Sources and pathways of bacteria affecting water quality on Darwin Harbour beaches and waterways:

What do we know?
What do we need to know?

DARWIN HARBOUR
BEACH WATER QUALITY TASK FORCE

Initial Report

October 2011

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Executive summary

In June 2010, following the detection of bacteria levels above recreational water quality guidelines in water samples taken from Lake Alexander by Darwin City Council, the Department of Health initiated weekly *Escherichia coli* and enterococci bacteria monitoring at 11 public beaches around Darwin Harbour. Further detection of bacteria levels above recreational water quality guidelines subsequently led to the Department of Health issuing precautionary advice against swimming at several Darwin Harbour beaches during the 2010 and 2011 swimming season.

In June 2011, the Northern Territory Government engaged Professor Andrew Campbell, of Charles Darwin University, to oversee the investigation of sources of bacteria on beaches and the development of actions to address these sources. Professor Campbell is chairing a Taskforce of senior officers from the Department of Health; Natural Resources, Environment, The Arts and Sport; Power Water Corporation; Darwin City Council and the City of Palmerston.

This initial report of Professor Campbell and the Taskforce outlines:

- What we know and what we need to know about the likely sources of bacteria on Darwin Harbour beaches;
- What investigations we need to undertake to find out about the most likely sources of bacteria on beaches and the risks to public health;
- What 'no regrets' measures we can implement in the short term to start to address sources of bacteria, while these investigations are undertaken.

Additional advice will be provided in the final report of the Taskforce, which will:

- Make detailed recommendations on a range of measures to address sources of bacteria on Darwin Harbour beaches;
- Include a succinct summary of key messages to underpin an education program for the wider community; and
- Outline a recommended long-term monitoring system for assessing water quality on Darwin Harbour beaches and to provide an early warning system for any future risks to public health from bacteria on beaches.

What do we know?

- There does not appear to be a single 'smoking gun' source of bacterial contamination of Darwin beaches and waterways.
- Both human and animal faeces in recreational waters pose risks to human health.
- *E. coli* and enterococci are indicators of faecal contamination, with enterococci being a more reliable indicator in marine waters.
- *E. coli* and enterococci are found in the digestive tracts of warm-blooded animals, but can also survive and even replicate in sediments in freshwater and in sediment at beaches.
- Few, if any, incidences of gastrointestinal illness outbreaks in Darwin can be linked to exposure to beaches and waterways.
- *E. coli* and enterococci have been found at Darwin Harbour beaches, sometimes at high levels, but more frequently at low levels.

- When levels were higher than trigger levels specified in guidelines for recreational water quality, precautionary advice against swimming was issued by the Department of Health. Seven beaches were closed to swimming on a total of fourteen occasions in 2010, and three beaches were closed on a total of four occasions in 2011.
- The beach water quality monitoring regime in Darwin Harbour over the last 18 months equates to best practice in Australia and overseas; is more frequent and intensive than in other northern Australian cities like Townsville, Cairns and Broome; and has more conservative trigger values for enterococci than are used in Western Australia and Victoria.
- In studies elsewhere in Australia and overseas, bacteria in coastal environments was found to be coming from wastewater treatment plants; leaking septic systems; sewage discharge from boats; campers or itinerants; domestic animals (such as dogs, horses); wild animals (such as bats, wallabies); or stormwater runoff from the catchment.
- Intensive monitoring around PWC sewage outfalls in Darwin Harbour, in offshore water and at beaches suggests that bacteria levels fall rapidly away from outfalls and that occasionally elevated bacteria levels at beaches are unlikely to be caused by sewage treatment plant outfalls. While sewage outfalls may increase bacteria loads to receiving waters, it is considered that during normal operation, bacteria present in discharge waters would be unlikely to survive in marine waters in sufficient quantity to impact on the water quality of beaches in the region.
- One of the possible sources of bacteria on Darwin Harbour beaches is sewage discharge from boats that are either moored in the Harbour or passing through the Harbour.
- Bacterial loads at particular points in stormwater drains and tidal creeks are often high, suggesting that some bacterial sources are land-based. More targeted monitoring will assist to identify potential bacteria 'hotspots' for further investigation.
- Monitoring in Rapid Creek over many years suggests that bacterial loads are sometimes very high, even in the headwaters at Marrara Swamp, but are extremely variable.
- Rainfall events are likely to flush contaminants including bacteria into the Harbour, so bacteria loads are likely to be higher immediately after rain.
- It is common in Australia and overseas for authorities to routinely advise against beach swimming in the days immediately after heavy rain.
- Dangerous aquatic animals (especially Box Jellyfish) probably pose a greater risk to human health on Darwin Harbour beaches than bacterial loads.

What do we need to know?

- According to a comprehensive world-wide review commissioned by the United States Environment Protection Agency (2009) there is *"a lack of detailed and unequivocal information concerning the relative risks of human illness from various sources of faecal contamination in recreational waters".*
- It has been widely assumed that, because many viruses and pathogens are host-specific, human faecal material poses a greater health risk to humans than animal faecal material, but the United States Environment Protection Agency review concludes that there is insufficient empirical evidence to substantiate this.
- It is unclear, at this stage, what the relative contributions of human and animal faecal material are to bacterial loads in Darwin Harbour beaches and water bodies.
- The concentrations of *E. coli* and enterococci in sediments in Darwin creeks and in

sand at beaches have not been measured.

- We also don't understand fully the profile of bacteria counts through time, for example through the Dry Season, then the first rains, then through the Wet Season.
- It is not yet clear what the proportional contribution of stormwater drains or creeks are to bacterial loads. While bacterial counts at particular sampling points may be high, this data needs to be related to flow rates to get a better understanding of the actual risk of beach contamination.
- We haven't yet identified the sources of bacteria in stormwater or creeks at particular 'hotspots'. Measuring a high bacteria count in a drain is relatively easy, but working out where it is coming from — for example an illegal (whether accidental or otherwise) connection of a toilet waste pipe into stormwater rather than the sewer pipe, or discharge of swimming pool waste into the stormwater pipe — is much more difficult.

What investigations do we need to undertake?

- Professor Karen Gibb of Charles Darwin University's Environmental Analytical Chemistry Unit is currently applying advanced genetic fingerprinting techniques to investigate the most likely sources of bacteria on Darwin Harbour beaches. This project will attempt to determine the relative contribution of human and animal faeces to bacterial loads.
- Officers from Power and Water Corporation, Darwin City Council, Natural Resources, Environment, The Arts and Sport and the Department of Health are commencing a program of detailed investigations at particular hotspots to try to identify the sources of elevated bacterial loads, e.g. inappropriate connections to stormwater rather than sewer pipes.
- Investigatory sampling will be undertaken during the 2011/12 Wet Season to better understand how bacteria counts are affected by rainfall.

What measures can we implement now?

- It is proposed that a multi-faceted and comprehensive 'Healthy Harbour education campaign' is developed to increase community awareness about the sources of pollution into Darwin harbour and actions we can all undertake to keep our Harbour healthy. The Healthy Harbour campaign would be developed by the Northern Territory Government and Local Governments, in consultation with a range of key stakeholders from industry and special interest groups. The key audiences for the campaign would be the users of Darwin beaches and waterways, anyone whose actions potentially impact on water quality in creeks, Lake Alexander and beaches, and the general public.
- It is recommended that Part Five of the *Marine Pollution Act* is enacted and that Darwin Harbour is prescribed as a sensitivity zone under the Act, to prohibit the discharge of sewage from ships.
- In 2006, the Territory Government developed a Draft Stormwater Management Strategy for the Darwin Harbour catchment. It is recommended that the Territory Government and Local Governments jointly review and finalise a Stormwater Management Strategy.

Introduction

In June 2010, following the detection of bacteria levels of above recreational water quality guidelines in water samples taken from Lake Alexander by Darwin City Council (DCC), the Department of Health (DoH) initiated weekly *E. coli* and enterococci bacteria monitoring at 11 public beaches around Darwin Harbour. The detection of bacteria levels above recreational water quality guidelines subsequently led to DoH issuing precautionary advice against swimming at several Darwin Harbour beaches during the 2010 and 2011 swimming season.

The Department of Natural Resources, Environment, the Arts and Sport (NRETAS) has undertaken aquatic health monitoring at various sites in Darwin Harbour since 2001. In response to beach closures and increasing community concern, NRETAS and Power Water Corporation (PWC) commenced additional monitoring at sites adjacent to some public beaches and near sewage treatment outfalls, in an effort to elucidate the sources of high bacteria levels. From May 2011, NRETAS also assisted DoH in conducting the beach water monitoring program.

In the first half of 2011, DCC, NRETAS and DoH again detected elevated bacteria levels at Lake Alexander and at various Darwin Harbour beaches.

In June 2011, in recognition of the complexity of the issue, the Department of the Chief Minister (DCM) engaged Professor Andrew Campbell, of Charles Darwin University (CDU), to oversee the investigation of sources of bacteria on beaches and the development of actions to address these sources. Professor Campbell will also be overseeing the design of a long-term monitoring program.

In undertaking this work, Professor Campbell is chairing a Taskforce of senior officers from DoH, NRETAS, PWC, DCC and the City of Palmerston (CoP). Membership and Terms of Reference of the Task Force are at APPENDIX A. The Darwin Harbour Advisory Committee (DHAC) and the Rapid Creek Catchment Advisory Committee (RCCAC) are the key stakeholder reference groups for the Taskforce. Professor Campbell reports to the Minister for Natural Resources, Environment and Heritage and the Minister for Health directly.

This initial report outlines:

- the existing state of knowledge about likely sources of bacteria on Darwin Harbour beaches;
- gaps in the knowledge base that need to be filled and an investigation program to fill these gaps in the knowledge base, to determine the most probable sources of bacteria on beaches and the actual nature and level of public health risks;
- complementary measures such as public education activities that could be initiated in parallel; and
- recommendations for actions to be undertaken in the short term, including likely resource requirements and probable timelines.

Existing knowledge

This section outlines the current state of knowledge, with respect to likely sources of bacteria on Darwin Harbour beaches.

Background information regarding *E. coli* and enterococci

Escherichia coli (*E. coli*) and enterococci are two types of bacteria that are found in the digestive systems of humans and other warm blooded animals. These bacteria are frequently used to indicate whether a water body has been contaminated by faeces and whether it is safe to swim (USEPA 2011a).

Infections and illnesses thought to be caused by recreational contact with water contaminated by faeces are usually mild and are therefore difficult to detect through routine health surveillance systems. Targeted epidemiological studies overseas have suggested that infections such as gastroenteritis, respiratory infections and ear infections, might be associated with faecally polluted recreational water (NHMRC 2008).

It has been widely assumed that, because many viruses and pathogens are host-specific, human faecal material poses a greater health risk to humans than animal faecal material, but a review by the United States Environment Protection Agency review (2009) concludes that there is insufficient empirical evidence to substantiate this. The United States Environment Protection Agency (2009) states that there is *"a lack of detailed and unequivocal information concerning the relative risks of human illness from various sources of faecal contamination in recreational waters".*

E. coli and enterococci are not thought to cause illnesses directly, but rather provide an indication of where faecal contamination might have occurred (USEPA 2011a). *E. coli* and enterococci are used as indicators as they are relatively cheap to analyse, in comparison to illness-causing bacteria, viruses and protozoans, which exist at very low levels and are expensive to detect. In freshwater, *E. coli* is commonly used as an indicator of faecal contamination, whereas in marine water, enterococci is now recommended to be used. This is because there is a clearer relationship between enterococci and disease rates in marine waters (NHMRC 2008).

When *E. coli* and enterococci are detected in water bodies at high levels, studies are often undertaken to determine the sources of these bacteria. Potential sources of these bacteria in coastal environments include wastewater treatment plants, leaking septic systems, sewage discharge from boats, campers or itinerants, domestic animals (such as dogs, horses), wild animals (such as bats, magpie geese, wallabies) or stormwater runoff from the catchment. Investigations frequently find multiple sources of bacteria, rather than just one source (USEPA 2009).

The levels of *E. coli* and enterococci in raw sewage are between 100,000 and 10,000,000 per 100mL (NHMRC 2008). By comparison, in the Territory, if two consecutive water samples within 24 hours include more than 200 enterococci per 100mL, precautionary advice is issued against swimming.

Recent studies have also determined that *E. coli* and enterococci can exist and replicate in the sediments on the bottom and on the banks of fresh water bodies, streams and creeks, and in the sediments and sands on beaches and coastal areas (Abdelzaher et al 2011; Pachepsky and Shelton 2011; Byappanahalli et al 2006). These bacteria can replicate in sediments and sands and can be resuspended in the water column, creating high levels of bacteria in water samples. This means that sediments can act as a source of *E. coli* and enterococci and that tidal fluctuations (such as spring tides) can influence counts of these bacteria found in water samples from beaches.

Rainfall can also influence the counts of *E. coli* and enterococci found in water samples. If the sources of these bacteria are in the catchment, rainfall can wash bacteria down streams and onto beaches (Kleinheinz et al 2010). A recent study in Florida (Abdelzaher et al 2011) has shown that after rainfall, indicators (*E. coli* and enterococci) appeared first, then pathogens appeared up to two days later. It appears that pathogens can have different transport routes compared to indicators and can be affected differently by rainfall. They may also occur deeper in the sediment and can be transported from groundwater to the beach water column due to hydraulic gradients induced by heavy rain. This effect may be particularly marked for the first flush events (first rains after a period of no rain).

These recent studies underline the importance of monitoring through time in both the wet and dry seasons to better understand the temporal fluctuation of bacterial loads in relation to rainfall and tidal events. In many jurisdictions, beaches are automatically closed after rainfall events in recognition of the effect of rainfall.

In the past 10 years, research has focussed on developing methodologies for tracking the sources of faecal pollution (Scott et al 2002). One method now being used is based on identifying a genetic 'fingerprint', or distinct DNA pattern, of the bacteria from a known source and comparing it to the bacteria in water samples from beaches or water bodies. To perform a source tracking study, samples of faecal matter from sources throughout the catchment are taken, and distinct genetic fingerprints are isolated from the bacteria from each source. The bacteria present in the water bodies is then compared to the potential sources (Clean Water Services 2005).

Monitoring and research in Darwin Harbour

Historic beach monitoring in Darwin Harbour

The Northern Territory Government conducted monitoring of bacteria in waters from Darwin Harbour beaches between 1966 and 1992. Monitoring was generally conducted monthly, during the Dry Season, with some monitoring undertaken in the Wet Season.

Due to differences in sampling and analytical techniques, it is difficult to make comparisons between the results of historic monitoring and the results of current monitoring of Darwin Harbour beaches.

However, a review of monitoring conducted between 1967 and 1983 suggested that counts of faecal coliforms were higher in the Wet Season than in the Dry Season, although this was not tested statistically (Allen 1983). In the Dry Season, median counts of faecal coliforms were generally between 1 and 200 faecal coliforms per 100mL, but counts

were variable with occasional counts as high as several thousand faecal coliforms per 100mL (Allen 1983). This suggests that occasional exceedances of the current national water quality guidelines for recreational water quality have occurred at Darwin Harbour beaches over several decades.

Between 1987 and 1992, Metcalfe and Townsend (1994) noted that the microbiological quality of Darwin Harbour beaches generally complied with national guidelines for primary contact recreation (at the time).

Darwin Harbour beach water monitoring program

The Darwin Harbour beach water monitoring program, which commenced in June 2010, involves the collection of water samples from shallow water at a number of popular swimming beaches in Darwin Harbour (See Table 1 and Figure 1). Samples are collected at nine beaches weekly (Rapid Creek (Chapman Road); Nightcliff (Walker Street); Casuarina; Little Mindil; Mindil; Vesteys; Cullen Bay; East Point; and Lee Point Beaches), with monthly sampling at Wagait Beach and Mandorah Beach, during the swimming season. Sampling follows a standard beach water sampling protocol, which involves collection of samples in knee deep water at 20cm depth using a sterile water sample bottle and aseptic sampling techniques.

Of note, the Department of Health advises that between October 1 and June 1, people should not swim at Darwin Harbour beaches due to the risk of Box Jellyfish.

Table 1. Beach sampling site locations

Site No.	Site Name	Latitude	Longitude
1	Lee Point Beach	-12.3316°	130.893°
2	Casuarina Beach	-12.3547°	130.870°
3	Nightcliff Beach (Chapman Rd end)	-12.3752°	130.856°
4	Nightcliff Beach (Walker St)	-12.3782°	130.847°
5	East Point	-12.4130°	130.829°
6	Vesteys Beach	-12.4306°	130.834°
7	Mindil Beach	-12.4429°	130.831°
8	Little Mindil	-12.4469°	130.829°
9	Cullen Bay Beach	-12.4497°	130.822°
10	Mandorah Beach	-12.4434°	130.767°
11	Wagait Beach	-12.4280°	130.736°

Beach water monitoring samples were collected by DoH in 2010 and by NRETAS in 2011. Until 30 June 2011, water samples were sent interstate for determining counts of *E. coli* and enterococci, with results received within 7 to14 days. From 1 July 2011, samples have been sent to the Department of Resources laboratories in Darwin, for enterococci analysis, with results received within 48 hours.

Until 30 June 2011, the results of analysis were assessed against the *Northern Territory Recreational Microbiological Water Quality Guidelines 2007*, to determine whether beach closures were necessary.

On 1 July 2011, the new *Public and Environmental Health Act* was enacted which enables national guidelines to be formally adopted. Under this Act, the National Health and Medical Research Council (NHMRC) 2008 *Guidelines for Managing Risks in Recreational Water* were adopted and gazetted. From 1 July 2011, enterococci only have been counted from beach water samples, as *E. coli* is no longer a recommended indicator under the guidelines.

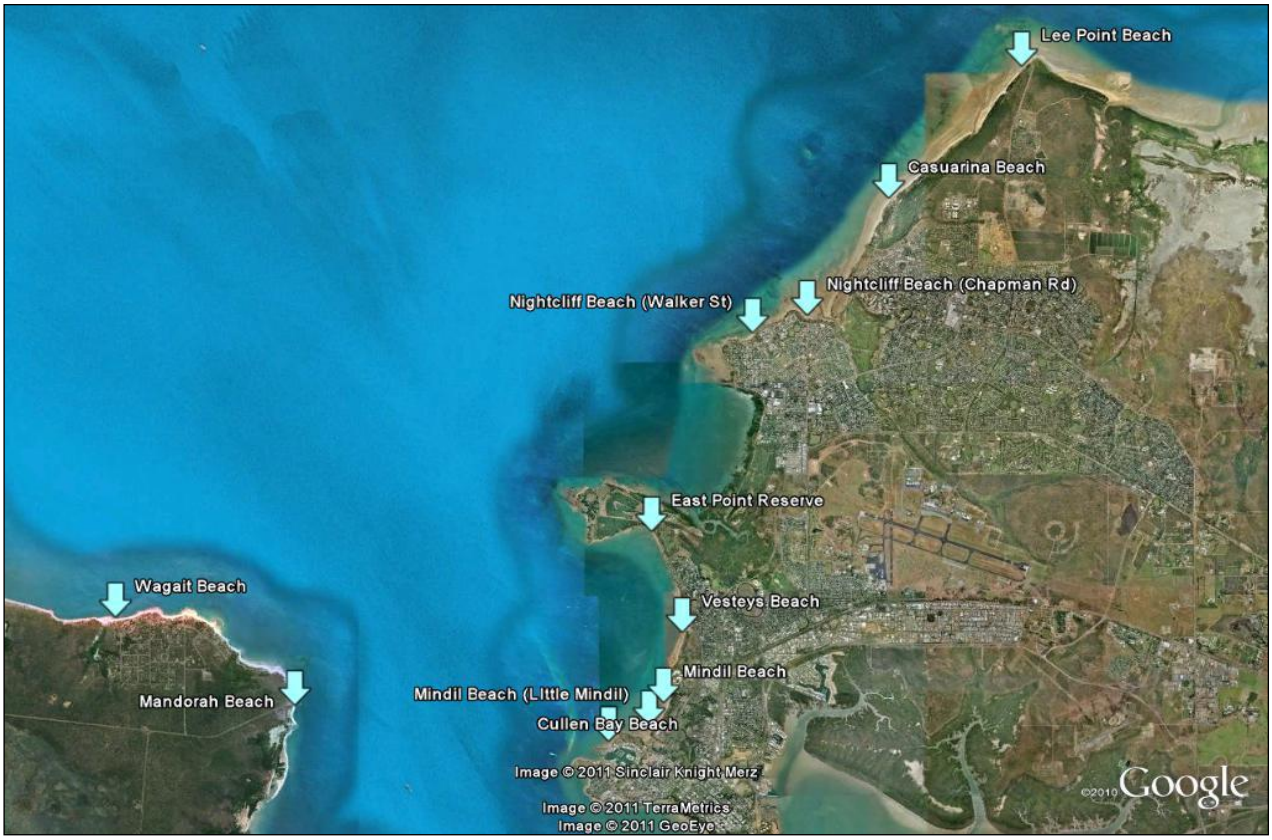

Figure 1. Beach water sampling sites

In the swimming seasons of 2010 and 2011, the following generic trigger levels were used to determine whether beaches were suitable for swimming:

- Green Mode (open for swimming) – All samples to be less than or equal to 50 enterococci per 100mL or all samples less than 200 *E. coli* per 100mL.
- Amber Mode (open for swimming) – All samples between 51 and 200 enterococci per 100mL or single sample greater than 200 *E. coli* per 100mL.
- Red Mode (closed for swimming) - Two consecutive samples within 24 hours greater than 200 enterococci per 100mL or single sample greater than 500 *E. coli* per 100mL.

From 1 July 2011, only the enterococci trigger level has been used.

In 2010, samples to determine microbiological beach water quality were also collected 200 metres offshore from beach water monitoring points by the Surf Life Saving Northern

Territory (SLSNT). DoH provided beach water sampling training to SLSNT personnel prior to water samples being taken from the jet ski. As far as practicable, the same method used by DoH Environmental Health Officers was used as for collecting shallow water samples. SLSNT members collected water samples from 200 metres off shore at Mindil and Nightcliff beaches. Samples were collected from the front of a jet ski away from the vehicle exhaust. A numbered sample bottle was inverted aseptically into water to elbow depth, turned upright and allowed to fill. Sample bottes were capped aseptically and transported on ice to await collection by DoH Environmental Health Officers for delivery to the analytical laboratory. SLSNT members are familiar with aseptic collection of water samples from their work at public swimming pools.

Results of 2010 beach water monitoring

Throughout the 2010 swimming season, there were a number of beach closures, as a result of either *E. coli* counts exceeding 500 per 100mL and/or two consecutive samples having enterococci counts exceeding 200 per 100mL (see Table 2). Of note, not all red mode classifications resulted in beach closures. For example, a beach closure on the basis of enterococci levels requires two consecutive enterococci counts exceeding 200 per 100mL.

Table 2. Darwin Harbour beach modes and closures in 2010.
Note: Both *E. coli* and enterococci were counted in 2010 to determine beach mode and closures.

Beach	Number of times beach classified at each mode or closed				
	Green	Amber	Red	Total	Closed
Casuarina Beach	61	6	5	**72**	1
Cullen Bay Beach	43	1	0	**44**	0
East Point Reserve	64	2	4	**70**	1
Lee Point Beach	41	5	2	**48**	0
Mandorah Beach	10	0	0	**10**	0
Mindil Beach	58	7	11	**76**	2
Little Mindil Beach	61	5	8	**74**	1
Rapid Creek Beach (Chapman Rd)	42	12	26	**80**	4
Nightcliff Beach (Walker St)	55	11	12	**78**	3
Vesteys Beach	55	6	13	**74**	2
Wagait Beach	9	1	0	**10**	0
	499	**56**	**81**	**636**	**14**

Key	Status	*E. coli* per 100mL	Enterococci per 100mL
Green Mode	OPEN FOR SWIMMING	0 - 200	0 - 50
Amber Mode	ALERT - OPEN FOR SWIMMING	201 - 499	51 - 200
Red Mode	CLOSED FOR SWIMMING	500+	201+
Closed	Closure Incidents - number of unique beach closures		

There were 636 separate beach water samples analysed in 2010. Of these, 499 samples resulted in beaches being classified as green mode, 56 as amber mode (alert) and 81 as

red mode (precautionary advice against swimming). Only 14 separate beach closures occurred in 2010. Closures were as follows:

- Cullen Bay, Lee Point, Mandorah and Wagait Beaches were not closed;
- Casuarina, East Point and Little Mindil were closed to swimming once;
- Mindil and Vesteys Beaches were closed to swimming twice;
- Nightcliff Beach was closed to swimming three times;
- Rapid Creek Beach was closed four times.

The results of the offshore sampling undertaken by Surf Life Saving identified consistently low counts of *E. coli* and enterococci, even when beaches were closed to swimming due to high bacteria levels at knee depth closer in shore.

Results of 2011 beach water monitoring

In 2011, at the time of writing this report, Casuarina Beach and Lee Point Beach had been closed once and Rapid Creek Beach had been closed to swimming twice (see Table 3). Other beaches have remained open.

Table 3. Darwin Harbour beach modes and closures - May to October 2011.
Note: Both *E. coli* and enterococci were counted until 30 June 2011 to determine beach mode and closures. From 1 July 2011, only enterococci were counted.

Beach	Number of times beach classified at each mode or closed				
	Green	Amber	Red	Total	Closed
Casuarina Beach	24	8	2	34	1
Cullen Bay Beach	32	0	1	33	0
East Point Reserve	32	1	0	33	0
Lameroo Beach	27	1	1	29	0
Lee Point Beach	30	4	3	37	1
Mandorah Beach	9	0	0	9	0
Mindil Beach	29	5	1	35	0
Little Mindil Beach	32	0	1	33	0
Rapid Creek Beach (Chapman Rd)	21	9	10	40	2
Nightcliff Beach (Walker St)	26	8	1	35	0
Vesteys Beach	31	2	1	34	0
Wagait Beach	7	2	0	9	0
Total	300	40	21	361	4

Key	Status	*E. coli* per 100mL	Enterococci per 100mL
Green Mode	OPEN FOR SWIMMING	0 - 200	0 - 50
Amber Mode	ALERT - OPEN FOR SWIMMING	201 - 499	51 - 200
Red Mode	CLOSED FOR SWIMMING	500+	201+
Closed	Closure Incidents - number of unique beach closures		

From 3 May until 24 October 2011, 361 separate beach water samples have been analysed. Of these, 300 samples led to green mode beach classifications, 40 to amber

mode (alert) classifications and 21 to red mode classifications (resulting in four precautionary advices against swimming being issued).

Sanitary inspections and classification of Darwin Harbour beaches

According to the NHMRC 2008 guidelines, sanitary inspections should be undertaken to determine the susceptibility of beaches to faecal contamination and the consequent risk to human health of bathers. Sanitary inspections involve identifying all sources of faecal contamination which may affect the water such as stormwater drains, native animals, sewage outfalls, septic tanks, and boating activities; calculating the likelihood of these potential impacts and then assessing the overall human health risk.

As part of this assessment, the following information is collected:

- Type of water body, and the level of mixing that occurs;
- Surrounding land cover including agricultural runoff;
- Number of bathers and type of recreational activities performed;
- Toilet facilities in the area, including sewered and non-sewered facilities;
- Sewage outfalls and pump stations;
- Stormwater discharges;
- Septic tank systems;
- Waste water reuse schemes;
- Stormwater runoff after rainfall events;
- Riverine discharges within 1 km, and stormwater/ sewage discharges to riverine system;
- Boats in the Harbour and whether pump out facilities are provided;
- Campers and itinerants living in close proximity to the beach or nearby waterways;
- Wildlife i.e. aquatic bird density;
- Domestic animals and their density on beaches, such as dogs being exercised and evidence of any defecating on beaches;
- Agricultural animals.

The NHMRC Guidelines also recommend assigning Microbial Assessment Categories (A to D) to beaches based on enterococci counts and the results of sanitary assessments. Beach classifications can then be determined from a combination of microbial assessments and sanitary inspections.

In 2010, sanitary inspections were undertaken for Darwin Harbour beaches by DoH environmental health officers and reports produced. These reports classified recreational waters according to their susceptibility to pollution, and the public health implications of that pollution. Public health consequences were graded minor, moderate or major according to a range of criteria in the NHMRC Guidelines. In accordance with NHMRC Guidelines, risk assessments were completed and Sanitary Inspection Categories were assigned, ranging from low at Mandorah, Wagait and Casuarina Beaches; to high at Nightcliff and Vesteys Beach.

The NHMRC Guidelines allow water bodies to be assessed after a minimum of 20 water analysis tests have been undertaken. Further testing during 2011-12 will allow for Darwin Harbour beach classifications to be developed. Until classifications are developed, it is

considered appropriate that generic microbiological trigger levels are used to determine beach closures.

Darwin Harbour water quality monitoring program

NRETAS has undertaken monitoring since 2001 to determine the water quality of the Darwin Harbour region. In 2011, 61 estuarine sites and 25 freshwater sites were monitored in Darwin Harbour, either quarterly, monthly, annually or on an as-needed basis. Indicators monitored included: electrical conductivity, turbidity, pH, temperature, dissolved oxygen, total suspended solids, chlorophyll a, nitrate, nitrite, ammonia, total nitrogen, total phosphorus, filterable reactive phosphorus. *E. coli* and enterococci were not measured at all 61 sites, but were measured at 16 sites (12 beach sites and four tidal creek sites) in 2010 -11.

In 2009 and 2010, NRETAS, with support from the Darwin Harbour Advisory Committee, produced a suite of Darwin Harbour Region Report Cards, providing snapshots of water quality and the health of aquatic ecosystems across the Harbour and its catchment. The Report Cards summarised water quality and biological health data collected by NRETAS from 2001 to 2010, from freshwater and estuarine monitoring sites in Darwin Harbour. In 2010, NRETAS also reported on results of bacteria sampling through the Darwin Harbour Region Report Cards.

The 2010 Report Cards showed that water quality in outer Darwin Harbour, Elizabeth River, Darwin-Palmerston regions and outer Shoal Bay was in excellent condition. However, water quality at Buffalo Creek was in very poor condition and water quality at the Myrmidon Creek was in poor condition. Water quality in the freshwater streams within the Harbour's catchments was assessed as being in good to excellent condition at the sites monitored. The water-bug community at the catchment biological monitoring sites is mostly unimpaired or equivalent to reference condition (Drewry et al 2010).

Monitoring of Lake Alexander

Lake Alexander is a recreational swimming lake built in 1990-91 on an area of low-lying coastal marsh at East Point. Lake Alexander has a maximum depth of 2.8 metres. Its seawater is drawn from nearby Fannie Bay Beach, but it is also subject to run-off from the surrounding area.

DCC conducted at least weekly monitoring of *E. coli* and enterococci at six sites in Lake Alexander in 2010 and 2011, including throughout the Wet Season. As for beach monitoring, water samples were assessed against *Northern Territory Recreational Microbiological Water Quality Guidelines* until 30 June 2011 to determine suitability for swimming, after which time, samples were assessed against NHMRC Guidelines.

Levels of bacteria above guideline levels resulted in closures of the Lake to swimming in May and June 2010 and during the 2010-11 Wet Season (December 2010 to April 2011).

Monitoring of the Darwin Waterfront Recreation Lagoon

The Darwin Waterfront Recreation Lagoon is a permanent body of seawater at the Darwin Waterfront Precinct, officially opened in 2009. The Lagoon is protected from the rest of the

Harbour by a seawall and provides for swimming and other water-based activities. Water is pumped into and out of the Lagoon from the sea continuously and the water quality is maintained through mechanical flushing and mixing. The Recreation Lagoon has an artificial beach that has been constructed using imported sand fill to a depth of 0.5 to 1 metre, on top of a geo-textile fabric on the natural surface.

As part of the Darwin Waterfront Corporation's management plan, water quality in the Lagoon is checked at least monthly. As for beach monitoring, water samples were assessed against *Northern Territory Recreational Microbiological Water Quality Guidelines* until 30 June 2011 to determine suitability for swimming, after which time, samples were assessed against NHMRC Guidelines.

From 20 April 2010 to 1 May 2010, the Recreation Lagoon was closed to swimming due to high counts of enterococci. During April and May 2011, monitoring of water quality was conducted fortnightly to check whether high counts would recur. However, counts remained below Guideline levels in 2011, and consequently the lagoon has remained open to swimming.

Monitoring of PWC sewage outfalls for bacteria

In July 2010, NRETAS requested PWC undertake fortnightly sampling at sewage outfalls and further downstream sites for *E. coli* and enterococci for a period of three months to determine the potential impact and extent of discharges. This sampling was in addition to the regular testing undertaken as part of their Waste Discharge Licences.

Throughout this testing period, results of both deep-water sampling and independent outfall testing in Darwin Harbour (undertaken by NRETAS) indicated there was no link to high levels of bacteria identified in beach water monitoring and PWC sewage discharges.

As part of existing Licence requirements, PWC continues to monitor outfall water quality on a monthly basis. New licences are progressively being developed for PWC, with monitoring from discharge points being expanded to include further monitoring in creeks and waterways into which they discharge.

Specialised testing of the foreshore water around Fannie Bay beaches in mid-June 2010 by NRETAS indicated that the *E. coli* responsible for elevated bacterial counts appeared not to have been related to the Larrakeyah and Ludmilla outfalls. While sewage outfalls may increase bacteria loads to receiving waters, it is considered that during normal operation, bacteria present in discharge waters would be unlikely to survive in marine waters in sufficient quantity to impact on the water quality of beaches in the region.

In 2010, Surf Life Saving NT sampled 200 metres off shore from Mindil and Nightcliff beaches to determine whether the source of the bacteria was coming from either on or off shore. Bacteria levels in these off shore samples have been consistently low, even when the beaches have been closed to swimming due to high bacteria counts.

PWC is currently completing works to close the Larrakeyah ocean outfall and provide treatment improvements at the Leanyer Sanderson sewage treatment plant. Information on these projects is available from the Power and Water Internet site as follows:

- http://www.powerwater.com.au/__data/assets/pdf_file/0014/27302/Leanyer_Sanderson_ponds.pdf

- http://www.powerwater.com.au/__data/assets/pdf_file/0016/3265/Larrakeyah_outfall_closure_plan_June_2011.pdf
- http://www.powerwater.com.au/__data/assets/pdf_file/0003/34761/EastPointOutfallPER.PDF

Of note, flows of sewage entering Sewage Treatment Plants typically increase dramatically during wet weather events. It is normal for sewage collection systems throughout Australia and internationally for sewage flows to increase by three to five times the dry weather flow. This is caused by illegal stormwater connections to the sewage system and through unsealed or faulty pipes, pits and connections allowing entry of the rising water table as soils become saturated during the Wet Season.

While sewage flows increase proportionally with rainfall events, the quality of treated sewage leaving the treatment plants typically improves due to dilution with stormwater during the Wet Season. Despite this seemingly positive benefit of stormwater infiltration into the sewage system during rainfall events, wet weather flows represent a high risk of hydraulically overloading the sewage collection network and treatment plants which may result in overflows to the environment. In order to mitigate this risk and maintain wet weather sewage flows within industry benchmark levels, PWC undertakes regular inspections of the sewage collection network and routinely invests around $2 million annually in Darwin on sewer pipeline relining and rehabilitation programs.

During extreme tropical wet weather events, stormwater inflows may exceed the treatment plant capacity. Lagoon type treatment plants such as Leanyer, Palmerston and Berrimah have significant capacity to absorb these increased flows and when combined with the dilution benefit of stormwater, discharge quality is usually unaffected or even improved. The Ludmilla treatment plant is a mechanical plant and does not have the lagoon buffering capacity to absorb wet weather flows beyond three times the normal dry weather flow. Excess highly diluted flows are screened before diversion to Ludmilla Creek. This periodically occurs during the Wet Season because it is impractical to capture and treat 100% of all tropical Wet Season inflows. While the diversion of sewage from the Larrakeyah catchment to the Ludmilla treatment plant will only increase wet weather flows by around 30%, PWC is upgrading the wet weather capacity at Ludmilla by over 400% (from 20 to 87 megalitres per day) to improve environmental performance and provide capacity to allow for future population growth in Darwin.

Blue-green algal blooms in Darwin Harbour

Lyngbya majuscula is naturally occurring marine blue green algae, identified in Darwin Harbour in June 2010 in bloom proportions. Lyngbya blooms led to closures of Mindil, Vesteys, Fannie Bay and Casuarina Beaches in June 2010.

Lyngbya has been an ongoing problem in the Queensland Moreton Bay area for a number of years, and was responsible for a major fish kill in the Port Bradshaw area on the East Arnhem coast in 2009. Scientific investigations have been conducted by the Queensland Government to determine the main causes and characteristics of the blooms in Moreton Bay. These investigations have identified dissolved iron, phosphorus and organic matter in the water as important triggers of blooms, although the complex mechanisms controlling Lyngbya blooms are not fully understood (Moreton Bay Waters and Catchments Partnership 2002).

At the time of the bloom in the Darwin Harbour in June 2010, development and landscaping was occurring on the foreshore adjacent to the Little Mindil Creek. This may have contributed to providing additional nutrients, iron and organic matter that catalysed the Lyngbya bloom that affected Mindil Beach.

Above average rainfall was recorded over most of the Territory during May 2010, with record breaking average minimum temperatures also recorded in the Top End. During the peak of the Lyngbya bloom, Darwin was also exiting a period of neap tides, where lower than normal tidal movement had occurred. The combination of these climatic factors probably also contributed to the production of the Lyngbya bloom at multiple sites around the Harbour.

Figure 2. *Lyngbya majuscula* blue-green algae on Mindil Beach (9 June 2010).

Charles Darwin University study to determine sources of bacteria

In July 2011, NRETAS, DoH and DCC engaged Professor Karen Gibb, head of the Environmental Analytical Chemistry Unit of CDU, to investigate the most likely sources of bacteria on Darwin beaches using genetic fingerprinting.

The study will address the following questions:

- Does the contamination on Darwin beaches originate from human faeces?
- What are the most likely source/s of *E. coli* and enterococci on Darwin beaches?

The project will address these questions by:

- Determination of faecal indicators and genetic fingerprints for water and sediment samples taken from creeks, drains, sewage effluent outfalls and beaches in the Darwin Harbour catchment.
- An assessment of human faecal contamination on Darwin beaches using genetic fingerprints of faecal biomarkers.
- An assessment of likely sources of *E. coli* and enterococci on Darwin beaches by comparing data from a range of sites in Darwin Harbour catchment, and matching not only biomarker genetic fingerprint patterns, but also additional environmental data such as pH, temperature, nutrients, total bacterial and viral biomass.

The project will undertake the following activities, using the following methodology:

- Sampling of water and sediment at various locations in the Darwin Harbour catchment at times when bacteria counts are expected to be high, based on 2010 data.

- Filtering each water sample in 500uL aliquots, keeping some filters frozen and placing others on specific bacteria culture media to enrich for target bacteria. A similar process was followed for sediment slurries.
- Extracting DNA from both the frozen filters and those from culture media.
- Amplifying biomarker genes from the conventional indicator species *E. coli* and enterococci, and the anaerobic *Bacteroides* genus.
- Developing genetic fingerprint techniques to generate patterns that will be compared between sites to assess sources and sinks.
- Collecting environmental data at the same locations to provide a physical, chemical and biological profile that can also be used to link sites – and in the longer term possibly indicate predisposing factors. These will include conventional indicator bacteria tests, nutrients, pH, temperature, water depth, Total Suspended Solids (TSS), total bacterial count, total virus count and sediment characteristics.

A final report from the study is expected in December 2011. This report will inform the next stage of work to be undertaken by the Taskforce.

Darwin stormwater drains and tidal creek monitoring

In 2010, DoH conducted limited monitoring of *E. coli* and enterococci levels in stormwater drains (Table 4). This sampling was opportunistic and flow rates were not measured. Counts of enterococci and *E. coli* in samples from stormwater drains cannot be compared to counts in samples collected from open water bodies.

Table 4. Results of monitoring of stormwater drains in 2010.
*Note: For the results marked, detection limits were reached and counts may have been higher than recorded.

Date	Sample Site	Time Sampled	*E.coli* per 100ml	Enterococci per 100ml
08-Jun-10	Golf Course Drain, opposite Little Mindil	12.10	560000	>2005*
09-Jun-10	Vesteys Lake, Fannie Bay	14.45	2005	10
10-Jun-10	Vesteys Lake, Fannie Bay	11.22	>2005*	42
11-Jun-10	Chapman Road Stormwater Drain, Rapid Creek Beach	11.40	111	271
	Vesteys Lake, Fannie Bay	10.47	>2005*	10
29-Jun-10	Rock pool, East Point	7.00	>20050*	>2005*
30-Jun-10	Chapman Road Stormwater Drain, Rapid Creek Beach	9.00	648	2005
	Gardens Golf Club, Darin below weir	9.30	384	624
15-Jul-10	Vesteys Creek, Fannie Bay	9.23	62	75
	Botanic Gardens Drain	10.17	2182	885
	Little Mindil Creek	10.02	198	531
03-Aug-10	Kulaluk Drain		1476	>2005*
	Nightcliff Pool Drain		40	31
	Rapid Creek Bridge		40	10
	Chapman Road Stormwater Drain, Rapid Creek Beach		384	885
	Nightcliff Pool Drain		58	70
	Nightcliff Boat Ramp Drain		1248	>2005*
	Hickory Street Drain, Fannie Bay		768	64
16-Aug-10	Rock pool, East Point	8.00	4010	406
18-Aug-10	Freer St Drain, Fannie Bay	10.40	<20	31

	Clancy Street Drain, Fannie Bay	10.45	84	<10
	Crush Street Drain, Fannie Bay	10.55	20	271
	Bleeser St Drain, Fannie Bay	11.10	300	238
27-Aug-10	Chapman Road Stormwater Drain, Rapid Creek Beach	15.10	222	53
01-Sep-10	Rock pool, East Point	8.00	6152	620
	Rock pool, East Point	8.00	5818	563
	Nightcliff Beach Stormwater Drain	11.05	82	30
	Rock pool, Nightcliff Jetty	11.40	194	20
08-Sep-10	Rock pool, Nightcliff Beach	8.20	<20	<10
	Rock pool, East Point	8.00	3304	2005
14-Sep-10	Rock pool, East Point	12.55	<20	<10
20-Sep-10	Gardens Golf Course Lake	14.03	>4010*	1091
22-Sep-10	Rock pool, East Point	8.40	270	1050
06-Dec-10	Rapid Creek, Henry Wrigley Dr	11.22	83	23
	Rapid Creek, Charles Eaton Dr	11.35	93	36
13-Dec-10	Rapid Creek, Henry Wrigley Dr	10.00	2420	1986
	Rapid Creek, Charles Eaton Dr	10.16	>2420*	2420
	Rapid Creek, Yankee Hole	10.32	>2420*	>2420*
	Rapid Creek, Pump Station	10.52	2407	>2420*
02-Feb-11	Rock pool, East Point	11.40	15402	2755
27-Apr-11	Chapman Road Stormwater Drain, Rapid Creek Beach	10.30	664	780
	Little Mindil Creek - Under Bridge	11.00	492	422
	Gardens Golf Course Lake	11.10	40	86
	Gardens Golf Course Lake Weir	11.20	126	171
	Vesteys Lake, Fannie Bay	11.30	428	197

Tidal creeks are often the interface between urban stormwater and Darwin Harbour beaches. Runoff from stormwater can deliver substantial loads of nutrients, sediments and other pollutants to Darwin Harbour beaches.

NRETAS currently undertakes monitoring at the entrance of four tidal creeks that enter Darwin Harbour, including Little Mindil, Mindil, Vesteys and Rapid Creek. While these creeks are not considered recreational water bodies, from June to November 2010, NRETAS conducted weekly monitoring of bacteria levels in these waterways (see Table 5).

Table 5. Results of tidal creek monitoring in 2010-11.

Tidal Creek	***E. coli* (mean) MPN/100ml**	***E. coli* (median) MPN/100ml**	**Enterococci (mean) MPN/100ml**	**Enterococci (median) MPN/100ml**
Little Mindil 2010	3229	1248	833	560
Little Mindil 2011	1626	1352	404	487
Mindil 2010	1935	758	1259	794
Mindil 2011	1225	62	534	31
Rapid Creek 2010	463	342	220	52
Rapid Creek 2011	515	492	186	108
Vesteys 2010	2377	62	255	52

Vesteys 2011	48	20	20	20

The results of tidal creek monitoring indicated fluctuating counts of *E. coli* and enterococci, generally above recreational water quality guideline levels. While people do not generally swim in these tidal creeks, there is anecdotal evidence of people swimming in some parts of Rapid Creek during the Wet Season.

Monitoring of Rapid Creek

Rapid Creek is the largest freshwater system within the Darwin city area and drains a catchment area of approximately 28 km^2. The Creek originates from Marrara Swamp, at the eastern end of Darwin Airport, flows for 9.8 km and discharges at Rapid Creek Beach. The Creek and the land adjacent to it provides for a variety of recreational pursuits, including walking, bike riding and swimming. Whilst a large proportion of the catchment has been cleared and is utilised in various ways (e.g. residential, commercial and semi-rural), the stream corridor itself remains relatively intact.

Monitoring of the water quality of Rapid Creek has been conducted for a number of years.

The Aquatic Health Unit undertakes monitoring within the Rapid Creek Catchment, results of which have been published on the RCCAC website and incorporated into the 2009 and 2010 Darwin Harbour Region Report Cards.

Darwin International Airport and the Department of Defence also collect water quality data at several sites in the upper parts of the Catchment. Darwin International Airport has provided their monitoring data to NRETAS for inclusion into the 2011 Darwin Harbour Region Report Cards.

Water Quality monitoring was also undertaken by Greening Australia and Waterwatch up until 1999. Monitoring conducted by Waterwatch between 1995 and 1999 suggests that high counts of *E. coli* were also detected in the headwaters of Rapid Creek, in Marrara swamp (Liza Schenkel, pers. comm).

A review of water quality and biological monitoring data from Rapid Creek, suggests that there are a number of factors affecting the quality and quantity of water entering Rapid Creek and the health of the aquatic ecosystem within the Creek (Aquatic Health Unit 2006). Examples of these factors include human developments in the catchment (e.g. suburban areas, sporting grounds, commercial/industrial, small-scale agriculture/horticulture), the condition of streamside vegetation, and general land management practices in areas of native vegetation (e.g. weeds, fire).

The review of water quality monitoring data for Rapid Creek freshwaters suggests that there are elevated levels of some pollutants in Rapid Creek, which are generally observed during the Wet Season, particularly early in the season when the first rains flush accumulated pollutants from the catchment into the Creek (Aquatic Health Unit 2006). Once the Wet Season sets in, water quality in Rapid Creek generally improves as pollutants are diluted and flushed from the system.

Monitoring of *E. coli* at various sites in Rapid Creek and its catchment conducted by Darwin International Airport from 2009 to 2011 suggests that bacteria levels in the Creek are sometimes very high (several thousand *E. coli* per 100mL) and are extremely variable (Darwin International Airport, unpublished data). The fact that high levels of *E. coli* have been measured even in the headwaters of Rapid Creek, on airport and defence lands, suggests that natural factors may also be implicated in elevated bacteria counts in Rapid Creek.

Summary

Since the detection of bacteria levels on Darwin Harbour beaches above recreational water quality guidelines in June 2010, numerous monitoring and research programs have been conducted in Darwin Harbour, seeking to determine whether beaches are safe for swimming and to identify the sources of high levels of bacteria on Darwin Harbour beaches. This includes weekly monitoring of Darwin Harbour beaches and Lake Alexander during the swimming season, sanitary inspections, monitoring of PWC outfalls and monitoring of algal blooms, stormwater drains and tidal creeks. This monitoring has built upon historic monitoring of bacteria in Darwin Harbour and ongoing water quality monitoring across the Harbour, as well as the work of RCCAC and DHAC in promoting responsible stewardship and management of Darwin Harbour and its catchment. These monitoring programs have identified varying levels of bacteria over space and time and have resulted in several precautionary beach closures.

A review of the Darwin Harbour beach monitoring program against beach monitoring programs elsewhere in Australia (APPENDIX B) and overseas (APPENDIX C), suggests that the Darwin Harbour beach monitoring program is generally consistent with what is occurring elsewhere, although guidelines and trigger values for bacteria vary across regions.

Notwithstanding the effort put into monitoring bacteria levels in Darwin Harbour over the past 12 months, researchers are yet to identify the sources of high levels of bacteria in Darwin Harbour. This is a result of the significant complexity of Darwin Harbour as a tropical, monsoonal, macro-tidal system and the paucity of appropriate scientific methodologies in this area of research. Research currently being undertaken by CDU, involving cutting edge science and genetic fingerprinting of bacteria from across Darwin Harbour, is expected to provide some answers in this regard in late 2011. In the meantime, monitoring of Darwin Harbour beaches and Lake Alexander will continue, to ensure the public is advised of high levels of bacteria on our beaches and that precautions against swimming are issued, when appropriate.

Gaps in the knowledge base and investigation program

As detailed in the previous section, numerous monitoring and research programs have been conducted in Darwin Harbour in the past 18 months, seeking to determine whether beaches are safe for swimming and to identify the sources of high levels of bacteria on Darwin Harbour beaches.

The following section provides a summary of some of the key gaps in the knowledge base and existing monitoring programs that need to be filled in order understand the risks to public health associated with bacteria on Darwin Harbour beaches and to determine the sources of these bacteria.

It also identifies programs that might be pursued to address the gaps in the knowledge base, to determine the most probable sources of faecal contamination, and the actual nature and level of public health risks.

Identifying sources of bacteria on Darwin Harbour beaches

As previously mentioned, it is anticipated that the CDU study to narrow down the sources of bacteria on Darwin Harbour beaches — specifically the extent to which bacteria levels are associated with human faecal material — will be concluded late in 2011.

At the conclusion of the study, further research may be required. For example, quantifying the likely contribution of bacteria from 'natural' sources in sand and sediments, and in waterways substantially free from human contact, is likely to require more intensive sampling and detailed investigation than was possible in the current CDU project. The current CDU study will weed out those biomarkers that provide no helpful information across the in-shore catchment, or which are too specific or too fastidious to be used with sediment. With a better set of biomarkers, it should then be possible to get a better understanding of the risks to human health from animal faecal material. Even with a refined set of indicators, there is value in retaining conventional enterococci counts (which can be done locally) to allow comparison against a familiar standard and to maintain consistency with national guidelines. Recommendations for further research will be finalised as the results of the study are known.

Tracking of bacteria sources at hot-spots and identifying actions to address sources

It is proposed that the Taskforce undertakes further investigations of identified areas of high bacteria readings (hot-spots) to investigate the potential sources of bacteria in the catchment. This would involve a more detailed review of existing monitoring data to identify potential hot-spots for investigation, a review of the relevant sanitary surveys conducted by DoH to determine potential sources of bacteria, tracking these potential sources and identifying measures to mitigate sources wherever possible.

Continuing existing Darwin Harbour beach water monitoring

In light of the work of the Taskforce in investigating and addressing the sources of bacteria on beaches, and providing recommendations for ongoing monitoring of Darwin Harbour beaches, it is recommended that the existing Darwin Harbour beach water monitoring program is maintained until a final report is delivered by the Taskforce.

Relationship between bacteria counts and rainfall

Scientific literature and monitoring of beaches in other parts of Australia and overseas suggests that bacteria counts in water samples are higher following rainfall events. To confirm and quantify this relationship for Darwin Harbour, investigatory sampling will be undertaken during the 2011-12 Wet Season. While beaches are normally recommended by DoH to be closed to swimming during the Wet Season because of the presence of Box Jellyfish, the additional sampling results will provide evidence for any further public health action to be taken.

Use of NHMRC Guidelines in tropical marine waters

From 1 July 2011, DoH has compared the results of analysis of beach water samples to the NHMRC 2008 *Guidelines for Managing Risks in Recreational Water*. *E. coli* is not a recommended indicator under these Guidelines, as there is no clear relationship between levels of *E. coli* and health risks to swimmers. In contrast, enterococci shows a clear dose-response relationship (in temperate waters) and is the preferred indicator of both the NHMRC and the World Health Organisation for recreational water quality.

Most of the epidemiological studies informing the use of enterococci were conducted in temperate marine waters and involved healthy adult bathers (NHMRC, 2008). Ideally, studies would be pursued to investigate whether enterococci is an appropriate public health indicator for Darwin Harbour beaches. At a minimum, a watching brief would be maintained with respect to epidemiological studies relating enterococci levels and disease rates in swimmers in tropical waters to inform the development of appropriate triggers.

Development of Darwin Harbour beach classifications

The NHMRC Guidelines recommend developing beach classifications for determining beach closures and sampling regimes. This would require a minimum of 20 water samples to be taken to allow an estimation of the density of the indicator organism to which water users are exposed. The development of classifications for Darwin Harbour beaches should be pursued in 2011-12, when more than two years of data and both Wet and Dry Season are available.

Determination of public health risks

Further research may also be required to ascertain the public health risk associated with background bacterial populations established at beach sites.

Complementary measures

While work continues to determine the sources of bacteria on Darwin Harbour beaches and the nature of the risk to the public associated with high bacteria levels, a number of 'no regrets' complementary activities should be pursued.

Development of the Darwin Harbour Integrated Monitoring and Research Program

In June 2010, the DHAC and the Northern Territory Government agreed to facilitate an Integrated Monitoring and Research Program for Darwin Harbour. This Program will foster promotion, sharing and coordination of existing and new monitoring and research programs among its members, to improve understanding of the health of the Harbour and to improve capacity to plan for and manage the Darwin Harbour region.

Several organisations have agreed to be part of the Program, including NRETAS, PWC, Darwin Port Corporation, DoH, Department of Defence, ConocoPhillips, OzMinerals, Inpex Browse, DCC, the Australian Institute of Marine Science and CDU.

These organisations have formed an Interim Management Committee to manage the Program and NRETAS has provided staff towards a Program Design Team to design and develop the Program. It is expected that the Program will be designed and up and running by December 2012.

The beach monitoring program currently undertaken by DoH and NRETAS will be included in the Integrated Monitoring and Research Program. It is anticipated that the Integrated Monitoring and Research Program will assist in interpreting the results of the beach monitoring program.

Finalisation of a Stormwater Management Strategy for the Darwin Harbour catchment

In 2006, the Northern Territory Government developed a Draft Stormwater Management Strategy for the Darwin Harbour catchment. There has been major infrastructure development undertaken since this Draft Strategy was developed and a range of technical issues will need to be addressed to enable a Stormwater Management Strategy to be finalised.

It is recommended that NRETAS, DCC and CoP jointly review the Draft Strategy and redevelop a Strategy in late 2011, enabling actions identified through the Strategy to be considered in the work of the Taskforce. An inter-governmental working group has been established to review the previous draft of the Strategy, update the proposed initiatives and develop key messages for a communication plan.

Development of a comprehensive Healthy Harbour education campaign

It is proposed that a multi-faceted and comprehensive 'Healthy Harbour education campaign' is developed. This campaign would include initiatives such as a community education program (fliers, advertisements etc), drain stencilling, signage in foreshore areas, tree and dune planting, working with sailors, fishers, industrial and commercial stakeholders to reduce discharges, a community water monitoring program, a Harbour Watch program encouraging reporting of dolphin, dugong, turtle sightings and fish catches, the annual Darwin Harbour Clean-up, programs targeting dog and horse owners to reduce animal faeces on beaches, and promotion of the Pollution Response Line. All data collected through community monitoring would be reported through the Darwin Harbour Region Report Cards.

The Healthy Harbour campaign would be developed by NRETAS, DoH and DCC in collaboration with CoP and a range of key stakeholders from industry and special interest groups. The key audiences for the campaign would be the users of Darwin beaches and waterways, anyone whose actions potentially impact on water quality in creeks, Lake Alexander and beaches, and the general public.

Prevention of sewage discharges from boats under *Marine Pollution Act*

One of the possible sources of bacteria on Darwin Harbour beaches is sewage discharge from vessels that are either moored in the Harbour, or passing through the Harbour.

Part five of the Territory's *Marine Pollution Act* deals with sewage discharge from vessels, however, this Part has not been commenced. This Part of the Act, if commenced, would prohibit the discharge of sewage from large vessels in Territory coastal waters, or from small vessels in pre determined declared sensitivity zones. This Part of the Act also requires large vessels to have holding tanks.

Enacting this Part of the Act would provide the opportunity to prescribe by Regulations parts of coastal waters as a sensitivity zone. The Regulations once made could prescribe sections of Darwin Harbour as a sensitivity zone, which would create an offence, essentially requiring people to ensure that sewage is not discharged from vessels.

Sewage pump-out facilities at Cullen Bay are to be installed in the planned replacement of the Cullen Bay pontoon (due for completion in 2012). Of note, for vessels moored in the Duck Ponds at Frances Bay, sewage holding tanks are pumped-out as required, by trucks from the service wharf.

Review of environmental protection legislation

NRETAS has recently been pursuing the reform of environmental legislation, including amending the *Environmental Offences and Penalties Act* to double penalties for environmental offences, amending the *Water Act* to ensure the validity of Waste Discharge Licences, and drafting amendments to the offence and duty to notify provisions of the *Waste Management and Pollution Control Act*.

NRETAS is also pursuing reform of the *Environmental Assessment Act*, to enhance transparency and strengthen the outcomes of environmental assessments and the *Waste Management and Pollution Control Act*, to ensure activities that pose a significant environmental risk are regulated appropriately.

Recommendations

In summary, it is recommended that the following activities are undertaken in the short term:

1. Continuation of the existing Darwin Harbour beach monitoring program by the relevant agencies until the work of the Taskforce is complete;
2. Finalisation of the CDU study to identify sources of bacteria on Darwin Harbour beaches;
3. Tracking of bacteria sources for identified hot spots, to determine possible sources of elevated bacteria levels and actions to address these sources;
4. Implementation of investigatory sampling during the 2011/12 Wet Season;
5. Determining beach classifications for Darwin Harbour beaches during 2011-2012;
6. Finalisation of a Stormwater Management Strategy for the Darwin Harbour catchment;
7. Implementation of a Healthy Harbour education campaign;
8. Enacting Part five, sections 30 - 35 of the *Marine Pollution Act* and prescribing part or all of Darwin Harbour as a sensitivity zone.

Additional advice will be provided in the final report of the Taskforce, which will:

- Make recommendations on a range of measures to address sources of bacteria on Darwin Harbour beaches;
- Include a succinct summary of key messages for the wider community; and
- Outline a recommended long-term monitoring system for assessing water quality on Darwin Harbour beaches and to provide an early warning system for any future risks to public health from bacteria on beaches.

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APPENDIX A. Taskforce membership and Terms of Reference

Membership

Professor Andrew Campbell — Chair
Charles Darwin University

Dr Samantha Fox
Department of Natural Resources, Environment, the Arts and Sport

Mr Xavier Schobben
Department of Health

Mr Steve McKenzie
Power Water Corporation

Mr Mark Blackburn
Darwin City Council

Alderman Sue McKinnon
City of Palmerston

Terms of Reference

Overall objective

To ensure that water quality in Darwin's beaches and waterways is of high quality and to minimise the risk of future beach closures.

Strategy

Establish a Taskforce of senior officials from relevant agencies, under independent oversight, to identify the most probable sources and pathways of contaminants implicated in recent beach closures, and to recommend measures necessary to reduce future contamination and minimise the risk of future beach closures.

Establishment of the Taskforce

1. The Taskforce will be convened comprising senior officers of DOH, NRETAS and PWC.
2. DCC and COP will be invited to join the Taskforce.

Independent oversight and reporting

3. Professor Andrew Campbell of CDU will be engaged by the DCM to chair the Taskforce. Professor Campbell is a research leader of national standing who is

highly experienced in the design and implementation of research and monitoring programs, and in facilitation of community consultation and engagement initiatives.

4. Professor Campbell will provide independent oversight of the design and implementation of an investigation program to determine the most probable causes of elevated faecal indicator results on Darwin beaches.

5. Professor Campbell will report directly to the Minister for Health and the Minister for Natural Resources, Environment and Heritage.

6. An initial report will be prepared by Professor Campbell and the Taskforce and will be provided within one month of agreement to these Terms of Reference. That report will:
   - outline the existing state of knowledge about likely contaminant sources and pathways;
   - identify gaps in the knowledge base and existing monitoring programs that need to be filled in order to increase certainty to the community about real risks to public health around contaminant sources and pathways;
   - identify an investigation program to fill critical gaps in the knowledge base to determine the most probable sources of faecal contamination, elevated bacteria levels and the actual nature and level of public health risks;
   - recommend complementary measures such as public education activities that could be initiated in parallel with the systematic investigation; and
   - outline likely resource requirements and probable timelines.

7. Professor Campbell will then provide independent oversight of the subsequent investigation program to be managed by the Taskforce, which will:
   - identify key contributors in space and time to bacterial readings in Darwin Harbour, especially those related to beach closures;
   - identify actions that will reduce or mitigate the effects of the inputs that lead to high bacterial loads; and
   - establish the requirements in terms of the types of data, the sampling methods and frequency and the distribution of sampling points or sensors, for a long-term, on-going monitoring system capable of identifying emerging issues as early as feasible, in order to maintain water quality at satisfactory levels.

8. A final report, to be prepared by Professor Campbell and the Taskforce, will:
   - make recommendations on the range of measures to mitigate contamination risks, and the consequent risk to public health and associated beach closures;
   - include a succinct summary of key messages for the wider community; and
   - outline a recommended long-term monitoring system that would underpin community confidence in the water quality of Darwin Harbour beaches, and provide an early warning system for any future risks to public health from bacterial pollution.

Recommendations provided by Professor Campbell and the Taskforce will be jointly assessed by both levels of government and the broader community.

Governments' support

9. All Northern Territory Government agencies, DCC and CoP will provide unfettered support for the Taskforce and Professor Campbell, including making relevant staff available to serve on the Taskforce, provision of access to existing monitoring

programs and results, and any other data and information relevant to possible causes of Harbour pollution, as soon as possible on request from Professor Campbell.

10. NRETAS will provide Secretariat support for Professor Campbell.

Community input and communication

11. DHAC and the RCCAC will be invited to act as community reference groups.

12. The Secretariat will assist with the engagement of DHAC and RCCAC.

13. Communications will be coordinated by DOH and NRETAS with support from DCM.

14. A public communications strategy will be developed jointly by DCM, DOH, NRETAS, DCC and CoP.

15. Communications measures will include a dedicated website for open and transparent reporting to the local, Northern Territory, Australian and international communities of progress on investigations and to provide regular updates on water quality at Darwin beaches.

Advisory Mechanisms

As outlined in the Terms of Reference, the key stakeholder advisory mechanisms for the Task Force are the Darwin Harbour Advisory Committee (DHAC) and the Rapid Creek Catchment Advisory Committee (RCCAC).

Darwin Harbour Advisory Committee

DHAC is a multi-stakeholder Ministerial Advisory Committee that provides the Minister for Natural Resources, Environment and Heritage with advice on land use, planning, development and the use of natural resources within the Darwin Harbour region. The Committee's focus is on sustainable development and the long-term protection of the Darwin Harbour.

In June 2010, DHAC released the Darwin Harbour Strategy, a comprehensive guide for the responsible stewardship and sustainable development of the Darwin Harbour region. Under the auspices of the Strategy, the DHAC and the Northern Territory Government are facilitating the development of a multi-stakeholder Integrated Monitoring and Research Program for Darwin Harbour.

Rapid Creek Catchment Advisory Committee

In 1994, DCC and Greening Australia developed the Rapid Creek Management Plan. The plan proposed a range of strategies to stimulate greater awareness of the presence and importance of the Rapid Creek area; promote increased protection and appropriate management of the Rapid Creek system; and to encourage government agencies and the community to co-operate in the development of protection and rehabilitation measures for the Rapid Creek system. One of the key recommendations of the Plan was to set up a management structure to coordinate implementation of the Plan.

RCCAC was formally established under the *Water Act* in 1996. Committee members are committed to improving the cooperative management of the catchment and advise the Minister on policy for management of the natural resources of the catchment.

RCCAC includes representatives from the Department of Defence, Darwin International Airport, DCC, Larrakia Nation Aboriginal Corporation, CDU, Greening Australia, Rapid Creek Landcare Group, Department of Lands and Planning and NRETAS.

APPENDIX B. Beach water monitoring programs in other Australian jurisdictions

The NHMRC Guidelines have been adopted in all Australian jurisdictions that currently routinely monitor recreational water quality (Northern Territory, New South Wales, Victoria, South Australia, Tasmania and Western Australia).

The NHMRC Guidelines advocate the use of enterococci as the single preferred faecal indicator in marine waters. The Guidelines recommend assigning Microbial Assessment Categories (A to D) to each site based on enterococci counts and conducting sanitary surveys and assessments. Beach classifications (very good to very poor) can then be determined from a combination of microbial assessments and sanitary inspections.

New South Wales

Key swimming beaches in New South Wales are sampled every six days during the swimming season (October to May) with monthly surveillance sampling undertaken between May and September when the swimming sites are generally not in use. The New South Wales Government provides a daily summary of beach closures (based on rainfall), weekly reports outlining the microbial assessment category (A, B, C, D), monthly reports and annual reports that classify beaches according to the NHMRC Guidelines.

Victoria

The Environment Protection Authority (EPA) in Victoria undertakes weekly beach monitoring, with daily updates on beach closures (based on weather) and weekly monitoring results in printed newspapers and online during the swimming season (November to March). The EPA uses the NHMRC Guidelines, with resampling if greater than 400 enterococci per 100mL are detected, and a swim advisory issued if the second sample has counts of greater than 400 enterococci per 100mL. A swim advisory is immediately issued if results are over 1000 enterococci per 100mL. As a general precaution, EPA Victoria also advises people not to swim near stormwater drains, rivers, streams and other outlets for at least 24 hours after rainfall.

The EPA also provides beach water quality ratings, based on results of beach monitoring.

- Good - Water quality is expected to be suitable for swimming.
- Fair - Water quality is expected to be generally suitable for swimming but may be affected by stormwater.
- Poor - Not recommended for swimming.
- Unacceptable - A no swim advisory has been issued for this beach.

Western Australia

In Western Australia, key swimming beaches are monitored for enterococci once every fortnight from November to May (swimming season). However, monitoring outside of the metropolitan areas is limited. For example, there is no regular monitoring of the beaches in Broome. The relevant authorities investigate further when beach water samples return results over 200 enterococci per 100mL. Where sampling identifies counts of over 400

enterococci per 100mL from two consecutive samples (within 24 hrs), a full investigation is undertaken and public health signage is erected at affected beaches.

Tasmania

Key swimming beaches in Tasmania are sampled weekly during the swimming season (December to March). Regulatory authorities appear to use both the ANZECC Guidelines and Department of Health Guidelines 2007. If levels of enterococci exceed a set trigger level, beaches are re-sampled. If the levels remain high, beaches are closed and the public notified via websites. The ANZECC criteria used are:

- 150 faecal coliforms per 100mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 600 faecal coliforms per 100mL);
- 35 enterococci per 100mL (maximum number in any one sample: 60 to 100 enterococci per 100mL).

The Tasmania Department of Health Guidelines identify that where enterococci counts in a single water sample are greater than 140 enterococci per 100mL, re-sampling is to be undertaken within 48 hours of becoming aware of the result and a sanitary inspection is undertaken. Where two consecutive water samples have greater than 280 enterococci per 100mL, then the public are advised of water being unsuitable for primary contact, re-sampling occurs within 48 hours of becoming aware of the result and a sanitary inspection is undertaken. The decision to remove an advisory notice is determined through a consultative process between the Director and the relevant Council's Authorised Officer.

Queensland

In the Moreton Bay region of Queensland, key beaches are sampled for enterococci. Of note, Queensland Health issued warnings about enterococci in waters following the Queensland floods.

South Australia

In South Australia, signs are erected where there are stormwater outlets and advice is provided to the public not to swim after rainfall events.

Interestingly, most jurisdictions only undertake beach water monitoring during the summer swimming season, although New South Wales conducts monthly surveillance monitoring in the non-swimming season.

APPENDIX C. International beach water monitoring programs

A number of examples of beach monitoring in other countries has been provided in the following section.

The United States Environmental Protection Agency

Under the *Beaches Environmental Assessment and Coastal Health Act 2000*, the Environmental Protection Agency (EPA) is authorised to provide grants to coastal and Great Lakes states, territories, and eligible tribes to monitor their coastal beaches for bacterial indicators that identify the potential presence of microbiological disease-causing pathogens, as well as notifying the public when there is a potential risk to public health. Thirty coastal states, five territories, and two tribes currently report their beach monitoring results, beach closure notifications and advisories to the EPA where it is uploaded and maintained on an electronic EPA database, that is accessible to the public.

In 2010, at least 37% (1,362 out of 3,654) of all coastal beaches monitored had at least one advisory or beach closure.

According to the EPA, there are multiple reasons for beach water pollution, including stormwater runoff after heavy rainfall, treatment plant malfunctions, sewer system overflows, waste from boats and pet and wildlife waste on or near the beach (USEPA 2011b).

United States Natural Resources Defense Counsel 'Testing the Waters Report'

The Natural Resources Defense Counsel (NRDC) is a major environmental action group with over 1.2 million members. The NRDC also produces an annual survey of water quality in participating United States beaches. The latest report 'Testing the Waters', indicated that 24,091 beach closures and advisories were issued in 2010, which is the second-highest number since NRDC began monitoring marine waters 21 years ago. In 2010, nearly 75% of the beach closures and advisories were issued due to bacteria levels exceeding health and safety standards (NRDC 2011). The NRDC maintain that bacterial pollution of United States beaches appears widespread and cites aging and poorly designed sewage treatment systems and contaminated stormwater as sources of pollution. It should be noted however that in 2010, the source of contaminated beachwater was reported as unknown, more than half the time.

The Testing the Waters report focuses mainly on microbiological testing results and consequent beach water quality concerns. The report also highlights 9,474 days of oil-related beach closures and advisories, due to the BP oil disaster (NRDC 2011).

The NRDC though legal pressure also claim credit for forcing the United States Environmental Protection Agency into updating its decades old beach water quality standards by 2012.

The legal settlement also requires the EPA to:

- Conduct new health studies and swimmer surveys.

- Approve a water-testing method that will produce same-day results, although there is no compunction for local beach managers to use the Environmental Protection Agency test methods developed.
- Protect beachgoers from a broader range of waterborne illnesses, including skin rashes, and hepatitis etc instead of just focussing on gastrointestinal illnesses such as the stomach flu.

In 2011, the NRDC rated 200 popular beaches in the United States based on the results of water quality testing and resultant quality or cleanliness of the water, the monitoring of the beach by relevant local authorities and public awareness and notification practices. The NRDC maintain that water quality fluctuates from year to year depending on the amount of rainfall, particularly at beaches most susceptible to stormwater contamination and contends that the safest beaches are those that meet public health standards during both wet and dry years. The NRDC identified that the most frequently identified pollution source is stormwater, which led to more than 8,712 closing and health advisory days in 2010. This was followed by miscellaneous sources, such as wildlife and boat discharges, which accounted for more than 4,512 closing/advisory days (NRDC 2011). Sewage spills and overflows were also identified as sources and were estimated to account for more than 1,880 closing and advisory days.

The NRDC also developed a coloured five star rating system of beaches, comprised of the following specific criteria:

★ These beaches have and consistently meet the national standards.

★ These beaches rarely, if ever, violated health standards for the last three years and deserve special recognition.

★ These beach locations were monitored more than once a week. Beaches that are monitored more frequently are more protective of beachgoers. Federal Beach legislation recommends that Tier 1 (heavily used and/or likely to be polluted) beaches be monitored at least once a week.

★ Closings and/or advisories at this beach are always issued promptly after an exceedance without waiting for resampling results or other information.

★ Beachgoers are notified if the water is unhealthy for swimming through both the Internet and a sign on the beach.

According to the NRDC, rain is often a contributing factor to beachwater pollution with heavy rain potentially overwhelming sewerage systems and causing raw sewage to spill into coastal waters. Rainwater by washing over land also picks up pollutants, including household and pet waste, motor oil, pesticides, fertilizer, animal droppings and virtually anything else that washes off developed land when it rains, ending up in stormwater catchments and ultimately coastal waters (NRDC 2011).

The NRDC admit that in many cases, communities simply haven't tracked down the sources of beachwater pollution and that over half of 2010's closing and advisory days were issued because monitoring revealed the presence of bacteria associated with faecal contamination, although importantly, officials invariably could not identify the source of this

contamination. The NRDC recommends that both local and state agencies step up efforts to investigate such pollution sources (NRDC 2011).

Healthy Beaches Program, Florida USA

This program was initiated in 1998 as a pilot program and involving 11 Florida coastal counties, which began conducting beach water sampling on a fortnightly basis. The Florida counties then reported their results on the 'Florida Healthy Beaches' website and in both local print and electronic news media. The beach water sampling program was expanded to include the 34 Florida counties in August 2000 and beach water monitoring frequency was increased to weekly by the coastal communities.

Coastal beach water samples collected by the county health departments are analysed for both enterococci and faecal coliform bacteria *(E. coli*). High concentrations of these bacteria result in County health departments issuing health advisories or warnings (see Table 6). Where necessary, signs are also placed near affected beaches (Figure 3) and remain in place until bacteria levels have been determined to be acceptable by US Environmental Protection Agency standards.

Table 6. Microbiological criteria used for beach monitoring in Florida

***Enterococcus* Results Description**		
GOOD	**MODERATE**	**POOR***
0-35 *Enterococcus sp* per 100 ml of marine water 0-35 CFU per100mL *Enterococcus sp (Geometric Mean)*	36-104 *Enterococcus sp* per 100 ml of marine water	105 or greater *Enterococcus sp* per 100 ml of marine water 36 and over CFU per 100mL *Enterococcus sp (Geometric Mean)*
Faecal Coliform Results Description		
GOOD	**MODERATE**	**POOR***
0-199 faecal coliform organisms per 100 ml of marine water	200-399 faecal coliform organisms per 100 ml of marine water	400 or greater faecal coliform organisms per 100 ml of marine water

*A Poor rating may result in a re-sampling event to confirm poor conditions, otherwise a Health Advisory or Warning will be issued immediately. These indicate that contact with the water at this site may pose increased risk of infectious disease, particularly for susceptible individuals.

Figure 3. Signage at a Florida beach stating "This Beach Monitored as Part of the Healthy Beaches Program – ADVISORY — High Bacteria Levels — Swimming NOT Recommended — Increased Risk of Illness at This Time".

Healthy Beaches Program, Maine USA

The State of Maine in the United States has a 'Healthy Beaches Program', which involves the monitoring of 46 public beaches and recreational waters on its coast. The Program also involves educating the public about potential health risks at these beaches, and notifying the public when disease-causing microorganisms are present and may pose a health risk to swimmers. Under the Program, beach advisories are posted when conditions at the beach sampling site indicate high bacteria counts and an exceedance of State and Federal standards.

The United States Environmental Protection Agency standards describe the exceedance criteria, or level at which a sample fails, at being 104 enterococci per 100mL, or exceeding the geometric mean of 35 enterococci per 100 mL of water in at least five samples collected over a 30-day period. This is just one consideration for placing advisories at the beach.

Beach water advisories are recommendations to the public to avoid water contact activities at the beach until further analyses reveal safe conditions. Beaches are not closed on just water results alone, but on Risk Assessment Matrix factors (including bather numbers, time of last rainfall event and history of known problems in the area) and are used by beach managers for ongoing management decisions.

The town/State Park beach managers may use their own discretion to actively close a beach to the public, but must notify the Maine Healthy Coastal Beaches Program of the intention to close a beach or erect an advisory sign at a particular beach through an on-line database. Consistent signage has been developed by the Maine Healthy Beaches Program to assist town/State Park beach managers in issuing a beach advisory.

Figure 4. Beach status signage used in Maine Healthy Beaches Program

Grand Traverse Bay Beach Monitoring Program, Michigan USA

During the summer months, beach water testing for *E. coli* is undertaken at nine Grand Traverse Bay area beaches (around Michigan, USA) by the Grand Traverse County Health Department. Results for Traverse City beaches are made available to the public via an advisory system initiated by the Grand Traverse County Health Department, which involves the posting of a water quality index (scale of 1 to 4) at the relevant beach each week, depending on the severity of the contamination when bacteria levels are elevated,
The following index forms part of the Michigan Department of Environmental Quality (MDEQ) advisory system which is available at www.gtchd.org:

- Level 1: No tag – *E. coli* levels meet MDEQ swimming standards for full body contact.
- Level 2: Yellow tag–*E. coli* levels meet MDEQ standards for wading, fishing and boating. Contact above the waist is not advised.
- Level 3: Reg tag – *E. coli* levels exceed MDEQ standards; no body contact is advised.
- Level 4: Reg tag. Avoid all contact with the water. This includes swimming and wading. However, other recreational beach activities will still be possible.

Sanitary surveys also form part of the monitoring program, including surveys of Traverse City's stormwater system inventory to determine any illegal outfalls into the Bay or the Boardman River and remedial action taken if necessary.

A study conducted by the Watershed Center and the U.S. Geological Survey in 2001 found that bird droppings and stormwater runoff are likely sources of *E. coli* in Grand Traverse Bay. A source tracking study will test for *E. coli* and other contaminants from upstream to identify whether any illegal sewer hookups are draining to the stormwater system. DNA testing may be utilised to determine the presence of any human sources.

The Program also includes some Healthy Beach Tips to keep beaches safe from *E. coli* bacteria:

- Don't feed waterfowl; politely discourage tourists from doing so. Traverse City has adopted an ordinance prohibiting feeding waterfowl.
- Place litter in trash cans.
- Clean up after Fido, and dispose pet waste in trash.
- Discourage children from playing in any algae, because it can stir up *E. coli* bacteria hiding there.
- Discharge boat and RV waste only at approved disposal sites.
- Properly operate and maintain your septic system.
- Properly dispose of automotive fluids and hazardous household waste during your community's scheduled collection days; don't dump them on the ground or into a storm drain.

Chesapeake Bay – Maryland Healthy Beaches Program USA

Maryland's Healthy Beaches Program was established to protect the health of visitors to public bathing beaches. There are 70 coastal beaches in Maryland lining 20 miles of the Atlantic Ocean, Chesapeake Bay, and other bays and sounds. Beach water quality is monitored in a program administered by the Maryland Department of the Environment (MDE). Local health departments are responsible for monitoring and notifying the public about the health of Maryland's beaches.

Water quality assessment begins prior to the swimming season when local health departments collect water samples from beaches and perform beach Pollution Source Surveys to ensure that there are no nearby pollution sources that may adversely impact water quality. Local health departments then collect water quality samples from beaches before and during the swimming season. Water quality results that exceed Maryland's water quality standards are immediately reported to local health departments so that beach managers can issue a notification if needed. When water quality standards are exceeded at a particular beach, Maryland issues a beach advisory that warns people to avoid contact with the beach water. MDE assembles and submits the monitoring and notification data to the Environmental Protection Agency.

In 2010, of Maryland's 70 monitored coastal beaches, 30 (43%) were monitored once a week, 25 (36%) every other week, and 15 (21%) once a month. A total of 16 monitored beaches had at least one advisory issued during the 2010 swimming season. In 2010, 7% of all reported beach monitoring samples exceeded the state's daily maximum bacterial standards.

In 2010, MDE worked with Salisbury University and Delaware Department of Natural Resources and Environmental Control to conduct a study to address questions about the degree to which populations of faecal indicator organisms found in sediment contribute to those found in beach water, and the length of time faecal indicator organisms found in sand can survive. The study also looked at the possibility for regrowth. The findings should be available later in 2011.

EUROPE AND OTHER COUNTRIES

There is an increasing number of countries participating in the ‘Blue Flag’ program which provides accreditation based on achievement and maintenance of high environmental and quality standards. The certification is provided by the Foundation for Environmental Education (FEE) and identifies that a beach or marina meets its stringent standards. According to FEE, the Blue Flag designates beaches that have met the European Union's high standard for cleanliness and sanitation both on the sand of the beach and in the water.

Figure 5. Blue Flag

The trademark ‘Blue Flag’ is owned by FEE, which is a not-for-profit, non-governmental organisation, consisting of 72 organisations. While starting in Europe, it is now widespread to 63 member countries across both Europe and Africa, Oceania, Asia, North America and South America. FEE's Blue Flag criteria include standards for water quality, safety, environmental education and information, the provision of services and general environmental management criteria. The Blue Flag is sought for beaches and marinas as an indication of their high environmental and quality standards.

The certification and issuing of ‘Blue Flag’ awards to beaches and marinas of FEE member countries occurs annually, usually on 5 June for northern hemisphere countries and on 1 November for southern hemisphere countries.

In the European Union, the water quality standards are incorporated in the European Commission Water Framework Directive.

BALI

There is limited information on beach water monitoring in Bali, although annual testing appears to occur as a result of significant bacterial blooms associated with sewage and waste discharges. Earlier this year, the government-run Ngurah Rai Fish Quarantine Laboratory announced that the bacterial bloom caused the sea to turn a turgid brown colour, due a drastic drop in the pH level of the water, making it more acidic and killing off large amounts of plankton. Testing of the beach water takes about 5 days to complete.

The local authorities warned people not to swim at Kuta Beach or nearby areas because of the risk of skin infections or even respiratory problems as a result of coming into contact with the bacteria. The warnings are issued through a Public Announcement System and

through the use of men posted on the beach to alert beachgoers. The warning included a statement that if people absolutely had to have a swim or surf, then the time in the water should be limited to 30 minutes. Local authorities are working with the Bali Tourism Office to raise awareness. The authorities are urging the public to tell them when they see the water turn an unusual colour so that the laboratory can conduct proper testing and make timely advisories for tourists going to the beach.

The beach contamination in March 2011 was initially identified following tests using a salinometer to measure the salt concentration in the water. The salt levels had plummeted thereby raising concerns over possible contamination.

SINGAPORE

Singapore's National Environment Agency (NEA) has developed the Singapore's Water Quality Guidelines for Recreational Beaches and Fresh Water Bodies 2008 to monitor its recreational beaches, which are based on the World Health Organisation recreational water quality guidelines 2003. The NEA conducts weekly sampling of water quality from the six recreational beaches in Singapore, including Sentosa Island Beaches; Seletar Island Beach; Sembawang Park Beach; Changi Beach; East Coast Park Beach; and Pasir Ris Beach.

The revised guidelines now use enterococci as the microbial indicator, which corresponds more closely to the health risks associated with the use of recreational beach water, compared to the previous indicator, faecal coliforms.

From August 2008, the parameters used to assess the water quality for recreational beaches are as follows (SNEA 2011):

1. 95% of the time, enterococci counts should be less than or equal to 200 counts per 100ml of water;
2. Susceptibility of the location to faecal influence;
3. Only beaches classified as 'Good' and above will be considered suitable for primary contact activities.

The NEA has a rating for each beach which it publishes annually. In 2008, 2009 and 2010, all beaches were rated as very good or good, with only Pasir Ris beach being graded as 'Fair'. The 2010 grading for Pasir Ris beach identified that 7% of the collected samples had enterococci counts greater than 200 per 100ml, compared to 8% in 2009 (SNEA 2011). The public was subsequently advised to refrain from swimming at Pasir Ris beach until the next review's results are available at the end of 2011 and beach advisories issued and signs erected were at the beach.

Figure 6. Singapore Beach Advisory notice

Singapore authorities identify that all monitored beaches, including Pasir Ris Beach, are generally considered safe for secondary contact activities like boating, canoeing and kayaking, as there is less chance of the person being fully immersed in water or swallowing a lot of water.

In general, beach users are advised:

1. Not to engage in water based recreational activities if they have open sores, skin infections or are unwell.
2. To avoid touching mouth/eyes with their hands which were in contact with sand/water.
3. To practise good personal hygiene such as washing hands thoroughly before eating or handling food.

For those who intend to engage in primary contact activities in beaches where swimming is not advised (e.g. Pasir Ris Beach), they do so at their own risk (SNEA 2011).