. Example ways include:

Education, leading to an understanding of such issues as the connection between solid waste disposal and contamination of water resources

Communication, such as inter-island web sites that discuss issues and solutions

Commitment to the long term

Creation of local technical expertise



Here are some general strategies. These are only guides. Start with these:

Baseline conditions seem to be poorly characterized, especially the significance of climate variability. Seasonal characterization is important, since dry seasons occur on most SIDS.

Learn from the Pacific/Caribeann SIDS

Prioritize problems: Too much to deal with all at once

Develop no regrets alternatives that will be effective regardless of whether climate change or continued population growth turns out to be most important

Use the concept of watershed management to access and protect water resources.

On longer term:

Develop infrastructure to convey and store water

Determine how different spatial scales can help with resilience

Success Stories

Seychelles
- Waste management and sanitary sewage treatment increasing.
- Desalination facilities constructed; service for up to 45,000 people.

Maldives
- Desalination beginning to augment natural supplies
- New island under construction: Hulhumale

Cape Verde
- Drip irrigation successful

Overall
- Resiliency of people

TETRA TECH, INC.

We will finish on a positive note.There are success stories relative to water resources.