SAFESWIM: A SEA CHANGE IN ASSESSING BEACH WATER QUALITY RISK

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ABSTRACT

Following an independent review in 2016, Auckland Council recognised some fundamental limitations of its recreational water quality programme (Safeswim). Despite complying with the relevant guidelines, the Safeswim programme did not represent international best practice in managing risks associated with the public recreating in water. Specifically, Council was concerned that the historical, traditional monitoring approach failed to adequately describe and effectively communicate the health risks to the public associated with contact recreation in coastal areas.

One of the key concerns with a “traditional” monitoring and reporting programme is the time it takes to obtain monitoring results under the approach promoted by New Zealand’s Microbiological Water Quality Guidelines for Recreational Areas. This is because natural systems are dynamic, and water quality changes more rapidly than the monitoring frequency (weekly) and the analysis time (up to 48 hours). Therefore; the monitoring does not accurately capture the water quality of a beach, and monitoring results are out of date as soon as they are available. This means that management actions are always retrospective and therefore beach users may be unknowingly exposed to elevated health risks, or warnings are issued unnecessarily.

The use of modelled and forecasted data, are the only methods that make water quality health risk information available to beach users in advance of exposure through recreational activity. The delayed notification system inherent in the traditional monitoring approach, no matter how rapid the test result is available, is unable to provide information in advance of exposure to risk.

It was recognised if modelled bathing beach water quality data could be made visible via the internet to the public, in an intuitive website we could better serve our community. This paper details the significant gains Auckland Council has made, in a short amount of time, in informing our communities about the real time risk of swimming at their local beaches.

KEYWORDS

Water quality, beach, public health, community outcomes, modelling,

1 INTRODUCTION

Aucklanders have a special relationship with the region’s marine environment. Surveys of the community indicate beaches and harbours are the most valued aspects of the environment (Auckland Council, 2014). Furthermore, beach water quality was identified as the second most important environmental issue after air quality.

Auckland Council has assessed beach water quality through its Safeswim programme for over 20 years, primarily using a weekly monitoring approach broadly consistent with the *Microbiological water quality guidelines for marine and freshwater recreational areas* (hereafter NZ Guidelines) jointly published by the Ministry for the Environment and Ministry of Health in 2003 (Ministry for the Environment, 2003).

Auckland Council had recognised that there were limitations of the weekly monitoring approach that underpinned the Safeswim programme, which was designed to comply with the NZ Guidelines. Specifically, Council were concerned that the monitoring approach failed to adequately assess and effectively communicate the health risks to the public associated with contact recreation at beaches.

Hence, Auckland Council had been proactively considering options to move beyond 'compliance' with the New Zealand Guidelines to better manage public health risk. However, following the Havelock North drinking water incident in August 2016, Auckland Council commissioned an independent review of the Safeswim programme, the scope of which included a mandate to create a 'benchmark framework' based on international best practice to guide improvements to the Safeswim programme.

The independent review identified several issues with the Safeswim programme and made a series of recommendations to move towards the benchmark framework that would effectively manage public health risk at the region's beaches. This framework sought to provide balance between Auckland Council's responsibilities of safeguarding public health and prudent financial management.

This paper presents the key high-level findings of the independent review and describes the two key changes to the programme that were implemented in November 2017 in time for the high-use summer season.

2 DISCUSSION

2.1 INDEPENDENT REVIEW

Auckland Council commissioned an independent review of the Safeswim programme in October 2016 that identified a number of shortcomings. The two key issues are described below.

2.1.1 MONITORING LIMITATIONS

The monitoring approach typically involves the collection of water samples from a beach and subsequent analysis in a laboratory, which takes up to 48 hours. This time delay results in a fundamental constraint of the monitoring approach, in that management actions are always retrospective and can only be implemented after human exposure to contaminated water.

In addition, contamination events in coastal water are typically short, with 70% of events lasting less than 24 hours. This means a weekly monitoring programme has a one-in-seven chance of detecting a typical contamination event. For example, a 2001 review of a weekly monitoring programme in California found that the programme missed 75% of guideline exceedances (Leecaster & Weisberg, 2001).

Therefore, monitoring programmes suffer from two fundamental flaws – they do not;

1. Adequately describe water quality conditions (because they miss up to 70% of contamination)

2. Provide timely information (because of the laboratory processing time).

This has resulted in a biased perception of Auckland beach water quality as the programme had consistently underestimated the frequency of contamination events, creating a 'false sense of security' amongst Auckland's beach users. For example, monitoring at Red Beach, on the Whangaparaoa Peninsula, identified 1 guideline exceedance from 330 samples collected over 22 years. This contrasts with a recent targeted sampling programme, which identified 4 guideline exceedances in a single day following a 6mm rain event in November 2017.

2.1.2 INEFFECTIVE COMMUNICATION

Even if health risk is reliably assessed, it is equally important that risk is communicated effectively to the public. However, the public profile of the Safeswim programme was low because its communication methods were basic, one-way and reactive (i.e. crisis-oriented).

The Safeswim communication approach involved un-engaging text-based webpages, with results presented in static tables. The long-term results from a location were not presented with the most recent result, which could create an unrealistic impression if the most recent result was inconsistent with longer term results.

The old webpage recorded 13,000-page views across the 2015/16 bathing season (November 2015 to March 2016), which is low when compared with other pages across the website or international best practice. Surveys of beach users revealed 5% of then had ever visited the Safeswim webpage.

There was no proactive information signage at beaches to communicate to the public that water quality is assessed, with on-beach signs only erected when contamination was identified (i.e. crisis-orientated). The low profile of Safeswim as the definitive place to find water quality information was compounded because there are third party information sources that are providing water quality information of uncertain provenance. This creates the risk of a misinformed public that may enter the water at times of high risk because they are not aware of Safeswim results or have used unreliable information sources.

2.2 PROGRAMME UPGRADE

2.2.1 TWO KEY CHANGES

In response to the independent review, a meeting of the Council's Environment and Community Committee endorsed a substantial upgrade to the Safeswim programme in February 2017. The upgrade focused on switching to a model-based programme and implementing a more proactive communication approach, to be implemented by November 2017 in time for the peak summer season.

2.2.2 ASSESSING RISK

Modelling tools that predict beach water quality are recognised as the only available option that can provide timely information to assess health risk from water-based recreation. Modelling approaches can address the temporal shortcomings of monitoring programmes, providing continuous predictions of water quality in time, supported and validated by targeted monitoring. The major advantage of the modelling approach is the ability to forecast water quality, providing the ability to estimate health risk in advance of the recreational activity and hence before human exposure to contaminated water.

Modelling approaches have been widely used internationally after being signalled as potential alternatives to monitoring by the WHO (in 2003), EU (in 2006) and USEPA (in 2012) and results from modelling tools have generally out-performed traditional beach monitoring. The New Zealand Guidelines (MfE, 2003) did not provide for the use of modelling tools, despite being developed in conjunction with the WHO guidelines, and this has contributed to the limited uptake in New Zealand.

Having recognised some of the shortcomings of monitoring, Auckland Council funded the development of a model to forecast water quality at eight beaches in the Waitematā Harbour, which was developed between 2014 and 2016 by DHI. Before transitioning to an approach where a modelling tool is the primary information resource, we need to understand its performance. In particular, can the model reliably predict periods of poor water quality?

Therefore, we carried out an assessment of model performance using two approaches;

- First, we compared the model forecasts with the monitoring data from the 2015/16 bathing season.

- Second, we undertook targeted sampling of beaches before, during and after rain events to test the ability of monitoring and modelling approaches to identify incidences of poor water quality (that are expected during these events).

COMPARISON WITH MONITORING

The old weekly monitoring programme collected 177 samples from the eight beaches during the 2015/16 summer season; 173 of these samples were classified in the 'Green mode' described in the Guidelines based on the observed enterococci results (i.e. < 140 enterococci/100 ml). The remaining four samples were classified in the Red 'alert mode' (i.e. > 280 enterococci/100 ml).

There was strong agreement between these monitoring results and the model forecasts; 169 (95.5%) of the sampling occasions were classified in the 'Green mode' using both approaches (Table 1).

Of the remaining eight samples, the model over-predicted FIB concentrations for four occasions (the model predicted Amber mode when Safeswim results indicate Green mode) and under-predicted FIB concentrations for four occasions. These four occasions are where the Safeswim results indicated red mode and the model predicted FIB concentrations that were in the Amber mode once and Green mode three times

This analysis shows that the model is performing well when compared with monitoring data, but the majority of the results from this monitoring programme are in the Green mode as they are collected at weekly intervals, during periods of fine weather. This means the monitoring results are likely to under-represent the water quality observed at these locations.

Table 1: Contingency table comparing alert mode based monitoring and modelling results

		Monitoring results		
		Green	Amber	Red
Model forecast results	Green	169	0	3
	Amber	4	0	1
	Red	0	0	0

TARGETED MONITORING

Given the likely under-estimation of water quality from the monitoring data and the objective to test the model's ability to predict periods of poor water quality, we undertook a programme of sampling targeted at rain events.

Between 8 March 2017 and 5 April 2017, we carried out targeted water quality sampling at eight beaches in response to four rain events. The beaches were sampled in the morning and afternoon for each event giving a sample size of 64 (8 beaches x 2 times of day x 4 rain events).

We compared the FIB results from the targeted sampling with;

1. FIB forecasts from the DHI model

2. The routine weekly monitoring data (i.e. a persistence model).

The concentration of enterococci at all eight beaches was far higher during the targeted sampling, with 54 of the sampling occasions exceeding the red mode guideline (84%). The results for the comparisons are presented fully in Tables 2 and 3, with a summary of key points below and in Table 4.

Table 2: Contingency table comparing alert mode based on targeted sampling and modelling results

		Model forecast		
		Green	Amber	Red
Targeted sampling results	Green	3	1	1
	Amber	1	1	3
	Red	10	5	39

Table 3: Contingency table comparing alert mode based on targeted sampling and monitoring results

		Monitoring results		
		Green	Amber	Red
Targeted sampling results	Green	5	0	0
	Amber	5	0	0
	Red	52	0	2

Overall, Table 4 shows the model forecasts were far more accurate (67% correct), and therefore more able to predict periods of poor water quality, than the monitoring approach perpetuated by the NZ Guidelines (11% correct).

Of concern, was the high proportion of false negatives (89%) for the monitoring approach – false negatives are of high concern because this is where the public are exposed to elevated health risks if they choose to enter the water.

The model substantially outperformed the monitoring approach at predicting periods of poor water quality during the targeted sampling. The model predicted 72% of red mode guideline exceedances compared with only 4% for monitoring.

Table 4: The performance of the model forecasts and monitoring approach when compared with targeted sampling.

Measure	Model forecast	Monitoring
Correct	43 of 64 = 67%	7 of 64 = 11%
Correct or precautionary	48 of 64 = 75%	7 of 64 = 11%
False negatives (i.e. high risk)	16 of 64 = 25%	57 of 64 = 89%
Red mode exceedances detected	39 of 54 = 72%	2 of 54 = 4%

MODEL MORE EFFECTIVE

Collectively, the tests of modelling approach described above provided us with confidence that its predictions are more accurate that the monitoring approach in terms of beach water quality. The Auckland model's performance is similar to models used internationally to inform health risk at beaches (e.g. 83% in Ohio (Francy et al, 2006); 84% in Scotland (Stidson et al, 2012) and 90% in Hong Kong (Thoe & Lee, 2014)). Given this understanding of the model performance, we can use its predictions to describe health risk over the entire summer season and compare this with monitoring results.

The difference between the monitoring results and model prediction (Table 5) is strong evidence that the current monitoring approach is not adequately assessing and managing the health risk at Auckland beaches. Even if we accept that the model is not 100% accurate, it clearly indicates periods of elevated health risk that are not detected by the current monitoring approach.

For six of the monitored beaches, the model predicted that elevated health risks were present more often than that suggested by the monitoring results; nearly 20% of model results from Point Chevalier and Herne Bay indicated elevated health risk, whereas the monitoring results indicated full compliance with the Green mode (i.e. low risk)

Table 5: A comparison of Auckland monitoring results and model predictions for the 2015/16 summer season. Results are summarised as the % of 'samples' in each of the alert modes

Beach	Monitoring results			Model predictions		
	% Green	% Amber	% Red	% Green	% Amber	% Red
Point Chevalier	100	0	0	81.4	5.7	12.9
Herne Bay	100	0	0	82.8	5.2	12.1
Home Bay	100	0	0	87.0	5.0	8.0
St Mary's Bay	91.3	0	8.7	91.5	4.5	4.0
Okahu Bay	100	0	0	94.7	2.2	3.0
Mission Bay	100	0	0	98.4	1.1	0.5
Kohimarama	90.9	0	9.1	97.1	1.1	1.8
St Heliers	100	0	0	97.7	1.1	1.3

2.2.3 COMMUNICATING RISK

The tools available for communicating the health risks to the public have radically changed since the publication of the NZ Guidelines in 2003. There are now numerous examples of excellent mobile, map-based communication tools which allow the public to interactively engage with environmental information.

WEB PRESENCE

To create such a platform for Safeswim, we engaged a digital technology company (Translate Digital) to develop a Web Application (webapp). The intent was to provide a user-friendly portal to Safeswim information, but also begin to consolidate information relevant to the beach experience (a suggestion from user groups we interviewed when designing the user interface). The webapp was designed to provide 'one click to insight, two clicks to detail'. That is, a user interested in a particular beach could access the information quickly, whilst a user interested in more detailed information could drill down to the next level.

The webapp has provided a more engaging interface than the previous Safeswim webpage (Figure 1) and its success can be demonstrated by the user statistics. As of 21 February 2018, there have been over 270,000 page views, with 124,000 unique users. This is for just under 4 months of operation and compares with the old website patronage of 13,000 page views for the entire year.

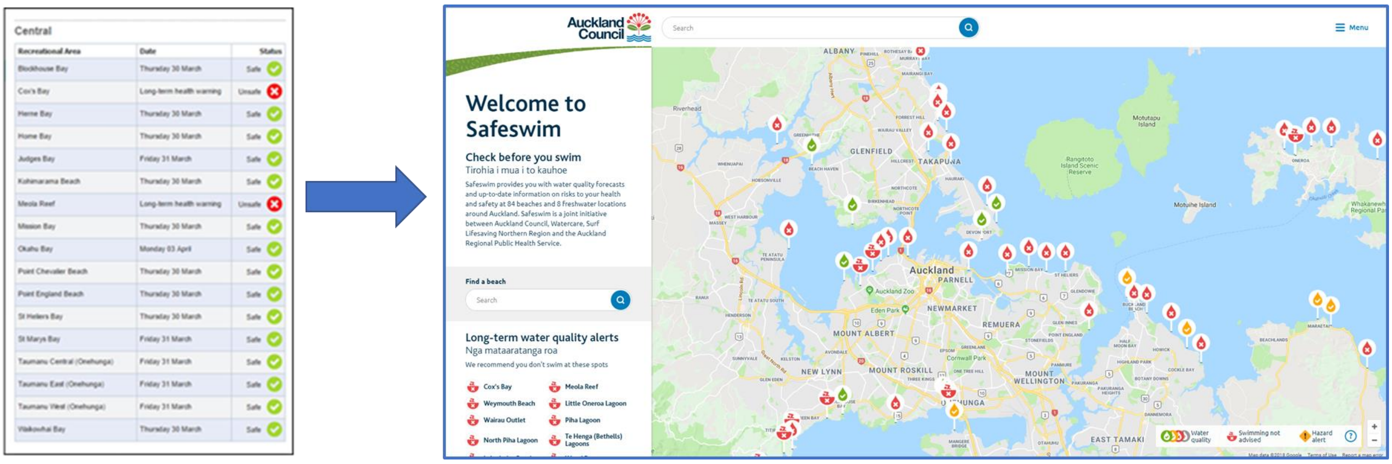

Figure 1: Safeswim user experience transformation

BEACH SIGNAGE

In addition to the web presence, we designed a series of on-beach signs to raise awareness of the programme and to create a culture of 'check before you swim'. The signs were designed to provide at least basic coverage for all beaches, but included a degree of complexity to utilize accessibility and technology at popular beaches. The three sign typologies are described below and there is an ongoing programme of evaluation designed to assess their impact on beach users' awareness and behavior.

- **Basic sign** – static design directing beach users to the Safeswim.org.nz webapp
- **Dial sign** – dynamic sign for beaches patrolled by lifeguards (who can move the dial as required)

- **Digital sign** – large digital sign that is controlled remotely allowing real time updates

Figure 2: Safeswim sign typologies

RISK BASED ASSESSMENT

The previous approach of reporting beaches as ‘safe’ is misleading and inappropriate. The guidelines are based on ‘tolerable risk’ rather than no risk at all. For most healthy people water conforming to the guideline value will pose a minimal level of risk of illness (< 2%). However, water conforming to the guideline values may pose a greater health risk to high-risk user groups such as the very young, the elderly and those with impaired immune systems (MfE, 2003).

3 CONCLUSIONS

This work provided clear direction to Auckland Council to inform its approach to beach water quality management and raised fundamental questions about the efficacy of the monitoring approach perpetuated by the NZ Guidelines, which is concordant with findings of similar assessments internationally. The monitoring approach is unable to identify periods of poor water quality and associated elevated public health risk, and therefore provides a false sense of security for the public when recreating at beaches. In addition, the biased sampling programmes implemented by some Councils magnify these shortcomings – several Councils choose to avoid periods of wet weather in their sampling programmes, which is contrary to the Guidelines, but further reduces the credibility of health risk assessments.

The Stage 1 report from the Havelock North inquiry provided strong direction that Resource Management institutions need to take action when they know there is a problem – knowing that the monitoring approach enshrined in the NZ Guidelines is flawed in its risk assessment creates an obligation to do something about it.

The use of models should be progressed for informing health risks, with an effective model;

- providing a reliable advance prediction of contamination events
- being fully automated using secure, readily available information sources
- providing for communication of results to beach users before arrival
- being applicable to a range of locations.

The models currently operating in Auckland meet these criteria and join other models being used operationally as the primary tools for managing public health risk, including in Scotland, Hong Kong, Ohio and Port Phillip Bay (Melbourne) (REFS). These examples provide important precedents for the use of modelling tools as they have addressed issues associated with model uncertainty and the communication of technical modelling information to the public.

As we have shown, assessing risk is as equally as important as being able to effectively communicate that risk to the public. The revised communication approach for Safeswim now provides a clear, user friendly communication package for Safeswim that would inform the public

- That there are health risks from recreating in water
- That Auckland Council assess water to describe the risk
- Where to find information about the nature of that risk.

The benefits of the new system are best illustrated by the example shown in Figure 1, which is a real forecast from the current forecast model that is operating in the Central Waitematā Harbour. This forecast was accessed on the morning of 7th December 2016 and showed that rain forecast (for later that day and the following day) was predicted to have impacts on water quality in the Harbour.

However, these effects are not consistent in space or time. Poorer water quality and higher health risk were forecasted at western beaches (Pt Chev and Herne Bay) when compared with Eastern beaches (Kohimarama and Mission Bay). In addition, the forecast shows that water quality changes over the course of the three days.

This type of forecast allows beach users to;

- Select **where** to go swimming to avoid beaches with higher health risk (e.g. Mission Bay rather than Pt Chev).
- Select **when** to go swimming to avoid times with higher health risk (e.g. Friday afternoon at Herne Bay rather than Thursday)

In this way, the beach water quality forecast can be used to inform the public's decision making about swimming at beaches, in the same manner that we use weather forecasts to guide our decisions about where and when to undertake activities.

The value of this forecast is driven home by comparison with the results of the old Safeswim weekly monitoring programme at these locations. Samples were collected from all four beaches on the 6th December and all were well within guidelines, which meant the beaches were declared 'safe' and they would not be sampled again until a week later. The declaration of 'safe' based on the weekly monitoring programme completely missed the periods of poor water quality on 7 December, leading to a false sense of security amongst beach users and creating a public health risk.

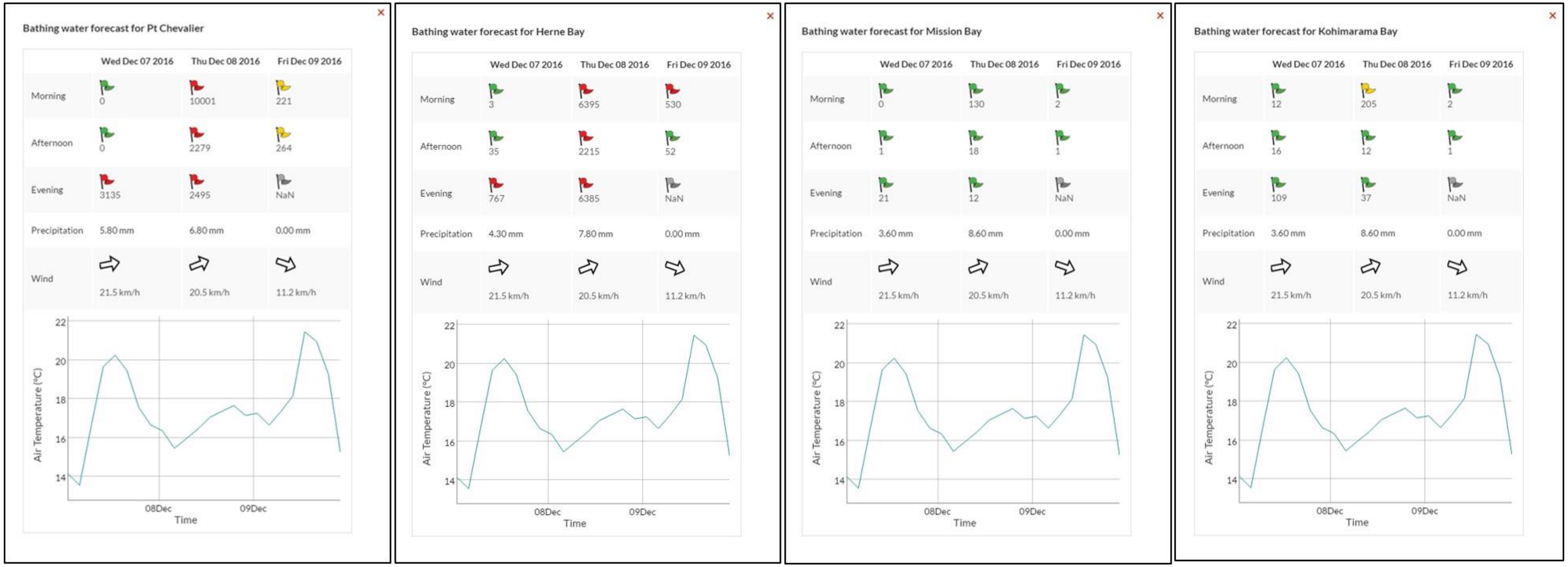

Figure 1: Beach water quality forecasts from the Safeswim model for four beaches (7 December 2016 to 9 December 2016)

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