AtkinsRéalis

BEACHBUOY EXPERT REVIEW

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Document history

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5.0	Report following amendments made after review by & discussion with Southern Water	HG	HV and SA	VJ and NM	VJ	04/12/23
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7.0	Section 4.6 removed and minor edits following Southern Water review	HG	BC	VJ	VJ	09/02/2024

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Executive Summary

An independent expert review of Beachbuoy, a web-based tool developed by Southern Water that provides near real-time information about storm release activity near coastal bathing waters, was commissioned by Southern Water. The review of Beachbuoy covered four key topic areas of relevance: water quality, oceanographic modelling, user and engagement, and software and systems. The aim of the review was to provide an assessment of the system's ability to provide consistent, reliable and credible near real-time warnings of potential water quality impacts from storm overflow releases, plus a series of recommendations to improve the accuracy and user trustworthiness and confidence of the system.

Individuals who are experts in their fields and able to provide an unbiased opinion about Beachbuoy were identified and appointed to undertake the review. Each review consisted of a wide-ranging review of the Beachbuoy system from the experts' point of view, plus answering a series of review questions as set out in the review scope. The scope of the review, and the questions to be answered within it, were written following engagement with key stakeholders including campaign groups.

Key findings from the reviews include:

- **Water quality:** Enhanced precision monitoring of intestinal enterococci (IE) should be undertaken; the inclusion of IE within the model is essential as well as the use of percentile values as the warning trigger, which are already planned updates to the model. Expansion of the modelling to cover other sources of faecal indicator organisms to the coastal zone is important, which also present a health risk.

- **Oceanographic modelling:** Beachbuoy is a valuable resource of data provision to the public, provided it is clear that Beachbuoy provides limited information focussed on Southern Water overflows. The models generally give reasonable agreement between field and Admiralty Chart data and, key refinements need to be made to the modelling. However licences for updated software have been acquired which will resolve some refinements.

- **User and engagement:** Beachbuoy has no significant usability barriers. Improvements should be made to the general interface and mapping interface. The reviewer also suggested providing information on manual updates in the release table and how they work plus setting a threshold for manual update times. Further improvements can be made which will improve the current trust gaps with users.

- **Software and systems:** There are many examples of the use of good industry practice within the system, for example data handling and accurate reporting. Transparency is a key area for improvements throughout the Beachbuoy system, and, some further recommendations relate to governance over the development process and how the products are configured.

A series of recommendations have been made by each of the reviewers based on the outcomes of their reviews. These recommendations have been collated in this over-arching report, and Southern Water have provided an action against each, describing how they will address each one, and a timeframe, indicating by when each of the actions

will be undertaken. Some of the key improvement areas from the recommendations include:

- **Short-term:** updating the bathing water quality modelling software and including IE within the modelling; undertaking a series of updates to the Beachbuoy interface; and, formalising the hybrid/agile IT standard.

- **Medium-term:** collecting further monitoring data of IE in bathing waters and hydrodynamic parameters; improvements made to the email notification service and the information contained within it; and, planning backup and disaster recovery.

- **Long-term:** undertaking further work to allow the coastal modelling to be embedded in a hydrodynamics tool with real-time input data; adding volumetric data; and, improvements to the telemetry hardware.

1.   Introduction

Beachbuoy is a web-based tool developed by Southern Water that provides near real-time information about storm release activity near coastal bathing waters in the Southern Water region[1]. The interactive map, pop ups and release table give information about any releases and their frequency.

An independent review of Beachbuoy was commissioned by Southern Water in order to address concerns by stakeholders and users of the Beachbuoy system. The scope of the review, and the questions to be answered as part of the review, were set out in the document 'Beachbuoy Independent Review Scope', dated February 2023, from Southern Water. They cover the broad topics of: human health; the review process and system; the automatic review process; general modelling; user engagement; software aspects, and, documentation. The scope was written following engagement with key stakeholders including campaign groups.

The review involved four independent experts who covered the four key topic areas of relevance to Beachbuoy:

- Water quality
- Oceanographic modelling
- User and Engagement
- Software and Systems

The overall objective of the independent review was to provide an assessment of the current Beachbuoy system's ability to provide consistent, reliable and credible near real-time warnings of potential water quality impacts from storm overflow releases, and to provide a series of recommendations to improve the accuracy and user trustworthiness and confidence of the system.

AtkinsRéalis was commissioned by Southern Water to coordinate the review by the independent experts and to provide an overall report summarising the review process and pulling together the results of the review.

This report is set out as follows:

- Section 2 – Introduces the experts who undertook the review.
- Section 3 – Provides the key findings from the review.
- Section 4 – Summarises the recommendations from the review and provides the next steps in terms of acting on the recommendations from a Southern Water perspective.
- Section 5 – Provides an overall summary of the review and its conclusions.

The individual expert review reports are collated in Appendix A. The collated answers to each of the review questions are provided in Appendix B.

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[1] Beachbuoy (southernwater.co.uk)

2.   The Experts

A short-list of potential independent experts was drawn up by AtkinsRéalis for each of the four topic areas. This list was reviewed by Southern Water and then selected potential reviewers were approached to see if they would be interested in undertaking the review. It was important that each reviewer was a specialist in their field and was able to provide an unbiased opinion about Beachbuoy. An initial conversation was then undertaken with the potential reviewers, to further explain the Beachbuoy system and what the review would entail. It also provided an opportunity for the potential reviewers to ask questions about the review before making any decision.

Following this process, the following independent experts were selected to undertake the review:

- **Water Quality – Prof. David Kay, Aberystwyth University and the Centre for Research into Environmental Health**. Prof. Kay is an Emeritus Professor in the Department of Geography and Earth Science at Aberystwyth University and the Centre for Research into Environment and Health. His research has focused on environmental epidemiology and bathing water quality, and he is an advisor to the European Union, World Health Organisation and the US Environmental Protection Agency on bathing water standards design.

- **Oceanographic Modelling – Prof. Roger Falconer, Cardiff University and Roger Falconer Water Consultancy Ltd.** Prof. Falconer is an Emeritus Professor of Water Engineering at Cardiff University and an independent consultant. He has extensive experience in water-environmental modelling and engineering projects, with particular expertise in hydrodynamic and water quality modelling, and as an expert witness and due diligence advisor.

- **User and Engagement – Dr. Artemis Skarlatidou, University College London.** Dr. Skarlatidou is a Lecturer in Citizen Science in the Department of Geography at University College London. Her research looks at the socio-technical and design perspectives in the implementation of geographic interfaces and technologies, in particular how technological design can improve accessibility and community empowerment.

- **Software and Systems – Dr. Robert Kevin Holmes, Staff Management Tools**. Dr. Holmes is a Systems Engineer/Enterprise Architect working as an independent consultant. He specialises in project definition, requirements engineering, solution concept design and data architecture, with accountability for project delivery.

3.   Findings from the Review

The full review reports are provided in Appendix A, with the answers to the review questions from each of the reviewers collated in Appendix B. A summary of the key findings from each of the reviews is provided below.

Water Quality Review

- Beachbuoy suggests microbial standards for Southern Water bathing waters which are derived from health-based criteria suggested by the World Health Organisation (WHO) (2003) and adopted by the EU Bathing Waters Directive (BWD) (2006). Having used these health-based criteria Southern Water need to make improvements to the approach to predict microbial water quality in Beachbuoy since these criteria were designed by the WHO (and later adopted by the EU in their Bathing Water Directive (2006)) to predict health risk amongst the bathing community.
- It is essential to predict intestinal enterococci (IE) within Beachbuoy, as this is the only microbial parameter proven by the UK epidemiological studies in saline waters to predict health outcomes in the bather community.
- Percentile values should be used as the warning trigger in the modelling. 95%ile IE <500/100ml equates to 5-10% rate of gastroenteritis amongst bathers.
- It is however understood that Southern Water are about to implement the modelling of IE, and the use of percentile values as triggers in the modelling.
- A well-designed testing and validation bathing water quality sampling programme, using enhanced precision for the enumeration of IE in coastal bathing waters, should be undertaken to test the prediction of IE by Beachbuoy. This sampling programme should be approved by regulators.
- Expand modelling to cover the other sources of faecal indicator organisms (FIOs) to the coastal zone, as multiple sources other than storm overflows also present a health risk.

Oceanographic Modelling Review
- Beachbuoy is a valuable resource of data provision to the public, provided the additional statement is made that Beachbuoy currently provides limited information specifically focussed on Southern Water's overflows.
- It is important that Beachbuoy provides information as accurately as possible relating to the potential impact of Southern Water's assets on bathing water health risks in order to prevent bathers receiving warnings too frequently when not appropriate, which often results in bathers deciding not to pay too much attention to the warnings. This experience has been quite common in flood alerts.
- It is suggested that terminology is updated to say that every attempt to aim to be as conservative as possible in coastal modelling predictions has been made.
- The models generally give reasonable agreement between field measurements and Admiralty Chart data, however there is over-simplification of some processes within the model and therefore key refinements need to be made.
- These refinements include: using a finer and unstructured grid model; collection of field observations of bed roughness coefficients to validate model values; relating key processes to depth and velocity; and, improved wind representation.

- The writer does however understand that licences for the newer version of the MIKE 213 model have been acquired, and the model is to be updated in the newer software, which will resolve some of the recommended model refinements.
- However, if it is desirable, the existing coastal models can continue to be used until a new model is set up for the region, taking account of the limitations of the existing model.

User and Engagement Review

- The interviewees consulted for the review unanimously agreed that the purpose and function of Beachbuoy is very important.
- The heuristic evaluation of usability and user interviews showed no significant usability barriers with Beachbuoy.
- There are recommended improvements to the general interface. These include providing: further information to correct misconceptions and address user concerns; a Frequently Asked Questions section; different audio-visuals to explain information; and, further information on the release status updates.
- There are recommended improvements to the mapping interface. These include: review and add all relevant map data; specifying time zones; adding a search bar; and, improving font size.
- There are significant trust gaps with the users. Various improvements can be made to Beachbuoy to ameliorate this and improve trust with the users. These include: increased engagement with a wider user group, which can be developed through stakeholder mapping; performing usability user testing; and, the aforementioned improvements to the general interface and mapping interface.

Software and Systems Review

- A holistic review of Beachbuoy was conducted on the entire end-to-end spills identification process and systems, via interviews, examination of documents and project control systems, and examination of the current Beachbuoy public facing functionality.
- There are many positives from the review. Event duration monitor (EDM) architecture, information flow and automated data processing is compliant to industry good practice. There is the use of well-established and industry strength products. Data handling is good with detailed mapping allowing accurate reporting to Ofwat and appropriate data retention.
- Additionally, there is an auditable configuration for assigning confidence levels against Check Value Limit values in spill reporting and, the conservative and false negative risk averse strategy in spill determination is commendable and Southern Water are addressing the time delays in manual reviews. System log files are available for spill reviews, and the project lifecycle follows good industry practice.
- There is a rigorous IT process for release approval, with good technical architecture implemented and maintained for the original Beachbuoy release.
- There is also the understanding that the original technical implementation is not scalable for future business needs and has limitations.
- There are a series of recommendations from the review, which can be summarised as the following. Enhanced end user involvement including profiling

different persona needs/scenarios and validating requirements through discovery processes and releases through beta testing and early involvement. Improvements to the user interface through utilising usability testing and UX best practice. Better provision of informational content to explain how the system works and where the data comes from and the context. Incorporation of additional data sources and system data including inland overflows and verification decisions.

- Additionally, improvements in governance, internal documentation and project management (both over the development process and how the products are configured) should be made as well as moving to a set of standard products, which will reduce maintenance cost and time and allow faster development and resilience to change.

- System latency should be improved through increased polling frequency and resolving telecoms constraints as well as improvements of backup and disaster recovery.

- However, it is acknowledged that the majority of these are now being addressed.

- In summary, the main issue identified was that in spite of demonstrable good practice there was no joined up clarity and documentation of the end-to- end spill data flow from overflow sensor detection through verification to the Environment Agency and Beachbuoy reporting. This, in the opinion of the reviewer, prevents Southern Water regaining the previously lost trust by members of the public.

All the recommendations from each of the reviews have been collated in Section 4; as well as responses from Southern Water on how each recommendation will be addressed, and by when.

4. Recommendations & Next Steps

The recommendations from each expert review report have been collated in the following sections:

- Water quality recommendations – Section 4.2.

- Oceanographic modelling recommendations – Section 4.3.

- User and engagement recommendations – Section 4.4.

- Software and systems recommendations – Section 4.5.

Alongside each recommendation a response is provided from Southern Water detailing the next steps as to how the recommendation will be actioned, as well as whether the recommendation will be applied in the next version of Beachbuoy v2, (due for release March 2024), plus a timeframe for recommendations which will be actioned beyond the next version of Beachbuoy.

The reviewers have provided their timeframe (short-, medium- and long-term) alongside their recommendations in their reports. For the user and engagement review, recommendations were classified as critical, medium or low –Southern Water subsequently added a time frame alongside each recommendation to consider technical complexities in delivering the recommendations.

The key improvement areas from the recommendations are summarised below. The water quality and oceanographic modelling key improvement areas are collated together since there is some overlap. These have been grouped based on the following time frames defined by Southern Water:

- Short – end of March 2024.

- Medium – this AMP (AMP7), by April 2025.

- Long – the next AMP (AMP8), beyond April 2025.

A final section (section **Error! Reference source not found.**) provides a summary of the findings of the reviews as to whether the current version of Beachbuoy, and its modelling, should continue to be used by Southern Water whilst the various improvements are being undertaken.

4.1 Key Improvement Areas from Recommendations

4.1.1 Water quality and oceanographic modelling

Short-term:

- Update the bathing water quality modelling software and refine/test the associated modelling parameters.

- Update warnings to include percentile values and IE.

- Update wind trajectories to most frequent at sites.

- Further investigate wind stress effects and effluent release around mean water level (MWL).

Medium-term:

- Further monitoring data of IE in bathing waters and hydrodynamic parameters.

- Further refinement to wind trajectory modelling.

- Refine/test the associated modelling parameters in the updated model – particularly the solute transport processes, including day/night FIO decay rates.

- Further sampling to understand key source inputs and for model calibration and validation.

- Engagement with the Environment Agency and Local Authorities on the modelling and prediction.

Long-term:

- Further work to allow coastal modelling to be embedded in hydrodynamics tool with real-time input data.

4.1.2 User and engagement

Short-term:

- Interface updates – including pop-up window size, search bar and improved visibility of points.

- Improved informational content about Beachbuoy, how it works and the data it is displaying– including videos and FAQs (frequently asked questions), manual updates and unverified releases.

- Create a user forum (also longer-term).

- Ensure all known outfalls are included, and exceptions identified.

- User experience testing of mobile version and further usability user testing and interviews of users.

- Stakeholder mapping and engagement with a wider audience.

Medium-term:

- Improved email notification service and the information contained within it.

- Provide information on manual updates in release table and how they work.

- Set threshold for manual update times (also longer-term).

Long-term:

- Add volumetric data and explanation of it.

4.1.3   Software and systems

Short-term:

- Produce retrospective documentation of IT (information technology) architectures including design.

- Redesign (short) and build and test (medium-term) data interface from Aspire to Beachbuoy.

- Implement updated project management for Beachbuoy redevelopment (also medium-term).

- Formalise hybrid/agile IT standard.

- Implement release management improvements (also medium-term).

- Closer to real-time updating.

Medium-term:

- Undertake planning of backup and disaster recovery.

- Separate database for inland waters.

- Improved management of workflow issues through Feature Manipulation Engine (FME).

- Validate releases.

Long-term:

- Improved telemetry hardware.

4.2 Water Quality

Table 4-1 – Water quality review recommendations (as provided by reviewer) and Southern Water actions (as provided by Southern Water team)

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#1 – Short-term Updating of the modelling to incorporate percentile values from the as triggers for the Beachbuoy warnings.	The modelling will be updated to calculate both the 95%ile and maximum values for both IE and EC (links to #2 below) and take the worst of those for both parameters to use as the trigger for Beachbuoy warnings.	Yes	End of 2023 – this will be in the current version of Beachbuoy
#2 – Short-term The model to be updated to include IE in Beachbuoy alongside EC.	A method has been developed, and will be adopted, to incorporate IE alongside EC n the modelling.	Yes	End of 2023 – this will be in the current version of Beachbuoy
#3 – Medium-term Acquisition of confirmatory data on IE to compare statistically with model predicted values. It is understood that SWS intend to implement this step using the EDM to predict IE in the bathing zone(s).	Further sampling will be undertaken as part of the Bathing Water programme in AMP7-8.	No	April 2025
#4 – Long-term Expand the modelling effort to cover the other sources of FIOs to the coastal zone from farming the human population including sewage flows and wildlife. If these sources prove trivial SWS need to have the empirical evidence to prove this judgement.	Southern Water has developed a research proposal to improve coastal bathing water quality forecasting nationally working with a series of key parties and experts.	No	Unknown – depends on funding outcome

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#5 – Long-term Validation of the utility of the modelling and prediction efforts in the SWS region need to be reviewed by the environmental and public health communities, the latter within Las and NHS, and the former with the EA.	A plan will be put together to work out the next steps for engagement with the key contacts at the EA and Local Authorities to discuss the modelling.	No	Jan 2025

4.3   Oceanographic Modelling

Table 4-2 – Oceanographic modelling review recommendations (as provided by reviewer) and Southern Water actions (as provided by Southern Water team)

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#1 – Short-term Replace oceanographic and coastal zone modelling suite with newer version.	Licences for the newer version of the unstructured MIKE 213 model have been acquired, and the model is to be updated in the newer version of the software.	Yes	May 2024
#2 – Short-term Check to ensure that the Coriolis slope effect is included in grid model.	Licences for the newer version of the unstructured MIKE 213 model have been acquired, and the model is to be updated in the newer version of the software – this will include exploration of carrying out sensitivity analysis of the impact of the Coriolis effect. DHI (the software product company) will be contacted to validate usage of this	Yes	May 2024
#3 – Short- and Medium-term Field monitoring programme is undertaken to measure the key hydrodynamic parameters for key sites (ADCPs).	Use existing datasets to recalibrate the hydrodynamic model. We will consider survey programs based on findings.	No	Sept 2024
#4 – Short- and Medium-term Provide a refined grid cell structure in nearshore areas.	Licences for the newer version of the unstructured grid MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – this updated software includes a refined grid cell structure in near shore areas.	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#5 – Short-term Change nested down ratios to ratios of 1:3 or 1:5.	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – this updated software will obliviate the need for nesting.	Yes	May 2024
#6 – Short-term Estimate the approximate bed roughness based on bed data to justify changes in the roughness coefficient.	Licences for the newer version of the unstructured MIKE 213 model have been acquired, and the model is to be updated in the newer version of the software. Model calibration and validation will be carried out and bed characteristics will be used to improve estimates of the approximate bed roughness.	Yes	May 2024
#7 – Short- and Medium-term Investigate wind stress effects on the variation in the trajectory and physical characteristics of the discharge plumes in more detail.	Worst case wind conditions replaced with most frequent wind trajectory at the site – updating of these lookup tables for Beachbuoy 2.0.	Yes	July 2024
	Further refinement with consideration to wind trajectories will be modelled using MIKE 213, and additional business logic layers will be added to Beachbuoy to reflect this data at a later date.	No	End 2024
#8 – Medium-term Consider implementation of at least a one-equation turbulence model to estimate the turbulent diffusion processes.	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – the implementation of eddy viscosity within this updated model will be carefully considered.	Yes	May 2024
	This work will be carried out based on existing datasets to achieve this by March 2024		

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#9 – Medium-term Refine solute transport model to include dispersion-diffusion processes related to velocity and depths effects.	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software –the newer model will be calibrated against monitoring data to ensure the solute transport model is refined accordingly.	No	July 2024
#10 – Medium-term Update the model to consider the difference in FIO concentrations based on day and night-time release events.	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – day and night-time varying decay rates will be incorporated into this updated model.	Yes	End of 2024
#11 – Medium- and Long-term Use state-of-the-art modelling tools for assessing health risk impacts. .	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – this model will have a refined grid structure, an improved representation of turbulence and dispersion-diffusion processes and a more realistic representation of wind driven effects.	Yes	May 2024
#12 – Short- and Medium-term Additional sampling studies for key bathing sites to understand key source inputs.	Further sampling of key bathing water sites will be planned, and the results from this will feed into any required updates within Beachbuoy.	No	Jan 2025
#13 – Short- and Medium-term Additional transect sampling studies for key bathing sites to acquire data for model calibration and validation.	Further sampling of key bathing water sites will be planned, and the results from this will feed into any required updates within Beachbuoy.	No	Jan 2025

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#14 – Long-term Embed the coastal modelling data within a hydroinformatics tool to provide real-time input data to Beachbuoy.	Further work will be undertaken to allow the coastal modelling to be embedded within a hydroinformatics tool to provide real-time input data.	No	2027
#15 – Short-term Run simulations of the effluent release from a typical outfall around MWL	Dependent on the new software for modelling	No	July 2024
#16 – Short- and Medium-term Refine Solent and IoW modelling grid to provide finer resolution in the region	Licences for the newer version of the unstructured MIKE 21/3 model have been acquired, and the model is to be updated in the newer version of the software – this model will permit a much finer grid without nesting.	No	July 2024

4.4   User and Engagement

Table 4-3 – User and engagement review recommendations (as provided by reviewer) and Southern Water actions (as provided by Southern Water team)

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#1 – Critical (short-term) Improve Beachbuoy access.	We will review navigation to the Beachbuoy product from the main southern water website, to make it easier to find.	Yes	March 2024
#2 – Critical (short-term) Reorganise and provide additional information.	We are improving the informational content provided in Beachbuoy for 2.0.we will ensure that the informational content can be navigated with ease / users can find the content that they need.	Yes	May 2024
#3 – Critical (short to medium-term) Provide videos and appropriate visualisations for users with different competency levels.	Further content can be written and uploaded (both visual and interactive) to explain Beachbuoy.	Yes	May 2024
#4 – Critical (short-term) Provide a Frequently Asked Questions section to answer user queries.	Analysis is being conducted into frequently asked questions by users. Content will be written and updated for Beachbuoy 2.0 based on these findings.	Yes	May 2024
#5 – Critical (medium-term) Provide tailored email notifications with sufficient content.	Discovery is being conducted within the next 6 months to explore improvements to the email notification service provided based on user feedback. Roadmap item for implementation in 2024.	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#6 – Critical (medium to long-term) Provision of brief explanation of manual data updates in 'Historical and current releases' Table	Southern Water commit to exploring how to implement this practically and report back options to the working group.	Yes	May 2024
#7 – Low (short and long-term) Provide a Forum for two-way communication with end users to promote transparency and trust	A user-forum will be created for the short term for the private beta for Beachbuoy 2.0 to engage with users and generate insight. A longer-term solution to user engagement, including the provision of a user community forum, is being explored.	Yes	Short term – March 2024 Long term – 2025
#8 – Critical (short-term) Optimise Beachbuoy Map Loading Speeds	The new version of Beachbuoy will include ESRI mapping, which should have faster loading speeds. We are targeting a load time of <1 second for the interactive map.	Yes	May 2024
#9 – Critical (short-term) Reduce the size of the pop-up window	User Interface design is underway for improving the size of the pop-up windows in the next version of Beachbuoy.	Yes	May 2024
#10 – Critical (short-term) Add all relevant map data or explain why specific background data are not provided to improve transparency and trust	All permitted outfalls will be added to Beachbuoy 2.0. Discovery is being conducted within the next 6 months to explore improvements and provision of background to improve transparency and trust	Yes	May 2024
#11 – Critical (short-term) Provide information about spatial data accuracy below the map	To be delivered May 2024 in-scope for Beachbuoy 2.0.	Yes	May 2024
#12 – Critical (short-term) Specify time zones for reporting outfall release duration	Inclusion of the time-zone used when presenting time-based data has been incorporated into the design of Beachbuoy 2.0	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#13 – Critical (short-term) Additional interviews and usability user testing to provide further insight into the white 'unverified release' symbol to make specific recommendations	Completed with the working group (9th Nov 2023) decision made to remove white icon. Logic changes in delivery for mk1 at time of writing. Additional user testing will be completed as part of the development of mk2 (Beachbuoy 2.0).	Yes	Jan 2024
#14 – Critical (short-term) Enable viewing impact of releases on bathing sites and releases from outfalls as two separate layers	To be delivered May 2024 in-scope for Beachbuoy 2.0.	Yes	May 2024
#15 – Medium (short-term) Provision of a search bar for a more tailored map navigation based on user's preferences	To be delivered May 2024 in-scope for Beachbuoy 2.0. Delivery will align with recommendation #5.	Yes	May 2024
#16 – Medium (short-term) Improve font size design to match different scales	To be delivered May 2024 in-scope for Beachbuoy 2.0.	Yes	May 2024
#17 – Medium (short-term) Improve visibility of selected objects/points on the map	To be delivered May 2024 in-scope for Beachbuoy 2.0.	Yes	May 2024
#18 – Low (short-term) Improve interaction with 'Historical and current releases' Table	To be delivered May 2024 in-scope for Beachbuoy 2.0.	Yes	May 2024
#19 – Not assigned (short-term) Choice of colours further evaluated.	Accessibility of colour blindness is a design requirement that UX colleagues work to. This is part of the QA process for design work moving forward, and will be accommodated in the Beachbuoy 2.0 release.	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#20 – Critical (short-term) Perform a User Experience Evaluation on the mobile version of Beachbuoy	We are evaluating the UX of mobile devices for the Beachbuoy 2.0 solution. This will be conducted as part of the private beta program with the user community.	Yes	May 2024
#21 – Critical (short-term) Perform Stakeholder Mapping and engage with a wider user audience to build trust	As part of the private beta program for Beachbuoy 2.0, we are engaging with three segments of external users (separate from our usual stakeholder groups) who represent a cross-section of water-users, alongside existing stakeholders (for example, Working Group, Campaign Groups) – which is approximately 50 users.	Yes	March 2024
#22 – Critical (short-term) Extend Interviews and perform Usability User Testing for different types of users with various competencies	As above (recommendation #21)	Yes	March 2024
#23 – Critical (medium-term) Inform users about all (actual or potential) RED warnings	This links to recommendation #5.	Yes	March 2024 May 2024
#24 – Critical (medium-term) Provide content so that email notifications become more meaningful	This links to recommendation #5.	Yes	May 2024
#25 – Medium (medium to long-term) Add brief explanation to justify data updates during the manual updates process. This should appear	This links to recommendation #6 Southern Water commit to exploring how to implement this practically and report back options to the working group.	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
next to the relevant change on the 'Historical and current releases' Table			
#26 – Critical (short to medium-term) Explain in lay terms how Beachbuoy updates work (both automated and manual)	Links to recommendation #3 & #4 This is accounted for in the information provision work being done for Beachbuoy 2.0.	Yes	May 2024
#27 – Critical (short to medium-term) Explain in lay terms the specifics of the 'unverified overflow release' feature and the reason it exists in the first place	Links to recommendation #3 & #4	Yes	May 2024
#28 – Critical (long-term) Add volumetric data	Southern Water are committed to exploring in a discovery session what is required and what the benefits are to the users	No	March 2024
#29 – Critical (medium-term) Improve transparency about concentration rates through Beachbuoy information page	Links to recommendation #3 & #4	Yes	May 2024
#30 – Medium (short to long-term) Ensure there is an explanation of what volumetric data means provided in lay terms	Links to recommendation #3 & #4 Implementation of volume data is dependent on output from recommendation #28	Yes	Dependent on Discovery into Volumetric Data
#31 – Critical (short-term) Perform additional interviews and usability user testing (observation) to capture functional and non-functional requirements for both desktop and mobile interfaces	Links to private beta testing programme in recommendation #21	Yes	March 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#32– Critical (short-term) To implement Human-Computer Interaction methods follow appropriate methodological protocols	Links to private beta testing programme in recommendation #21.	Yes	March 2024
#33 – Critical (short-term) Interviews and usability testing should be used to engage end users (outside the existing stakeholder group) with different competency levels and categorise needs and requirements accordingly	Links to private beta testing programme in recommendation #21.	Yes	March 2024
#34 Methods such as interviews and usability user testing can create a connection/bond with users, build rapport and demonstrate an ethic of care which is necessary to promote and rebuild trust with end users. For this reason, might be best performed by independent experts	Links to private beta testing programme in recommendation #21.	Yes	May 2024
#35 – Low (medium to long-term) Run usability testing to evaluate how easy are different visualisations to use by different types of users (i.e., beginners, intermediate and advanced competency levels)	We will provide content where there are gaps in content and based on user feedback.	No	2025
#36 – Critical (short-term) Provide clear explanations of how updates work	Links to recommendations #3 & #4	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#37 – Critical (short-term) Provide clear explanation of Beachbuoy update times (i.e. both manual and automated)	Links to recommendations #3 & #4	Yes	May 2024
#38 – Critical (medium to long-term) Set threshold for manual updates (e.g., no less than two hours) to improve reliability and help users efficiently manage health risks	In the long term the plan is to automate spill verification process and remove delays due to manual reviews for 80% of events.	No	2025
#39 – Critical (short-term) Explain why some longer releases are described as multiple smaller releases even when these are just a few minutes apart	Links to recommendations #3 & #4	Yes	May 2024
#40 – Critical (short-term) Specify time zones for start and end release times	Complete in current version	Yes	May 2024
#41 – Critical (short-term) Explain in lay terms on Beachbuoy information page the 'unverified overflow release' feature and the reason it exists in the first place	Links to recommendations #3 & #4	Yes	May 2024
#42 – Critical (long-term) Set threshold for manual updates that verify a release	Links to recommendation #38	No	2025
#43 – Critical (short to medium-term) Perform stakeholder analysis to map all relevant stakeholder groups across the South-East coast	We have already mapped relevant stakeholders and groups but will revisit this activity with the support from relevant internal teams. If necessary, we'll update the Beachbuoy Working Group to reflect the mapping	Yes	Jan 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
	exercise, ensuring suitable representation. This will also be used to recruit stakeholder groups to feed into Beachbuoy 2.0 and beyond.		
#44 – Medium (short to medium-term) Emphasis should be paid on improving awareness about Beachbuoy and engage more actively with members of the public who might benefit from it	We already actively encourage feedback from the public, and promote Beachbuoy wherever possible as a tool. We will continue with this approach and continuously evaluate how we can do this more effectively. Videos and written materials are in the process of being created to help with promotion, and a communication plan will be devised and implemented for Beachbuoy 2.0 launch.	Yes	May 2024
#45 – Medium (short to medium-term) Provide incentives or other mechanisms to encourage participation	Incentives are being made, via our partner Relish, to participants of the beta program who are outside of the Working Group community to encourage participation.	Yes	Feb 2024

4.5 Software and Systems

Table 4-4 – Software and systems review recommendations and Southern Water actions (as provided by Southern Water team)

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#1 – Short-term Retrospective documentation of IT architectures: design of database physical model; documentation of detailed state-change scenarios; collation of business rules.	This is being undertaken as part of Beachbuoy v2.0.	Yes	May 2024
#2 – Long-term Improvement to restrictions to telemetry bandwidth.	Work is being done, separate to the Beachbuoy project, to improve Southern Water infrastructure on telemetry hardware.	No	2027 – 2030
#3 – Medium-term Backup and disaster recovery.	Beachbuoy 2.0 will be hosted in the new data centres, and therefore covered in-scope for Beachbuoy 2.0 Prism, Aspire and PI will be delivered with target date end of November.	Yes	May 2024
#4 – Short and Medium-term Reduce the 1 hour clock based batch delay in passing data from Aspire to Beachbuoy (NOTE Given the current High Level Design the extension to include Aspire rivers spill data via using the existing Quartz interface will probably compromise performance even further) Short term – redesign interface	Discovery in progress (December-March) to determine feasibility. Roadmap item for 2024.	Yes	Discovery – March 2024 Implementation – By end of 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
Medium term – build and test interface			
#5 – Medium-term The new inflight Beachbuoy redevelopment will address the extension to inland water via a separate database	Cost/benefit analysis of creating a separate database was conducted and it was determined that this would not be beneficial to implement; creation of one database was a preferred option.	Yes	Not doing
#6 – Medium-term The new Beachbuoy redevelopment will address integration and workflow issues through the implementation of FME	Deliver FME as the business logic layer for managing workflow issues by March 2024.	Yes	May 2024
#7 – Medium-term The new Beachbuoy redevelopment will address the maintenance cost and maintainability via the FME Low Code development platform.	Deliver FME as the business logic layer by March 2024, which will reduce technical debt/maintainability for future product growth.	Yes	May 2024
#8 – Short and Medium-term Updated project management for the new Beachbuoy redevelopment: • Stakeholder analysis and stakeholder management plan. • In depth Business and Investment case development. • Traceable Governance via Project Board and Separation from the Aspire work. • Corporate Risk analysis mitigation and management.	Stakeholder – We have already mapped relevant stakeholders and groups but will revisit this activity with the support from relevant internal teams. If necessary, we'll update the Beachbuoy Working Group to reflect the mapping exercise, ensuring suitable representation. This will also be used to recruit stakeholder groups to feed into Beachbuoy 2.0 and beyond. Business and investment case development – business cases will be developed for future funding of Beachbuoy development.	Yes – stakeholder and in-depth business and traceable governance No – others	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
	Traceable governance – Beachbuoy 2.0 project is being handled separately from Aspire. Risk – risk is managed internally for the various steps and processes in Beachbuoy development.		
#9 – Short-term Formalisation of the hybrid/agile IT standard	IT Department to review and formalise agile methodology in-line with product development goals (Within next 6 months).	Yes	May 2024
#10 – Medium-term Validate releases with external audiences	Beachbuoy 2.0 will employ the use of a private beta testing / iterative development approach to test/validate releases with external audiences prior to public release.	Yes	May 2024
#11 – Short-term Business analyst centre of excellence	Assumes a waterfall model of delivery, not currently being considered for the long-term growth of the product, given its requirements to be responsive and iterative. No current plans to implement a Business Analyst centre of excellence.	No	N/A
#12 – Short to Medium-term Release management improvements	Private beta testing / iterative development (AGILE) will essentially mitigate risk / serve the UAT Function of Waterfall UAT. Build Validation, through Private Beta mitigates release risks and by design incorporates feedback / is responsive to change.	Yes	May 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#13 – Medium-term For Beachbuoy the one hour on the hour delay must be addressed (the Quartz / stored procedure method (effectively a batch process) must be replaced by something closer to real time updating) in order to meet the Environment Act requirement of 1 hour end to end from start of spill to public.	Links to recommendation #4.	Yes	March 2024
#14 – Short to Long-term **Spatial Mapping and Reference Data for site** Integration and reference data updates (from CALMS and CATalogue in the first instance, as this is mastered reference data. Specifically the mappings of bathing sites to outfalls, outfalls to treatment works overflows, the EA Permit restrictions on overflow/outfall (assumed to be in the public domain via the EA). There are two actions: 1. These configurations being available via the public interface add to the user trust 2. Internal documentation as it is understood this reference data is cascaded to Aspire (and possibly PI AF) but whether and how this is cascaded from Aspire to Beachbuoy is unclear given the Beachbuoy Admin portal. These should be considered as a medium-term extension to the Beachbuoy redevelopment and evaluated as part of the Business Analysis in the short term. The association of other location reference data such as EA sample points could be	1. We will provide textual informational content that explains how we determine 'associated outfalls' for a Bathing Site. 2. We are implementing a feature in Beachbuoy 2.0 that lists all associated outfalls for the bathing site that a user clicks on for greater visibility of the relationships between these two site types. 3. We will provide textual information on how we have determined the location of Bathing Sites, with reference to their classification by the EA (see provision of Spatial Information in the user engagement recommendations). 4. We will conduct technical and value discovery to validate the possibility of including EA Water classification data based on their sampling.	1 to 3, and 5 – Yes 4 – No	1 to 3, and 5 – May 2024 4 – By end of 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
included, however, the reporting of cross correlation of sample test data with spills may require exception investigation (the no spill but high contamination scenario. This is more medium to long term.	5. Internal Documentation and analysis into the accuracy of location data between systems will be undertaken as part of the initiative to include all SW Outfalls in the new version of Beachbuoy.		
#15 – Long-term Mobile app development for Beachbuoy	There are no current plans for mobile app development, but we will continue listen to users on the need for a mobile app.	No	N/A
#16 – Short-term Formal Beachbuoy design documentation	High and Low level designs have been carried out as part of the Beachbuoy 2.0 re-platform work.	Yes	May 2024
#17 – Short-term Formal Aspire design documentation	Aspire documentation is being completed, as part of the end-to-end system design and database migration work underway.	Yes	May 2024
#18 – Short-term Include operational decisions / data from the spills team in Beachbuoy data	It will be explored how the operational/data decisions that are made about how a spill event was actioned and assessed can be provided to the public. Southern Water commit to exploring how to implement this practically and report back options to the working group.	Yes	May 2024
#19 – Short-term Control/authorisation for sensitive control data for Beachbuoy configuration	There are already controls in place to authenticate / block unauthorised access to making these changes. Every change is logged for auditing. This is already controlled for.	Yes	March 2024

Recommendation	Southern Water Actions	In scope for Beachbuoy 2.0?	Date for recommendation to be implemented
#20 – Short-term Expose check factor limit value to public in Beachbuoy, more generally explain as part of the web interface the principles of how check factors are used in automating spill probability determination.	We will provide textual information around the semi-automated process for reviewing spill events. This will include reference to the use of 'check factor limits' which are used to determine false alarm events.	Yes	May 2024
#21 – Short-term Functionality associated with the map colours needs redesign by a Human Factors expert as part of the Beachbuoy redevelopment	As part of the private beta program for Beachbuoy 2.0, we are engaging with three segments of external users (separate from our usual stakeholder groups) alongside existing stakeholders (for example, Working Group, Campaign Groups) – which is approximately 50 users.	Yes	May 2024
#22 –Short-term The business rules included in the various filters across the whole spill data supply chain need formalising in one place with associated governance with any specific Beachbuoy filters incorporated in the new Beachbuoy redevelopment design and documentation	Re-platforming of Beachbuoy into a logic-based low/no-code FME solution essentially documents the business logic in this form.	Yes	May 2024

5. Summary & Conclusions

A review of Beachbuoy has been undertaken by four independent experts looking into the water quality, oceanographic modelling, user and engagement, and software and systems aspects of Beachbuoy. The reviews focussed on a wide-ranging review from the experts' point of view, plus answering a series of specific questions defined in the review scope.

The key outcome from the reviews was a series of recommendations for Southern Water, which have been split in to short, medium and long-term actions. The key improvement areas from these recommendations within each of the timeframes are collated below in Table 5-1. Southern Water will now start to implement these recommendations as part of the updates made to Beachbuoy.

Table 5-1 – Summary of key improvement areas from recommendations made by the independent reviewers

Short-term	Medium-term	Long-term
Update the bathing water quality modelling software and refine/test the associated modelling parameters.	Collect further monitoring data of IE in bathing waters and hydrodynamic parameters.	Further work to allow coastal modelling to be embedded in hydrodynamics tool with real-time input data.
Update warnings to include percentile values and IE.	Undertake further refinement to wind trajectory modelling.	Add volumetric data and explanation of it.
Update wind trajectories to most frequent at sites.	Refine/test the associated modelling parameters in the updated model – particularly the solute transport processes, including day/night FIO decay rates.	Implement improved telemetry hardware.
Further investigate wind stress effects and effluent release around MWL.	Undertake further sampling to understand key source inputs, and for model calibration and validation.	
Undertake some interface updates – including pop-up window size, search bar and improved visibility of points.	Engage with the Environment Agency and Local Authorities on the modelling and prediction.	
Improve the informational content about Beachbuoy, how it works and the data it is displaying– including videos	Improve the email notification service	

Short-term	Medium-term	Long-term
and FAQs, manual updates and unverified releases.	and the information contained within it	
Create a user forum (also longer-term).	Provide information on manual updates in release table and how they work.	
Ensure all known outfalls are included, and exceptions identified.	Set threshold for manual update times (also longer term).	
Complete user experience testing of mobile version and further usability user testing and interviews of users.	Planned backup and disaster recovery.	
Undertake stakeholder mapping and engagement with a wider audience.	Provide a separate database for inland waters.	
Implement retrospective documentation of IT architectures including design.	Improved management of workflow issues through FME.	
Redesign (short) and build and test (medium term) data interface from Aspire to Beachbuoy.	Validate releases.	
Implement updated project management systems for Beachbuoy redevelopment (also medium term).		
Formalise hybrid/agile IT standard.		
Release management improvements (also medium term).		
Closer to real-time updating.		

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APPENDICES

Appendix A. Review Reports

A.1 Water Quality

A.2 Oceanographic Modelling

A.3 User and Engagement

A.4 Software and Systems

These are provided as separate files.

Appendix B. Review Question Responses

B.1   Human Health

Table 6-1 – Human Health Review Questions & responses (as provided by the reviewer).

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
1. Beachbuoy (BB) compliance with current Government Health & Safety Legislation	**Water Quality** This is difficult to assess with certainty, perhaps the most relevant legislation is the Bathing Water Directive (2006). From a public health perspective, design of the Bathing Water Directive is based on UK epidemiology and approved by the World Health Organisation. The Bathing Water Directive defines 'Fail' or 'Poor' water quality as having a >10% risk of GI in the bather cohort and the Good condition on 5% risk of gastrointestinal (GI) illness risk (as recommended by WHO (2003)). However, in marine waters, this is predicted by IE not *E. coli* which does not seem to be modelled by the present incarnation of BB although the prediction of IE by BB is envisaged by the SWS team leading this initiative. The BB system is only designed to model counts derived from storm flow inputs to the bathing zone. However, SWS do acknowledge that there are other FIO fluxes to the bathing zones from treated effluents, livestock farming areas industrial effluents and dredge spoils. The papers by Kay et al. (1994 and 2004), Pruss (1998) and WHO (2003) explain how these studies were used to develop the water quality criteria for marine waters outlined in Kay et al. (1994 and 2004): and WHO GSRWE (2003) and later for German fresh waters by Weidenmann et al. (2006). It is understood that SWS are about to implement the modelling of IE (alongside EC) within BB as well as the use of percentile values as triggers alongside upper percentile values for warnings. **Oceanographic Modelling** The writer has limited experience in answering this question and particularly in comparison with the expertise of the 'Water Quality Expert' (who is internationally renowned for his expertise in this field). However, based on the writer's experience of working with water quality experts on a number of comparable projects for other water companies and similar studies, the writer would make the following comments:

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	• It appears from the internal Southern Water report provided to the review group (Southern Water, 2023a) that Beachbuoy is compliant with the Government Health and Safety Legislation in terms of *E. coli*, with a warning being issued if the predicted concentration exceeds 500 cfu/100ml at the bathing water sites. However, it is not clear to the writer if Intestinal Enterococci (IE) is to be predicted in the same way as there is limited reference to IE in the coastal model study reports provided.
	Note: The writer since understands that modelling of intestinal enterococci is currently in progress and will form part of the Beachbuoy analyses in the future.
	• Based on the Southern Water (2023a) report cited above, the comment is made that "a time series of FIO concentrations were extracted from the coastal modelling results---". For the reasons outlined in Section 2 of this report[2], the writer is concerned about a number of key hydrodynamic and solute transport processes and coefficients being over-simplified in the coastal modelling simulations. Whilst the FIO concentration predictions may not change significantly with improved physical and biological process representations, the representations and parameters currently used in Southern Water's coastal models are particularly vulnerable to concerns being raised about the reliability of the model predictions.
	• More bathing water data are needed to support the assessment of the bathing water quality against Government Health and Safety Legislation. More data are recommended, particularly in the form of nearshore data, for future applications of Beachbuoy, so that more confidence can be acquired in the parameters used in the coastal models. In particular, the models need to be calibrated and validated against hydrodynamic and FIO field data in the regions of most concern, namely the bathing waters.
2. Identify ALL Circumstances where BB users are not receiving RED warnings when they should be! Is this a problem for BB users?	***Water Quality*** In order to fully answer this question, it is most important to see sufficient enumerations of the IE concentrations at marine bathing sites (measured with enhanced precision (i.e. not 'compliance' samples which are enumerated with poor precision at regulated UK bathing waters)) and calculate 95%ile compliance values at these bather-exposure sites. Currently this data is not available to

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[2] The full oceanographic modelling review report in Appendix A.2.

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	answer this question fully. My concern expressed in point 1 above (in this Section of my report) might be taken to imply a systematic underestimate of risk because only the storm data is being predicted by the EDM data recorded and used for prediction? The WHO (2003) water quality guidelines listed above really makes measurement of IE in the bathing sites essential as only IE is correlated with health effects in marine waters. It is understood that SWS recognise that in BB they are only modelling the impact of the operation of their overflows, and they are not providing general advice on whether beach users should bathe or not.

Oceanographic Modelling

The writer is particularly concerned about the representation of wind driven effects and the modelling of wind impact on a discharge plume using a 2D coastal model. The implication in the results is that wind-driven impacts above about 5 m/s have little further im-pact. A wind analysis report (Port & Coastal Solutions, 2023) provides valuable information about the frequency of winds from various directions, but no details have been provided as to how the wind stress is represented in the 2D model and, in particular, how the surface roughness coefficient and the assumed velocity profile are refined for stronger winds, i.e., over about 5 m/s. In the writer's experience it is difficult to predict wind driven effects on the hydrodynamic and dispersion processes accurately in a 2D model, with wind effects becoming increasingly 3D in nature in nearshore bathing waters and particularly for stronger winds. It is therefore more difficult to model accurately wind driven effects in shallow waters using a 2D model, with field data measured for Esthwaite Water showing velocities being closer to a second order parabolic profile, vis-à-vis a logarithmic profile, following earlier studies by Chen and Falconer (Kocyigit & Falconer, 2004b).

Based on the Technical Note (2023) at almost all sites quoted in the note the most frequent winds are from the Southwest and West. In the writer's experience it would seem possible that the stronger winds from these directions, and an improved representation of wind stress effects in the model, might well lead to RED warnings not being predicted in Beachbuoy when improved representations of the processes in the model may well advect higher concentrations of FIOs to the bathing waters.

User & Engagement

From a User & Engagement point of view *Expert Review Questions #1 and #2[3]* were discussed with respect to Beachbuoy data and the alerts that users sign up to receive for specific geographic areas of interest[4]. All, but one, participants have signed up for this service and they are particularly interested in continuing to receive accurate and meaningful information when it is relevant to them. The only participant who has not signed up, **was not aware of the service as they are not a regular user** and never uses the pop-up window, as they access 'Historical and current releases data' through the table below the map.

The main reason end users sign up for these alerts is **to get informed quickly and accurately** about any recent releases that may affect water quality of their local bathing sites. Some may decide to not to get into the sea. Most participants agree that it is **very problematic** not to receive a RED warning when they should as this exposes them to health risks. Although not equally ideal, yet they prefer to receive a RED warning, when there is no real threat (*Expert Review Question #2*) rather than not receiving one when there is real threat (*Expert Review Question #1).*

The first scenario (*Expert Review Question #1)* they describe it as *"dangerous"*, *"worrying"* and *"trust-breaking"* (e.g., *"That's very worrying. I lose all faith on Beachbuoy. Why have a system if it doesn't give me correct information? You better off without a system"; "When this happens we are not happy with Southern Water"* (interview comments), while the second scenario (*Expert review Question #2*) as *"annoying"* (e.g., *"I may have wished to go swimming and didn't go. Not life threatening but it is annoying"* (interview comment)*.*

Participants further expressed their concerns about the usability and design of these alerts. Notifications report a system status change for the geographic area of their interest, but they provide no content about the characteristics of this change (e.g., *"They are useless because I get an email that something changes and then I have to go to Beachbuoy to figure out what's going on. These emails should actually say what changes in my area"* – interview comment). Users, once they receive a notification, they must check Beachbuoy for relevant data, which might not always be possible due to lack of appropriate equipment, Internet access and so on. When this happens users will not be able to see a RED warning and therefore still be affected.

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	Recommendations
	✔ Inform users about all (actual or potential) RED warnings (critical).
	✔ Provide content so that email notifications become more meaningful (critical).
3. Identify ALL Circumstances where BB users are incorrectly receiving RED warnings whilst there is no real threat. Is this a problem for BB users?	*Water Quality*
	As with question 2 above, in order to fully answer this question, it is important to see sufficient IE data (e.g. intensive sampling over the bathing water season) measured with enhanced precision. Due to the very high imprecision in FIO enumerations (as in regulatory compliance samples) enhanced precision through new acquisition of IE data, at the regulated bathing waters, is essential if this assessment is to retain scientific credibility.
	Oceanographic Modelling
	Based on the coastal models currently being used to predict the bathing water FIO concentrations to provide the data for Beachbuoy to interpret, it is difficult to confirm with confidence if the predicted concentrations are conservative or not. For example, in the opinion of the writer typical values using improved representations of the dispersion and diffusion processes would lead to larger (typically x10) values than used in the current models. The effect of using larger values is likely to produce a wider plume, but with a lower peak concentration. However, the disadvantage of receiving RED warnings too frequently when not appropriate, often results in bathers deciding not to pay too much attention to the warnings; this experience has been quite common in flood alerts.

[3] The review questions as numbered in the User and Engagement review report in Appendix A.3

[4] None of the participants mentioned - with respect to *Expert Review Questions #1 and #2* - getting additional alerts derived from other water quality monitoring sources, which show some impact to bathing sites. This at the moment is beyond the scope of Beachbuoy functionality. If additional water quality monitoring data are matched up against Beachbuoy data this may improve transparency and trust, however this feature needs further investigation to understand functional and non-functional requirements (see *Expert Review Question #6*).

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	Part of the problem in incorrectly receiving RED warnings is that the sampling consists typically of 1 spot sample on any particular day being taken by the EA, as understood by the writer, whereas the model offers the opportunity of a time series of *E. coli* predictions along the bathing water. It is noted that the coastal model produces time varying *E. coli* predictions at all grid points and the impact in Beachbuoy is identified from consideration of the timeseries data, which covers a 72-hour period. Impacting sites are those which exceed the *E. coli* threshold for one or more model timesteps, but a finer grid model of ca. 50 m grid size along the coast would give more accurate predictions of *E. coli* levels along the bathing beaches.

For any information provided with the Beachbuoy tool it should be made clear that the health risks along the bathing water are predicted only from inputs from Southern Water's assets. Clearly Southern Water cannot be held accountable for inputs from agriculture sources etc.

User & Engagement

As discussed in the *Expert review Question #1* above[3], this question also refers to current Beachbuoy data and the alerts that users sign up to receive for specific geographic areas of interest. Users find it much more problematic not receiving a RED warning when there is a real threat (8/9 interviewees) rather than receiving a RED warning whilst there is no real threat. As discussed above they simply describe this scenario as *"annoying" (e.g., "I may have wished to go swimming and didn't go. Not life threatening but it is annoying"; "If they send me an alert at 10:03 and was about to go swimming and 11:03 I get a cancellation I'll still be able to go for a swim. It's not a big deal. If I didn't get though a genuine alert when there should be one that could make me ill which is much more bothersome"* – interview comments), but they do not find it *"dangerous"* or suspicious for the data provider to significantly impact their trust into the system (7/9 interviewees). For other stakeholders (2/9 interviewees) though (e.g., local authorities) this scenario *"puts them in an awkward position"* (interview comment), yet those affected are more likely to agree with participants' comments above.

Recommendations

See *Expert Review Question #1* above. |

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
4. Examine if white BB icons are helpful to bathers. Incompetent/ineffective remote sensing instrumentation is not the user's problem. Identify, how many white icons settle to red and if that is a problem for BB users?	Information on the views of white icons to users is found in responses to human health questions 3, 7 and 9 as well as through the heuristic review in the User & Engagement expert review report (Appendix A.3). The interviews found that many users treat the white unverified icons as a red alert as they are not willing to undertake any risk and get into the water. Consequently, they do not trust the white unverified release symbol, and participants mentioned that it can take several hours or even days for it to be verified. Subsequently, white icons have been removed from Beachbuoy – see user and engagement recommendation #13.
5. Identify ALL undocumented threats to bathing waters examples to include: - Lavant (Chichester Harbour), - Eastney Long Sea Outfall (several bathing waters in Eastern Solent), - Budds Farm (Chichester Harbour intermixing with Langstone Harbour), - CSOs in the tidal River Medina up to Newport impacting Cowes/East Cowes and Gurnard beaches. Are these a problem for BB users?	*Water Quality* Given that IE is the only FIO to indicate health-based threats, its omission from the current BB monitoring system (where enhanced precision would be possible and is essential) makes this assessment difficult. Imprecision in regulatory compliance samples at bathing waters makes it difficult to undertake a scientifically credible and evidence-based assessment Table 1[5]). Further advice from the modelling expert should be taken in response to this answer. *Oceanographic Modelling* The writer understands that Lavant WwTWs isn't included in the current coastal models. However, whilst the modelling carried out for other outfall impact investigations indicates that the Lavant WwTWs would not have an impact on any bathing waters, it is under-stood that the WwTWs will be included in a refined unstructured grid coastal model to be set up in the near future. The writer expects that these model studies would then eliminate the Lavant WwTWs as a potential source of non-compliance. The writer understands that Eastney long sea outfall discharges some 5.7 km offshore, into the fast-moving waters of the Solent. The writer further understands that due to the location of the outfall, i.e., at some considerable distance from Eastney Beach and the entrance to Langstone Harbour, it has not currently been included in Beachbuoy. However, it is suggested that it could be

[5] The full water quality review report in Appendix A.1.

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	included in future coastal models. This would give some reassurance to all stakeholders that it had been considered in the modelling.

Budds Farm WwTWs and the outfalls have been included in Langstone Harbour. In the writer's opinion the grid resolution in Langstone Harbour is too coarse and it is under-stood that this basin will be modelled with a finer grid resolution in the future, giving more confidence in the predicted faecal bacteria concentration levels across the harbour and discharging out through the entrance on ebb tides.

For the Medina Estuary, whilst all overflows downstream of Fairlee are in Beachbuoy and have been modelled, overflows upstream of this point have also been modelled and found not to have any impact on the bathing waters using the current model. However, it is recommended that these simulations are redone with improved coastal modelling process representations and appropriate coefficients at some stage in the future and with a finer grid resolution. |
| 6. Identify cumulative threats from discharges within harbours/rivers/estuaries/etc where ALL Blue Flag beaches are unexpectedly affected eg West Wittering (from Chichester Harbour outfalls) and Hayling Beachlands (from Langstone Harbour Outfalls). Are these a problem for BB users? | *Water Quality*

From a bathing water quality perspective, the cumulative impacts would come from many different sources of FIOs (not just storm overflows predicted by EDMs). Again this would need model validation against the FIO parameter IE which does not seem to have been done (but is planned) and must involve enhanced precision enumeration of the IE parameter. All relevant FIOs have multiple sources in addition to EDM storm flows: e.g. (i) land surface fluxes from livestock discharged via rivers; (ii) avian and other animals (e.g. donkeys and seals) on the intertidal areas; (iii) treated effluents, especially at times of high flow when plant retention times may reduce; and (iv) effluents from boat traffic with informal effluent disposal facilities. It is recommended that modelling is updated to take into account the numerous sources of FIOs in bathing waters, which can have counter-intuitive cumulative effects, and that SWS are about to implement the modelling of IE (alongside EC) within BB. Further advice from the modelling expert should be taken in response to this answer.

Oceanographic Modelling

In the writer's opinion, and based on similar experience from related projects, it is desirable that all the key point and diffuse source inputs discharging along the bathing beaches (including river inputs and from semi-enclosed embayments, such as Chichester Harbour), should be included in the coastal model, including non-Southern Water inputs where available, such as river inputs |

(including diffuse sources from agriculture etc.). The writer understands that all Southern Water's key inputs are currently included in the coastal models, although it is noted that these outfalls are not included in Beachbuoy if they are shown not to have an impact on the bathing waters. The reasons for the writer advising that all key point and diffuse source inputs should be included in the model are two-fold: (i) if there is an unpredicted failure along a bathing beach, and not identified in Beachbuoy, then in the experience of the writer key stakeholders (including the public) are more likely to blame the water company, even if the company is not responsible for the input; and (ii) some other water companies are already including all key point and diffuse inputs in their modelling studies, with several now also using 3D models. Such an example is illustrated below and where Dwr Cymru has included all the known outfalls illustrated in Figure 6.1, along Swansea Bay, see King et al. (2021). The resulting predictions for the *E. coli* levels in Swansea Bay using the 3D coastal model are shown in Figure 4 in Section 2 of this report[2], with further details being given in King et al. (2021).
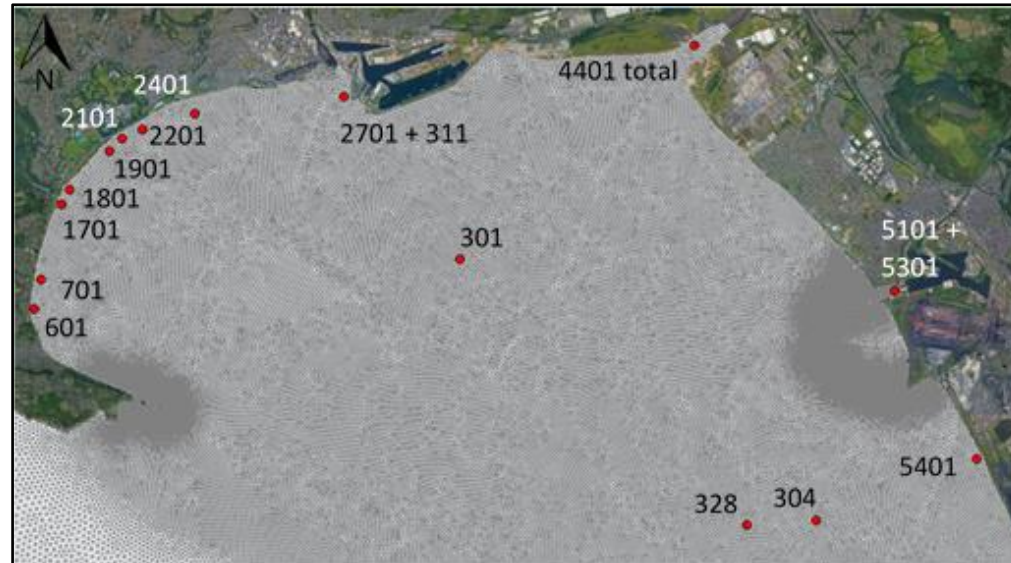
Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	Figure 6.1 All outfalls shown for the input location of CSOs and outfalls in the 3D model of Swansea Bay (in collaboration with CREH and Dwr Cymru).
	Note: From data recently provided to the writer it is clear that cumulative impacts (including Southern Water's assets and other impacts where available) are now being assessed by Southern Water and this approach is deemed to be appropriate and welcomed by the writer.
7. Identify ALL outfalls, anywhere on the Southern Water patch, which have yet to be linked as a threat to bathing waters. The most recent example is Peel Common affecting Portsmouth (modified in 2021). Peel Common has been operational for decades. Are these problematic for BB users?	***Water Quality*** Model predictions for IE at bathing sites would be needed to start delivery of this component and it would require wider data on worst case scenarios that only the modelling expert(s) could provide. Disinfection of effluents can be effective but the presence of this treatment step and its effectiveness would need well designed sampling programmes to acquire real-world and representative (i.e. credible) data which are an essential first step. It is understood that SWS are constantly reviewing and updating which fluxes of FIOs have the potential to impact bathing waters and are going to be including IE (alongside EC) within the modelling. ***Oceanographic Modelling*** The writer's response to this question is the same as that provided in the response to question 5.
8. Is the upper limit of 500 cfu/100ml a reasonable for *Escherichia coli* (EC) when most of the 83 bathing waters show EA testing well under 100 cfu/100ml during the bathing season. Southern Water says, "in our area, 80 out of 84 bathing waters are rated excellent or good, with none rated poor". Should the limit be reduced to say 250?	***Water Quality*** The assumption in this question that you can define a limit value from a percentile value is simply wrong. It is important to recognise that the BWD (2006 page 46 of 64) does not specify 'limit values it does specify a 90%ile value of 500 cfu/100ml for *E. coli*. This is not an upper limit value (or single sample threshold), rather it is a 90%ile value, Depending on the log10 standard deviation and geometric mean of the samples collected at the bathing water the log10 mean value needed to achieve the 90%ile standard may be quite low, certainly much less than 500 cfu/100ml (see EU BWD (2006) Page 48 of 64). BB would have to generate long sequences of predicted IE values to allow this prediction run to produce a sufficient 'n' value of perhaps weekly model predictions. A value for 'n' suggested by WHO is a minimum of 100 samples used for the required upper percentile limit values indication 10% risk of gastroenteritis. I note the 'fail' percentile may only rarely be exceeded given the number of good quality bathing waters in the SWS region. Recent intensive sampling and analysis by CREH suggests that the likely GM value for IE to

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	produce am EU BWD compliant bathing water is in the range 33/100ml (Nolton Haven) to 39/100ml (Swansea bathing water) These were outcomes of the EU funded Acclimatize and Smart Coasts projects and the Nolton Haven report has been sent to SWS. It is understood that SWS are about to implement the modelling of IE (alongside EC) within BB as well as the use of percentile values as triggers alongside maximum values for warnings.
	Oceanographic Modelling
	The writer is not an expert in this field and the advice of the Water Quality Expert (who has an international reputation in this field) should be taken in response to this answer.
9. Should the pathogen Intestinal enterococci (IE) be modelled in BB given EA sampling routinely shows IE significantly higher than EC (ie composite modelling)	***Water Quality***
	Given the epidemiology used in standards design by the WHO and EU for marine waters (WHO GSRWE (2003) EU BWD (2006)). BB should be developed to predict IE in marine bathing waters as per the bathing waters under consideration in SWS. I understand that the recommendation to predict IE has been accepted by SWS. It is worth noting that IE is more correctly described as a Faecal Indicator Organism (FIO) rather than a pathogen. It is understood that SWS are about to implement the modelling of IE (alongside EC) within BB as well as the use of percentile values as triggers alongside maximum values for warnings.
	Oceanographic Modelling
	In the writer's experience the main focus over recent years in assessing bathing water standards in nearshore coastal and transitional waters has been on *E. coli* concentrations. However, with the growing engagement of citizens involved in 'citizen science projects' through the clean river groups etc., there has also been a growing concern about IE levels in freshwater basins. Therefore, in the writer's experience, it is not surprising that there also appears to be growing concern about IE in coastal and transitional waters. In the opinion of the writer, it would therefore be prudent to plan to include IE in the coastal modelling studies, as well as *E. coli*, with these data then also being included in Beachbuoy.
	In the Review Question document, the writer notes that suggestions have been made as to how IE could be included in the existing models, using a simple relationship between IE and *E. coli*, and also using a higher constant T_{90} decay rate of 80 hr. However, such an approach does not include the effects of irradiance in daylight hours and does not take account of whether the CSO

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	discharge occurs during day- or night-time. As for the previous question, the Water Quality Expert is more experienced in being able to comment on this question. Note: The writer understands that Southern Water are planning to include IE in future modelling. Additionally, day- and night-time decay rates will also be considered for inclusion in future modelling studies.
10. Propose how BB could distinguish between discharges involving rainfall and discharges of raw undiluted sewage caused by infrastructure failure. Typically these are typically "disguised"/"camouflaged" as stormwater discharges eg Event id 638885 (Bexhill). Maybe these should attract black or skull and crossbones icons?	*Water Quality* Improved monitoring is needed to understand the sources. The sources of effluent in discharges from the sewerage system and other inputs will generally not be quantified by standard FIO analyses some distance from the input flux but, rather, they can be quantified by phage tracing (i.e. with harmless viruses) tracing as is approved by the Marine Management Organisation (MMO). A well-designed phage and sampling study could afford this type of information on relevant contributions from different assets or contaminated areas. It is understood that SWS are working on distinguishing infrastructure failures within BB. *Oceanographic Modelling* In the writer's experience there are generally two main sources of effluent discharges of FIOs into coastal waters. These include: (i) storm exceedance of the 1 in 30 designs (or similar) of the WwTWs, resulting in untreated effluent being discharged into the outfall and with this input primarily being caused by excessive rainfall; and (ii) diffuse source in-puts, primarily from agriculture sources or similar, added to the river due to high rainfall and then discharged into the estuary. So far as the writer is aware there is no reliable method of distinguishing in an urban drainage model between rainfall and raw undiluted sewage caused by infrastructure failure. However, this distinction could be made by data collection of sewage effluent fluxes into a river or coastline from CSO inputs and then subsequently including this information in the coastal model, post the event. This approach would not be possible to deliver in real time, and therefore diffuse and point source inputs could be difficult to include in Beachbuoy in real time, other than by monitoring riverine flows at the tidal limit. Where undiluted sewage is discharged into an out-fall because of an infrastructure failure then in the experience of the writer this is more likely to arise when the rainfall intensity is either zero or relatively low. The writer would therefore suggest that the potential to revise Beachbuoy to include advice on whether the release is the result of rainfall

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	or equipment failure should be investigated and, if possible, included in the next available release of Beachbuoy.

In the 'Interim supporting information ----' in the 'Review question' document, it states that "The modelling undertaken is conservative". However, for the reasons given in Section 2 of this report[2] and in sub-section (v) of this Section, the writer believes that there are sufficient concerns reported about the technicalities and setup of the coastal models (particularly the fine grid models) to question this statement. Alternative terminology is suggested to be used, such as: 'The company has made every attempt to aim to be as conservative as possible in their coastal modelling predictions, such as assuming that the entire wastewater load is discharged at 3 x Dry Weather Flows (DWFs)'. This approach effectively assumes an emergency undiluted release of 3 x DWF.

Several key model numerical features (such as grid size) and physical process parameters also first need to be made to represent the numerical, hydrodynamic and kinetic processes more accurately before it can be said with confidence that the modelling is conservative – many of which the writer notes are planned to be refined when the model is up-dated to the latest MIKE 21/3 software. Alongside these key refinements, more intensive and accurate hydrodynamic and FIO data needs to be collected, ideally along transects in the horizontal and vertical planes for a preferred beach, and with the resulting model data then being used for further model validation before including in Beachbuoy. |
| 11. Consider Beachbuoy could be extended to cover all shellfish water and bathing water points from Bracklesham Bay in the east to Totland Bay in the west would therefore provide the level of coverage appropriate to the leisure water users of the Solent. | ***Water Quality***

For the reasons outlined above, I could not recommend the spatial extension of the present system at this time. The central problem with BB is not its spatial coverage but, rather, its methodology which measures the wrong microbial parameter for marine bathing waters as outlined above. As noted in question 9 above in this section, I understand that the recommendation to predict IE has been accepted by SWS. Additionally different standards are used for shellfish waters.

Oceanographic Modelling

In the writer's experience there can be considerable differences between the predicted FIO concentrations near the surface and the bed layers, particularly where turbidity levels are relatively high. The surface waters can have significantly lower concentrations than the near bed levels |

Review Question – Human Health	Responses (as provided by the reviewer – details in Section 2)
	(primarily due to reduced light penetration and longer decay rates near the bed), with swimmers more likely to ingest near surface waters, whereas shellfish are more vulnerable to near bed FIO concentrations. This disparity in the near-surface and bed concentrations can only be predicted relatively accurately in a coastal model using a fully 3D model. An example of these findings is published for Swansea Bay in King et al. (2021). In the writer's opinion 2D models of FIO predictions can be extended to cover both shellfish and bathing water points of interest, but the extension of a 2D model for shellfish water compliance assessment needs to be treated with caution without extensive 3D hydrodynamic and FIO data.

Note: The writer understands that after the implementation of MIKE 21/3 Southern Water will explore the scope for 3D modelling, which will give more confident predictions of near-bed water quality parameters, and which will be particularly relevant to shellfish waters. |

B.2   Review Process & System

Table 6-2 – Review Process & System Review Questions & responses (as provided by the reviewers).

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)

1. Propose how BB can be more open and transparent with regard to data being routinely and in some cases being extensively manipulated, deleted and dismissed as false alarms in the release history. How does such misleading information affect BB users?	**_Software & Systems_**
	
	The overflow event and spill monitoring (EDM process) is compliant to the EDM Good Practice Guide and in meeting Enterprise Agency Reporting requirements as per the Overflow Permits.
	
	1. Spill data is, as a principle, not deleted kept as per the Data Retention requirements as a minimum (6 years) and in some cases for ~20 years where this is required for investment planning.
	
	    a. raw data is archived in PI Historian for a minimum of 6 years as per the Environment Agency data retention rules in the Overflow Permits, automatically assessed spill frame data is archived in Aspire.
	
	    b. PI AF spill event frames are not deleted but stored for analysis and Control Period investment planning (over 20 years data is currently stored).
	
	    c. Aspire spill event data received from PI AF, since Aspire entered production), is retained. NOTE in addition when a user edits a spill record in Aspire, e.g. to change a state to genuine, this is logged in Aspire and these logs are also retained (for audit purposes).
	
	2. Spills are validated as both genuine or non-genuine both by algorithms and manual validation and all decisions (state changes) are logged and are available for audit in the event of a query.
	
	3. New reporting has and is being introduced to report on BB event accuracy

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	4. The only transformation is the sensor analogue signal into a state value wrt the threshold and where a positive state (threshold exceeded) is converted into an event frame start for a possible spill (in PI AF). Subsequently that spill record is not 'transformed' rather new data is added to it in terms of attribute values e.g. the tide type for the associate bathing water site for the event frame start time (in PI AF), the result of the validation (genuine or non-genuine) (in Aspire), and the spill impact due to tide and spill duration (in Beachbuoy).

5. Filters are introduced into the publication of spills to reduce information overload from non-directly relevant information (BWS displays where spills do not affect that site for example assuming the user is a casual recreational bathing water user). The Reviewer recommends these filters are made more transparent and that they can be removed by users who have different points of view, such as environmental protection (User Interface functionality profiles set by user interest)

6. The information about spills is correct and accurate, however, delays due to technology limitations can cause the spill data to be delayed in being published on the Beachbuoy web site and with publication delays possibly misinterpreted due to the functionality of the map interface. The Reviewer recommends greater transparency in giving reasons for delays on the user interface and more detail on the status of a review with a rationale for a decision. NOTE some of this is already in development.

User & Engagement

Outfall releases detected by sensors are automatically reported on Beachbuoy. A verification process through manual updates then takes place to identify and correct false triggers/positives and Beachbuoy data are updated accordingly. |

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	Several participants in this study report how data are manipulated to provide different duration times, hours or - in some cases even - days after the actual release, explaining that *"these times always go down, never up"* (interview comment); *"It comes out as Southern Water pays no attention to Beachbuoy updates. There are so many inconsistencies in the data"* (interview comment). Participants also describe how information about genuine releases turn into non-genuine and vice versa. This process has caused a lot of attention, i.e., three interviewees started collecting screenshots of the 'Historical and current releases' Table to capture these changes.

Interviews reveal that this feature **has a significant negative impact on users' trust perceptions into the system and the perceived usefulness of Beachbuoy**. Although the table feature exists to improve transparency, in fact it has the opposite effect on users' trust perceptions, mainly – as users report - **due to the lack of a clear explanation of why Beachbuoy data are manipulated during the process of manual updates.** An important reason for this is that not everyone understands how the automated and manual updates work (e.g., with respect to manual updates participants mention: *"This is not true. I don't think SW goes around every single pump and check it"*; *"I don't think they know that I don't know how this process works"* – interview comments). To address this, **a clear explanation of how the system works, especially with respect to updates, in lay terms should be provided on the information page**.

One participant explained that they contacted Southern Water and *"they've never been able to tell me the reasons of these changes"* (interview comment). When discussed what information is essential to the users to have at hand to confidently decide whether they trust data updates most participants explain that **short textual explanations should be added to the table to explain and justify manual data changes when these occur.**

Participants further **heavily criticise the use of the white 'unverified release' symbol**, explaining that once this is shown on the map **they treat it as a red alert as they are not willing to undertake any risk and get into the water** (*"Surfers Against Sewage uses the same data but seems these are not* |

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	being manipulated in the same way. The white icon of Beachbuoy would be red on Surfers Against Sewage and that works better for me"- interview comment). All participants explain that the perceived purpose of Beachbuoy is to provide them with accurate and timely information to inform their decisions of accessing the water and that data manipulations as well as releases which are reported as 'unverified' *"defy this purpose"* (interview comment). **Recommendations** ✔ Add brief explanation to justify data updates during the manual updates process. This should appear next to the relevant change on the 'Historical and current releases' Table (medium). ✔ Explain in lay terms how Beachbuoy updates work (both automated and manual) (critical). ✔ Explain in lay terms the specifics of the 'unverified overflow release' feature and the reason it exists in the first place (critical).
2. How can the BB manual review process be modified to avoid confusing, misleading and errant decisions.	***Software & Systems*** Given the worst case scenario detailed in response to the following question, some manual validation can be automated but not all. It is recognised in the EDM Good Practice guide that some manual validation is required in some circumstances. Southern Water is introducing automated validation as part of the Aspire Beachbuoy Enhancement project (see ref. [25]) but it is neither simple nor quick as dependency on algorithmic evaluation must in itself be tested and shown to be accurate and repeatable. Where implemented in Aspire the performance of all reviews both automated and manual is now subject

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	to KPIs and reports as part of the ongoing performance improvement by the spills team, which increases transparency.
3. Fundamentally, manual reviews on ALL discharges (10,000+ of them in 2022 alone) are undertaken because Southern Water does not trust their own remote sensing instrumentation and requires human inspection. Are unsound remote sensing instruments causing any issues for BB users	***Software & Systems*** Not so, in order to be compliant to Environment Agency requirements in spill reporting all EDM events that are (pessimistically) deemed to be possible spills must be reviewed to determine if genuine. From the Check Factors a low probability event may be given a low review priority but it is still treated as a spill until proven otherwise. In summary the EDM system (sensors, telemetry, PRISM and PI AF) is trusted but can give erroneous readings due the environment in which it operates (a rat on the weir, foam detected not water, etc.), so a worst case approach is taken. Overflows typically have multiple sensors (signals) which monitor water levels. If a measured level exceeds a threshold for a sensor it triggers a possible spill event even if the other sensors show no threshold exceedance. Southern Water is obligated to report spills accurately to the Environment Agency and Regulator so even with 1 out of say 4 sensors indicating a level threshold exceeded it must be reviewed. This may require corroboration from other data sources that cannot be processed automatically e.g. weather, throughput volumes, possible sewer blockages, etc. The fact that it was one out of 4 indicates a low confidence level that a spill actually has occurred, however, a) for overflows that discharge to sea outfalls and are mapped to bathing water sites (Beachbuoy sites) these are given the highest priority and are passed to Beachbuoy as unconfirmed spills as soon as possible, and b) dependent on the Environment Agency permit reporting requirements is prioritised for manual validation. The EDM site systems are maintained once per year and in addition failures can be detected and raised as alarms to the control centre (a PRISM function). Research has been carried out to assess if

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	instrument drift is an issue, with other factors (the UKWIR project) – so far not, but in the hostile environment cables can stretch and when tolerances are in mm this can give a false positive, irrespective of this risk all spills are validated.
	In addition the converse is true in that a spill can only be indicated as ended if all the sensors indicate a level below the threshold.
	The worst case scenario, although fundamentally an Environment Agency requirement prioritises Beachbuoy users.
4. Why does it take so long for the review process to complete? Evidence is available demonstrating reviews are taking multiple days even weeks to complete, this is denying bather access to the water	**_Software & Systems_** Without sight of the individual cases referenced comment on this assertion cannot be made. However, there are a number of issues with how review results are disseminated, primarily the one hour polling delay between Aspire and BB. The newly introduced reporting of the review times and results will make this more transparent. As well as prioritisation by probability there is always the issue of a fixed manual resources and a varying review demand which will peak in adverse weather conditions. However, increased automation is being introduced as a priority as well as improved reporting and performance improvements (review start times for a spill, if paused for a reason, rationale for result of review. The Reviewer recommends greater transparency in this reporting.
5. Identify all of the data sources used in the manual review process and how the data is used for decision making. Establish if decisions are accurate and timely given the information used.	**_Software & Systems_** The management of the review process for spill validation has been improved in Aspire as part of ongoing performance improvement (July / Aug 2023) via new reporting (see User Story ABEW-2053 copied below): Description

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	The current User performance table in the Admin module requires enhancing to include some more meaningful metrics in order to support the Spills Reporting Team Manager during performance reviews and 1:1 with team members on their user performance activities.
	User Story
	As a spills team manager
	I want to see how many events are being Reviewed by spills users
	So that I can use this to identify any potential improvement opportunities
	Acceptance Criteria
	AC1) There will be a new field named 'Reviewed' that will be displayed to the Right of the 'Partial Reviewed (>5 days)' field as per the mock up
	AC2) This will field contain the total number of Reviewed events a spills user has actioned
	AC3) The definition of Reviewed is:
	An event that has been assigned to a Spills User in the Workflow Module, the Spills User has reviewed the Event and clicked 'Complete Review'
	AC4) The data in this field will be configurable with the filters mentioned below
	• *Source Site: When single or multiple Sites selected, new field will only display the Reviewed Events for the sites selected*
	• *User: When single or multiple Users selected, new field will only display the Reviewed Events for the Users selected*

Review Question – Review Process & System	Responses (as provided by the reviewer – details in Section 2)
	• *Start Date: When Start Date is selected, new field will only display the Reviewed Events from the Start Date*
	• *End Date: When End Date is selected, new field will only display the Reviewed Events from the End Date*
	• *Last One Month: a rolling 30 days view from today's date* **(Covered in ABEW-2059)**
	• *Last One Week: a rolling 7 days view from today's date* **(Covered in ABEW-2059)**
	• *Last 24hrs: the last 24hrs from today's date* **(Covered in ABEW-2059)**
	Note: *The current functionality for these existing filters is to remain the same where the filters have the ability to work as a combination or in isolation*
	Oceanographic Modelling
	The writer is not familiar with the manual process of data collection and transfer on an hourly basis from the coastal models to Beachbuoy. With the current models and data availability this approach seems appropriate, and the writer will defer a response to this point to the Software and Systems Expert.

B.3 Automatic Review Process

Table 6-3 – Automatic Review Process Review Questions & responses (as provided by the reviewers).

Review Question – Automatic Review Process	Responses (as provided by the reviewer – details in Section 2)
1. Is the use of single "pixel" (just a few square metres on the ground) automatic "sampling" reasonable on a multi-km long beach particularly considering the juxtaposition of the "pixel" with outfall threats. (eg Eastney)	*Water Quality* Carefully planned spatial sampling (not modelling) would be essential in making this judgement of whether information from a small pixel surrounding an automatic monitoring point or modelled elevation in IE cfu/100ml was sufficient to define health risks for a multi-km stretch of bathing waters. It is understood that SWS are reviewing the process for identifying the extent of the bathing water areas. *Oceanographic Modelling* In the writer's opinion there are two separate issues in response to this question: (i) the validity of assessing bathing water quality taken just at one point on a long bathing beach, and assessing risk based on data from a much larger model grid; and (ii) the validity of assessing the bathing water quality at one point along a bathing beach where the variation in the FIO concentration along the beach could vary considerably from point to point. In considering the first point, the finest grid resolution in the Southern Water coastal models along the bathing waters is typically 125 m x 125 m (although for one site the grid size is 100 m x 100 m and for some sites much larger). This means that the predicted FIO concentration value in the finest grid point along the beach, covering the compliance point, has a plan surface area of 15,625 m^2. In comparison, this area equates to a larger area than the size of two adjacent full size football pitches (i.e., 105 m x 68 m x 2 = 14,280 m^2). In contrast if the finest grid resolution was 50 m, as a recommended minimum, then the surface area of the finest grid cell would be 50 m x 50 m = 2,500 m^2, i.e., just over 1/3rd of the size of a single football pitch. Hence, reducing the grid resolution in all the fine grid coastal models to 50 m or less, particularly along popular bathing beaches, would improve the representation of several complex hydrodynamic processes (as

Review Question – Automatic Review Process	Responses (as provided by the reviewer – details in Section 2)
	illustrated in Figure 1, Section 2[2]) and, in particular, would also improve on the accuracy of predicting the concentrations at the compliance point (i.e., the monitoring site).

In addition to monitoring FIO concentration levels at the compliance point(s) more recent monitoring studies, undertaken by some water companies, have included transect FIO da-ta normal to the beach. Such an example is given in Figure 6.2 below, for Swansea Bay, as shown in King et al. (2021), with these data monitoring transects being planned and monitored by Prof. David Kay and his team at the Centre for Research into Environment and Health (CREH). Such data allow more evidence-based calibration and verification comparisons to be made for coastal models, particularly in nearshore bathing waters.
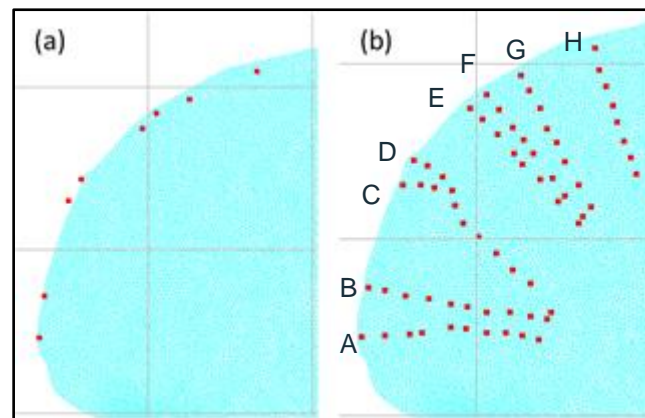

Figure 6.2. Static source points at outlet locations (a), and source transects along Swansea Bay (b).

Software & Systems

This question is not understood, what is meant by automatic 'sampling'?

Issues with the map display have been identified in terms of BWS pin location (outfalls are precise geographic locations). It is accepted that a) a BWS pin is a point location which by inference |

Review Question – Automatic Review Process	Responses (as provided by the reviewer – details in Section 2)
	applies the spill impact warning to the whole site which may be a very long beach. This was a constraint of the use of Google maps and restrictions to the use of pins. The new ESRI ArcGIS system (a market leader in the GIS domain) will have the ability to map polygons in a multi layered OS derived map interface. It is understood initially pin point locations will be used, however, an extension to map physical beaches for more precise spill impact prediction could be tabled as an enhancement once the new development has been implemented as a Minimum Viable Product in Feb 2024.
2. Is the use of 1, 3 & 12 hour tidal assessments reasonable given so many discharges are well in excess of 12 hours in duration and frequently multiple hundreds of minutes in duration. All in the context of T_{90}=40 hours (ie 3 tidal cycles)	*Water Quality* T_{90} values are highly dynamic in the marine environment due to diurnal effects of UV irradiance and the dynamic nature of entrained turbidity in the vicinity of the bathing areas. In my view, the chosen T_{90} values need empirical validation by laboratory and/or field (i.e. in situ) experiments (see Kay et al. (2004b) below. It is understood that SWS will use a variable T_{90} in the updated model. *Oceanographic Modelling* In the writer's opinion, these tidal assessments seem reasonable and not dissimilar to typical values used by other organisations. However, with some discharges being "well in excess of 12 hours" it would seem prudent to run some simulations of the corresponding coastal models, for popular bathing beaches, for a longer discharge duration and for the maximum discharge time known to occur. Although a constant T_{90} value of 40 hours would seem conservative, this value does not differentiate between night- and day-time discharges. For late evening or early morning discharges, following a storm event, this value might not be conservative. Likewise, during the daytime, and particularly with high irradiance, then this value of T_{90} would be unduly conservative. It is recommended previously that a time varying T_{90} value based on field data, or a more representative process-based equation (such as Mancini, 1978), be used in the coastal models to give more accurate time varying predictions. Note: The writer understands that Southern Water are going to consider including day- and night-time varying decay rates in future coastal modelling studies.

Review Question – Automatic Review Process	Responses (as provided by the reviewer – details in Section 2)
3. Is it reasonable for the "initial" impact/no-impact assessment to stick with the event for its lifetime of tens or even hundreds of hours. Does the impact/no-impact assessment get routinely recalculated	***Water Quality*** There should be real-time event monitoring in my view, but this would require real-time monitoring data and model runs. BB updates every hour with EDM. Further advice from the software and systems expert should be taken in response to this answer. ***Oceanographic Modelling*** In the writer's opinion it is not reasonable to use the outputs from Beachbuoy for say longer than 24 hours without updating. A storm event and a south-westerly wind could change the assessed health risk for swimmers, surfers etc. along a bathing beach, and in a relatively short time scale. In an earlier response the writer advised that the data inputs to Beachbuoy could be automated and if Beachbuoy is to be extended to provide a real-time online tool then in due course data could be updated online and in real-time through informatics tools, such as Artificial Neural Networks (ANNs). However, the current hourly updating is commendable based on the existing data availability.
4. Low atmospheric pressure storms (the main cause of stormwater discharges) bring huge changes in tidal height(+/-20%), high tide time(+/- 30mins), wind speed (x4), wind direction +/-180 degrees), UV (cloud cover) and other parameters. ALL of these parameters have a significant impact on E-Coli longevity, dispersion and advection in the real world environment. Are these parameters realistically modelled and used in automatic decision making?	***Oceanographic Modelling*** The writer agrees with the concerns raised in this point about the coastal models and Beachbuoy and, for the reasons outlined in more detail in Section 2 of this report[2], the writer has some concerns as to why the answer to this question should be: 'No'. The main reasons of concern by the writer can be summarised as follows: (i) the open boundary conditions driving the coarse grid model, which then provide the hydrodynamic boundary conditions for the finer grid models, are based on the tidal harmonics and do not account for significant low- pressure storms, including surges etc. (so far as the writer can establish the models have not been run for such conditions); and (ii) the wind speed can have a significant impact on the trajectory, vertical velocity distribution and mixing, and dispersion-diffusion processes of an outfall plume. From the information provided to the writer it is not clear that these impacts have been adequately included in the coastal models. The recommendation to address this point is within Recommendation 7. It is also worth noting that as a result of climate change the UK has become more vulnerable to convective storms, thereby leading to significant storms during a day, or part of a day, often followed by calmer and drier conditions soon after. Thus, bathing water quality and health risk can be more vulnerable to storm events on the previous day, or night. Also, the main impact of UV

Review Question – Automatic Review Process	Responses (as provided by the reviewer – details in Section 2)
	(cloud cover) would be to affect the decay rate for *E. coli* and Intestinal Enterococci, with the T_{90} value likely to be longer (i.e., reduced decay) during a storm event. The coastal model studies undertaken for most bathing water studies for Southern Water have used a generally conservative constant decay rate of typically 40 hours. Whilst this is commendable, and generally deemed to be conservative, it is also worth noting that comparable bathing water quality studies being undertaken by other water companies are increasingly using at least diurnal changes in T_{90} decay rates.

B.4 General Modelling

Table 6-4 – General Modelling Review Questions & responses (as provided by the reviewers).

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
1. Are pertinent bathymetric aspects properly modelled (eg Langstone/Chichester Harbour entrance) for all tidal sequences	***Oceanographic Modelling*** The writer is satisfied that based on the information provided in the reports the bathymetry is generally pertinent for the coastal models, with the Environment Agency Lidar data and coarse grid boundary conditions being updated annually. It has not been possible for the writer to check on the specific bathymetric representation associated with the entrance conditions to Langstone and Chichester harbours. It is therefore recommended that particular attention is paid to the bathymetry at the entrances to Langstone Harbour and Chichester Harbour during the construction and testing of the new unstructured MIKE 21/3 model. The model should be tested to ensure that fluxes through the harbour entrances are correctly represented.
2. Are ALL parameter "safety factors" reasonable for accurate modelling (eg but not limited to UV, Wind speed, wind direction, DWF)	***Oceanographic Modelling*** In the writer's experience there are a number of physical processes that are not well rep-resented in the model and currently use the simplest of representations. These are out-lined in more detail in Section 2 of this report[2], but include, in particular: (i) the finest grid size – which could be finer for bathing water hydrodynamic and solute transport predictions; (ii) nesting and the conservation of tangential momentum at the boundaries; (iii) turbulence – where the simplest 0D equation is used, i.e., where the eddy viscosity is in-dependent of the local velocity and depth; (iv) dispersion and diffusion of FIOs, where again a simple 0D equation is used and independent of local velocity and depth; and (v) the wind representation appears to be oversimplified for a 2D hydro-environmental coastal modelling study. In the Bathing Water Quality report prepared by Port & Coastal and Atkins (Port & Coastal and Atkins, 2023) refence is made to similar modelling studies undertaken as part of a major hydro-epidemiological monitoring and modelling assessment of *E. coli* concentrations in the River Ribble Basin and along the Fylde Coast (Huang, Falconer, & Lin, 2017). However, in this paper (along with other papers reporting on this study) all the processes cited above were addressed using

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
	more accurate hydrodynamic and biologically based process representations, as outlined in Falconer et al. (2005) and previously Falconer (1991).

Regarding the DWFs these values are based on typical data as used conventionally in simi-lar studies and would meet realistic inputs from the outfalls and CSOs.

In summary, it is not possible to confirm that the parameters used in the coastal models provide adequate "safety factors" for bathing water quality predictions. Some parameters, such as the constant T_{90} value of typically 40 hours, are conservative, but the related processes of turbulence, dispersion and diffusion are not well represented, and particularly for high south westerly wind conditions. |
| 3. Reassess all outfall threats to bathing waters should Automatic Review Process scope #4 (above) should parameter modification that extends the reach of outfall pollution be required. This should include all outfalls irrespective of being 10km distant. | *Water Quality*

I have been informed that the 10km distance has been revised and all outfalls which have the potential to impact are considered regardless of distance. Further advice from the modelling expert should be taken in response to this answer.

Oceanographic Modelling

So far as the writer can establish it appears that the main outfalls and CSO inputs have been included in the model, although there are none of any significance identified along the shoreline from the plume plots. It should also be noted that in the experience of the writer it is generally unlikely that an outfall located some 10 km offshore would significantly affect bathing water faecal bacteria concentrations. In the document 'Review Question' and 'Interim Supporting Information' reference is made to using the same models for shellfish waters. However, for shellfish waters then FIO concentrations are needed near the bed, and in the experience of the writer these would be different from those values near the surface or depth averaged concentrations, based on the predictions obtained using a 3D model. Hence, any extension of the results of the model studies being reported herein will be considered differently, in that focus will be more on bed rather than surface concentrations, and a different set of standards will be used, namely the EA guidance concentrations for the water column rather than bathing water standards. |

4. Would both volumetric and duration data be more helpful to BB users. Volumetric discharge data is far more informative than time (because of significant outfall diameter variations) The level of risk is after all directly proportional to the volume of sewage effluent not its duration.

Water Quality

I am not really sure how volumetric data could be communicated to the public (if this was just EDM information it would potentially miss a great deal of explanation of other pollution sources and of health risk as stated above).

Oceanographic Modelling

In the opinion of the writer an estimate of the volumetric and duration data for the out-fall discharges would be appropriate to include in Beachbuoy and would be as meaningful as providing the average concentration for a fixed time duration. This information would be appropriate to complement the input data specified in the coastal model. However, the writer understands that volumetric data are not currently measured.

User and Engagement

All participants unanimously agree that it is extremely important to continue having access to duration data, *and further be informed about the volume of outfall releases*, which is currently not provided.

Participants expressed their concerns about the lack of transparency with respect to: a. the diameter of the pipes and b. details of not only *'how much'* and *'how long'* but also *'what' is* being released (e.g., *"Volumetric data would be only useful if I know the concentration rate"* – interview comment). Provision of such information might be essential to further improve transparency and trust in the data provided. Some participants suggested that volume should be provided in lay terms, for example, using the dimensions of a standard swimming pool as a unit size, for communication purposes.

Recommendations

✓ Add volumetric data (critical).

✓ Improve transparency about concentration rates through Beachbuoy information page (critical).

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
	✓ Ensure there is an explanation of what volumetric data means provided in lay terms (medium).
5. Should the cumulative effects of multiple outfall threats from single and/or multiple bathing waters be modelled. Currently the impact of each discrete discharge from each and every outfall on each bathing waters are considered entirely in isolation. There is significant oversight here causing significant RED flag suppression (eg Cowes/Gurnard area)	***Water Quality*** Yes, if only to prove such effects from other pollution sources were minimal (if indeed they were thought to be minimal). It is understood that SWS plan to provide cumulative impacts from releases in the future. ***Oceanographic Modelling*** In the writer's opinion it would be advisable to include all outfall threats in the coastal models and subsequently into Beachbuoy. It is understood that cumulative potential threats of non-compliance at bathing water sites have not previously been undertaken, but that Southern Water are currently planning to investigate such threats in the future. A method is currently being developed to combine short events from the same outfall and this is to be welcomed. It is also encouraging to note that Southern Water are planning to acquire 'intelligent buoys' which include sensors for *E. coli* and IE, and which will provide near real-time monitoring. It is understood by the writer that two 'intelligent buoys' have already been deployed and this is to be welcomed.
6. Could any discharge events, at any time, be masking or camouflaging other discharges irrespective of status	***Water Quality*** Of course, unless this has been tested with phage tracer studies, which are approved by MMO, and can quantify effluent dilution approaching 10^{15}, and provide information on different sources of pollution. Further advice from the software and system expert should be taken in response to this answer. ***Oceanographic Modelling*** It would be advisable for Southern Water to include any known discharge events that might be masking RED flags in Beachbuoy. However, it is acknowledged that it is difficult for any water company to include all discharge events and especially those not related to the operations of a water company. Many of these unknown discharges are related to diffuse source pollution from agricultural run-off, leakage from septic tanks etc.

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
7. Is there a problem with modelling discharge inputs into harbour/river/estuary confined bodies of water. E-Coli longevity, dispersion and advection is going to be different in confined water spaces as compared with the open sea. Is this more concentrated material from a confined body of water considered in the modelling from a limits perspective? (eg a discharge into Langstone Harbour will come back when the tide turns and affect a bathing water like Eastney in less than 12 hours when initially no impact)	*Water Quality* NB *E. coli* is irrelevant for any health risk evaluations in marine waters. This approach could be deployed to address such situations under different tidal conditions. I have no expert view on how this could be modelled but the MMO approved phage tracers have been deployed to inform the modelling process for UK water companies. However, very different microbial decay rates may be experienced in a turbid harbour environment within a stream-dominated estuarial system. It is understood that SWS will use a variable T_{90} in the updated model. *Oceanographic Modelling* This is an important point for consideration and particularly where the harbour entrance is narrow and near a bathing water, such as the case for Langstone Harbour. In modelling such a narrow-entranced basin it is critical to ensure that the flow and FIO flux across the entrance is predicted as accurately as possible. For this purpose, it is desirable to use an unstructured grid model, thereby enabling a very fine grid resolution to be set up in the entrance region to reproduce accurately the area of flow (including deep channels) and velocities through the basin entrance. This point is covered in Recommendations 1 and 4. In confined water bodies with a narrow entrance, such as harbours and large marinas, the treatment of many of the processes outlined in Section 2[2] become even more critical, particularly turbulence, dispersion and diffusion. However, it should also be noted that a conservative decay rate (or T_{90} value) was used in calculating the *E. coli* concentration values. Also, where a tide induced jet flows through a relatively narrow harbour entrance it can lead to the process of 'tidal pumping' (Zheng, et al., 2016) wherein effluent/sediment discharges at the head of the harbour can accumulate over time, leading to higher concentrations of bacteria than those discharging from the outfall, particularly at night. The process of tidal pumping is schematically illustrated in Figure 6.3 below. Although the paper by Zheng et al. (2016) focuses on nitrates, as mentioned in the paper similar processes can occur with bacteria. More recent studies by the writer and others have shown that bacteria adsorption and desorption onto the sediments (on the bed and in suspension) can lead to the decay rate for bacteria being very long, particularly for dark conditions. With sediment brought back into suspension on the subsequent spring tide, particularly under storm conditions, then sediment transport and bacteria desorption can also be a mechanism of FIO transport in a river or coastal basin. This was found to be the case in the River Ribble Basin

study and contributed to the flux of *E. coli* from the Ribble catchments to the Fylde Coast (Huang G., Falconer, Lin, & Xu, 2022). In the past the writer also has experience of studying a range of water quality parameters in Poole Harbour and Holes Bay, where several of the pro-cesses referenced above were found to be critical (e.g., Falconer, 1986).
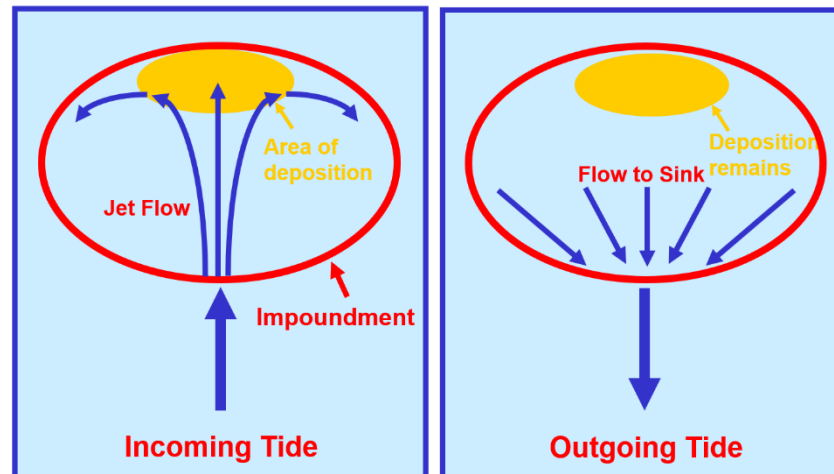

Figure 6.3. Schematic illustration of tidal pumping impact on sediment transport processes (also applicable to FIO processes).

8. How would real time satellite tidal/cloud data and other real-time data sources improve BB accuracy and levels of user trust. Copenhagen's well respected and trusted system uses real time data, is this considered best practice?	*Water Quality* Real-time data could only improve the modelling effort in my non-expert view. It is understood that SWS plan to change to a system of using more real-time data in the future, ideally using modelling of each release as it occurs with appropriate and sufficient calibration data. *Oceanographic Modelling* The writer is aware of the Copenhagen real-time satellite tidal data etc. system, through being one of three members of the Independent Expert Group reviewing the extreme London floods of 2021.

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
	In the opinion of the writer, it would be difficult for a water company to develop such a sophisticated real time modelling system as that for Copenhagen, both in terms of the need for a supercomputer and the continuing expertise and engagement of a specialist organisation, such as DHI (originally the Danish Hydraulic Institute, but now a not-for-profit international company specialising in state-of-the-art applied modelling). Although it would be expensive and difficult to replicate the Copenhagen real-time system directly, in the longer-term Southern Water could investigate the scope for undertaking numerous runs of the latest DHI unstructured grid models and apply these models for a wide range of extreme events. The data from these model runs could then be stored and implemented into a hydroinformatics tool, such as an Artificial Neural Network (ANN) or Genetic Algorithm (GA), with the outputs from the hydroinformatics tool then being included directly into Beachbuoy and generating real-time risk assessment information for the public about bathing water quality. The writer is aware of such approaches currently being investigated for optimising tidal range energy generation in tidal lagoons and barrages (Xue, Ahmadian, Jones, & Falconer, 2021), and more recently for application to coastal bathing water studies (Lam & Ahmadian, 2023). Such a course of action by Southern Water in the longer term, would put the company at the forefront of bathing water quality risk assessment information for the public.
9. Are there any missing BB features from the reviewer's perspective	**Water Quality** It should be modelling IE concentrations with a high level of field data collection to be used for model verification and calibration. It is understood that SWS plan to incorporate IE into the modelling (alongside EC) in the model update. **Oceanographic Modelling** In the opinion of the writer the main missing feature of Beachbuoy is that information is not included for releases at MWL (Mean Water Level) in assessing whether flags should be '1' or '0'. The releases only seem to be provided at high or low water when, in general, the tidal currents are in the slack water phase and are a minimum. In contrast at MWL, for both flood and ebb tides, the tidal currents would be close to a maximum and the dis-charge plume would be advected by the largest currents and before the plume had diffused extensively, i.e., the highest concentrations at the centre of the plume would be maintained at a higher level for further into the plume trajectory.

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
	User and Engagement

This review apart from usability issues of existing features, also identified missing features that could be provided to address specific user concerns and improve overall interaction. These are discussed in Section 2.2[3]. A summary of key missing features is further provided below:

    i.   A clear link to access Beachbuoy from the home page of the service provider.

    ii.   Missing information with respect to the following: How to use the Map; Description of Beachbuoy Spatial Data; How Updates Work; Beachbuoy Modelling; Background and water quality information (see issue #2 in Section 2.2.1).

    iii.   A Frequently Asked Questions page (see issue #4 in Section 2.2.1)

    iv.   A Forum to enable two-way communication, promote transparency and trust (see issue 5 in Section 2.2.1).

    v.   Relevant content to make email notifications more useful (see issue #6 in Section 2.2.1).

    vi.   Explanation of the nature of each manual update to improve transparency (see issue #7 in Section 2.2.1).

    vii. Missing information about map data and spatial accuracy (see issues #10 and #11 in Section 2.2.2).

   viii. Specifying time zones for duration times (see issue 13 in Section 2.2.2).

    ix.   Adding a search bar to navigate the map more easily (see issue #15 in Section 2.2.2).

    x.   A detailed stakeholder analysis and plan to engage with a broad spectrum of Beachbuoy users with different characteristics to capture and subsequently integrate needs and requirements into the design of future versions (see recommendation #21 and #22 in Section 2.2.3)

Software and Systems

Yes and some of these are enabled by the in-flight redevelopment of Beachbuoy using ESRI ArcGIS as the mapping front end rather than Google Web Services, also in the current Aspire development. Fundamentally this is the provision of more information to qualify the meaning of the map flags, the reason for a review decision, what the review involves (see the PI AF screen shots in the previous sections of the Report), user profiles for distinct stakeholder personas, etc. Other

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
	aspects such as consideration of the length of a beach are possible with ArcGIS but are not yet identified. NOTE in the Recommendations there are other aspects that should, in the Reviewers opinion, be implemented in relation to documentation, development process, etc.
10. Consider how closely the software modelling tools used map to the unique tidal environment of the Solent over a rolling period of at least 14 days, understanding the applicability of the models to the local conditions within the Solent system and capturing the change in effect across the tidal cycle from neaps to springs	*Water Quality* I would need to review empirically gathered marine and local T_{90} data to make this judgement. However, T_{90} is highly dynamic, see Kay et al. (2004), and varies through the day in response to solar irradiance and is affected by changes in nearshore turbidity which is often impacted by sediments washed into nearshore zones. Further advice from the modelling expert should be taken in response to this answer. *Oceanographic Modelling* In the writer's experience the finest grid resolution of 125 m is too coarse to predict accurately the complex hydrodynamic processes in the Solent over a spring-neap cycle. To-wards the western end of the Isle of Wight (near Norton), there is a headland from the mainland coast, protruding seawards about 2.25 km (towards the Isle of Wight) and with the minimum flow width in the Solent of about 1.25 km, leading only to about 10 grid squares across the entrance width. With a simple 0D turbulence model, and a relatively coarse fine grid resolution for this region, then the model would be unlikely to predict accurately any tidal eddies generated in the region (see Figure 1 of this report). This is further evidenced by the predicted velocity data comparisons in this region against Admiral-ty Chart data, as shown in the Figure 3.5 plots in the Southern Science report (Southern Water Services Ltd, 1998). Furthermore, the entrance into the Solent between the headland and the nearest land location on the Isle of Wight is at an angle of approximately 45% to the grid orientation. It is also noted that the southern boundary location of the finest grid is relatively close to the southernmost tip of the Isle of Wight, thereby potentially constraining the velocity structure along the southernmost reach. It is understood by the writer that Southern Water have acquired an unstructured grid version of MIKE 21/3D from DHI, and this model would offer the potential for improved hydrodynamic predictions in the region.
11. Focus on the on the decision process behind the recently adopted category of non-impacting discharges. Given the cyclical movement of water within the Solent over many	*Water Quality* What is the empirical evidence, for and against, this assumption of cyclical effects within the Solent, what is its observed and measured periodicity and does this affect water quality within the Solent? EDM data alone are not enough to investigate this potential problem. It is certainly the

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
tidal cycles, it is difficult to understand how a decision that a discharge is 'non-impacting' can be made. It would be helpful if the review could report on the level of confidence that could be applied to the output. MIKE 21 is a long established and respected suite, but it is important to assess the accuracy of its models as used within the unique Solent environment.	case that FIO inputs to bathing waters is impacted by urban runoff, livestock farming, sewage treated effluents, stormflows and avian and intertidal defecation by avians and other species. Further advice from the modelling expert should be taken in response to this answer. ***Oceanographic Modelling*** Based on the model setup and results in the Southern Water Services report (1998), in the writer's opinion it is currently difficult to state that a discharge is 'non-impacting' in the Solent and primarily for the reasons outlined in the previous section (i.e., question 10), including the model grid resolution in a highly turbulent region and due to several pro-cess modelling simplifications. However, using an unstructured grid model with a higher grid resolution in the Solent (ca. 50-75 m minimum resolution) and with improved turbulence, dispersion and diffusion representations in the model, then more confidence can be obtained in establishing whether a discharge is 'non-impacting', or not, on a bathing beach. The unstructured latest version of MIKE 21/3 provides an improved grid representation, without the need for nesting, as well as a much-improved turbulence model (namely the Smagorinsky model), which is grid-size dependent. These recommendations are covered in Recommendations 1, 4, 5 and 8. Regarding MIKE 21/3, this is a highly refined and widely used model world-wide. In the field of hydro-epidemiological modelling for predicting hydrodynamic processes and bathing water quality standards in coastal waters, there are three internationally leading commercial computational models. In the writer's opinion these models are similar in quality and structure, as outlined in Section 2(i) of this report. The models include: MIKE 21/3D from DHI, Delft 3D from Deltares, and Telemac from HR Wallingford. Whilst all three models are similar in terms of the processes modelled and parameterisation, the only disadvantage of MIKE 21/3D is that the code in not open source. This is a disadvantage in that the code cannot be refined through specialist university research teams etc., where such refinements have been made to Delft 3D and Telemac. However, the argument against open-source software is that refinements can often be made by third parties, where the changes made are not numerically or physically correct, or sufficiently proven, and then passed on to other modellers or commercial organisations for model application to practical studies. The writer has personal experience of such failings being made to his own open-source model DIVAST, which was provided widely to companies in the early 1990s.

12. The report should assess whether the modelling adequately covers the various tidal flows and back eddies throughout the Solent and through each tidal cycle when assessing the level of impact over 24 hour and 72 hour time frames.

Water Quality

As a non-modeller, I cannot make authoritative judgement on this matter it will depend also on the availability of precise temporal water quality data of high spatial resolution. Further advice from the modelling expert should be taken in response to this answer.

Oceanographic Modelling

As outlined in response to questions 10 and 11 above the writer has reservations about the accuracy of the model predictions, particularly regarding the hydrodynamics, for the reasons outlined in Section 2 of this report[2]. For example, in the writer's experience a finer grid resolution and a more accurate turbulence model, at least based on the local velocity and depth, would have been expected to show signs of a pronounced and well-structured tidal eddy around the headland to the west of Pennington and in the narrow Solent entrance. However, in viewing the spring tide currents throughout the tide in this region, there is no evidence of the formation of any well-structured tidal eddies in the region, as illustrated in the model current predictions shown in Figure 3.7 (a-m), in the Southern Water Services report (1998). The prediction of tidal eddies in nearshore coastal waters can be critical in assessing bathing water quality (see Figures 1 and 2[2]), and particularly for shellfish water quality, as the formation of tidal eddies leads to sediment accumulation at the centre of the eddy and pollutant trapping – particularly near the bed – as illustrated for sediments in Figure 6.4.
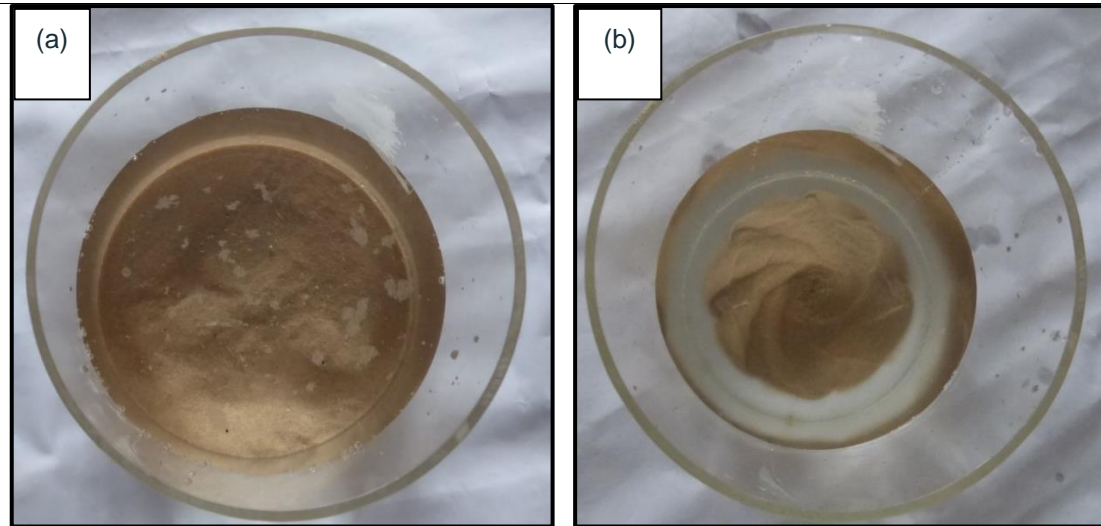
Figure 6.4. Schematic illustration of eddies causing sediment to accumulate at centre: (a) uniformly distributed initially, and (b) accumulated at centre after stirring.

Furthermore, for several of the current predictions in Figure 3.5 of the Southern Science report, where comparisons are reported against Admiralty Chart data, the comparisons show several predicted peak currents which are noticeably less than the Chart data, particularly as shown in Figure 3.5 (e) where the measured current is ca. 2.0 m/s, whereas the corresponding predicted value is ca. 1.0 m/s, i.e., only 50% of the Admiralty Chart value. This comparison is well out with the FWR criteria, which is widely used within the water industry and adopted with reasonable confidence, particularly in deeper water and as for this region. Further field data collected with ADCPs and a much finer grid resolution model are therefore recommended. These points are included in Recommendations 3 and 4.

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
13. Review whether the volumetric loadings and conversion from duration applied in the model are appropriate representation.	***Water Quality***
	Volumetric loadings and conversion from duration: again, this a question for the modeller I do not have expertise in this area. Assumptions and predictions of FIOs on discharge dynamics and peaks to the coastal zone can only be fully addressed by well-designed sampling programmes focused, as a minimum on the local sewerage system. Further advice from the modelling expert should be taken in response to this answer.
	Oceanographic Modelling
	In the writer's experience and compared to similar studies being undertaken by other water companies etc., the volumetric loading of 3 x DWFs (Dry Weather Flows) is at least comparable to, and in many cases greater than, that used by other water companies in comparable studies. However, whilst it is acknowledged that the DWF is population dependent, it would have been useful to have had typical DWF rates cited in each report to give the reader an indication of the relative solute flux and dilution extent for each outfall. In some reports a figure has been quoted (typically between 1.0 and 1.5 m^3/s), with these figures appearing to be as expected. It would also have been informative to have included both peak and mean flows for each outfall. The FIO bacteria levels were generally assumed to be 2.0 x 107 cfu/100 ml, with this level being scaled during post processing to give a release concentration of 5.0 x 107 cfu/100 ml. In comparison to similar studies this value would generally be considered to be a conservative value in the experience of the writer, with values often used in some comparable studies being ca. 5 x 105 cfu/100 ml.
	As stated in the response to question 4 above, in the writer's opinion it would be useful to provide some mean volumetric flow data, as well as a concentration value and a time of duration of the discharge. Therefore, mass fluxes could be calculated and added into the reporting. This point is included within Recommendation 3.
14. Are the judgements being made about tidal water flows in order to determine 'impact' on a bathing beach reasonable in the context of the Solent?.	***Oceanographic Modelling***
	In the opinion of the writer there is a particular need to improve the processes represented and the parameters (or coefficients) used in the nested models for the Solent region. The writer has outlined the main refinements that could be made to give improved confidence in the model predictions and these points are outlined in detail in Section 2 of this report[2], and in response to questions 10, 11 and 12 above.

Review Question – General Modelling	Responses (as provided by the reviewer – details in Section 2)
15. What is your level of confidence that the MIKE 21 can closely model the actual tidal conditions close in to the Solent shoreline, its harbours, estuaries and beaches?	***Oceanographic Modelling*** The writer has full confidence in the model MIKE 21 being capable of closely predicting the actual tidal currents 'close into the Solent shoreline, its harbours, estuaries and beaches'. However, for the reasons outlined in Section 2 of this report[2] and in response to questions 10, 11 and 12 above, the writer would have more confidence in the predictions if a finer grid had been used in the region and if the southernmost boundary had been cited further away from the Isle of Wight. Also, in view of the length of the headland just to the west of Pennington, the writer would suggest that a higher order turbulence model and improved representations of the dispersion and diffusion coefficients would have been more appropriate.
16. Given the mapping between the GIS coordinates used for the Beachbuoy sites and the EA defined 'Bathing Water' and 'Shellfish Areas', assess the feasibility of extending Beachbuoy coverage to include all Solent and Kent shellfish areas, an upgrade that would provide required coverage for Solent water users and enable Southern Water to meet the shellfish water quality priority set by Defra	***Oceanographic Modelling*** In the experience of the writer the difference between the near surface and near bed FIO levels can be significantly different in coastal waters, with the concentrations near the bed often being either much higher or lower than the values in the surface layers. For bathers in nearshore coastal waters, it is more likely that any water ingested will be near surface water. In contrast, shellfish sites are generally in deeper water and where the sur-rounding FIO concentrations may be higher due to the lower level of light penetration and reduced decay through the water column, or lower due to the limited transport of faecal bacteria from the buoyant surface plume to the near bed zone. The near bed concentration can also accumulate with time due to the increased impact of adsorption to, or desorption from, the bed and suspended sediments. It is therefore ideally more appropriate to consider using a 3D model if near bed FIO concentrations are needed for shell-fish sites, alternatively data of *E. coli* and/or IE concentrations could be measured through the water column at critical sites and then functionally related to the corresponding depth mean FIO concentrations predicted using a 2D coastal model.

B.5 User Engagement

Table 6-5 – User Engagement Review Questions & responses (as provided by the reviewers).

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
1. How do the developers know what users want/need. Would independent elicitation of system requirements be helpful over what developers think we need	***User and Engagement*** Requirements engineering plays a very important role in the product development lifecycle; it supports not only understanding – and subsequently managing - users' (i.e. a broad range of different types of stakeholders who utilise the system) expectations with respect to how the system should or should not be performing (i.e., what tasks it should or it should not support) and what kind of user experiences it should generate (e.g., be enjoyable to use; informative in terms of educating users about what they want to know; and other hedonic values). This process of consulting the users further helps build a relationship with them, which is particularly important in low trust contexts. Different methods can be used to help developers identify user needs, functional and non-functional requirements; these mainly include ***"focus groups, use cases, prototyping, observations, interviews, workshops and role-playing"*** (Karshiladze and Luo, 2015). Some of these methods are more effective than others depending on the stage of the product's lifecycle development; e.g., whether existing features are being evaluated, or the system is being redesigned to incorporate new features to address additional user needs. Also, some of these methods are more appropriate than others in terms of understanding users' emotions and feelings evoked by interaction, especially with respect to non-functional requirements (e.g., reliability, trustworthiness, how perceived risk is managed through different features, etc). This is extremely significant for systems like Beachbuoy where trust plays a significant role not only in terms of how people manage risk based on the information provided, but also in terms of their overall trust perceptions towards the service provider. This review found that although stakeholder involvement informs Beachbuoy development, ***this is limited to key stakeholders*** (see *Expert Review Question #10*) rather than a much broader

spectrum of different types of end users who could equally contribute by getting more actively engaged in this process. Participants, members of the stakeholder meeting group that's been formed for this reason, comment *that product development could benefit from a wider selection and engagement of local users.* This can be decided following a stakeholder analysis as further discussed in *Expert Review Question #10*.

Although not mentioned in the literature as the most suitable method to support user requirements' elicitation, surveys have been also employed by the service provider to get user feedback and further identify needs and expectations. A major interface design change which was applied in September 2022 - to show on the landing page the impact on bathing sites instead of releases was based on the results of a feedback survey which took place in 2021. Based on this independent expert review's findings, *several users are not satisfied with this change and they still want to see all releases regardless of how much they impact or not relevant bathing sites.*

Surveys, can be effective as a requirement elicitation technique, but there are several limitations especially when it is the only method used for this purpose when they are used to draw conclusions on low response rates (as it was the case in this example, with a response rate of 10%); and when the results are not based on a well-balanced and targeted participation sample which captures requirements of users with different experience and competency levels (e.g., beginners, intermediate and advanced users). Also, surveys are asking for feedback outside the context of using the application, which may result in various types of bias; they do not necessarily help the service provider build a connection with end users; empathise with them by better understanding their concerns and emotions and; ensure they are being heard building in that way customer rapport and an ethic of care.

For these reasons, this review recommends *the use of appropriate Human-Computer Interaction methods* for the elicitation of user requirements, with an emphasis on both functional and non-functional requirements. This review found for example, that Beachbuoy is currently lacking the provision of appropriate information to help users understand how the system works and build rational trust perceptions and such elements can only be explored with appropriate emphasis on non-functional requirements. *Interviews, usability testing and focus groups* can

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	support the aims described earlier in this section. Once user requirements are identified within specific contexts-of-use, they can be further evaluated with a wider population sample using surveys, social media or even a forum. These should be applied in the context of both Beachbuoy desktop and mobile interfaces.

Note: Human-Computer Interaction methods may require the use of strict methodological protocols to ensure that these are correctly applied and minimise bias. Human-Computer Interaction experts should check the validity of methodological protocols before such methods are being employed.

Recommendations

✓ Perform additional interviews and usability user testing (observation) to capture functional and non-functional requirements for both desktop and mobile interfaces (critical).

✓ To implement Human-Computer Interaction methods follow appropriate methodological protocols (critical).

✓ Interviews and usability testing should be used to engage end users (outside the existing stakeholder group) with different competency levels and categorise needs and requirements accordingly (critical).

✓ Methods such as interviews and usability user testing can create a connection/bond with users, build rapport and demonstrate an ethic of care which is necessary to promote and rebuild trust with end users. For this reason, might be best performed by independent experts.

Software and Systems
The 'developers' code to deliver functionality required in the form of User Stories (organised in Sprints of two weeks duration) given that the current development activity (from Jan 2022) follows |

| Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	Agile principles using a Scrum delivery framework. The redevelopment project will use the more traditional Waterfall lifecycle.
	User Stories are derived from Epics and Features (to use Agile terminology) which are elaborations of business requirements. The Southern Water Beachbuoy and Aspire Product Owners are the responsible and accountable people who own the product 'vision' and mediate the business need as cascaded from multiple business sources and including the Beachbuoy Working Group as representing the public user constituency. Essentially Beachbuoy is a Southern Water business response to the Environment Agency and OfWat's requirements to be open and transparent in communicating spill information to the public. The Working Group is the primary nominated representation of the public interest and has an obligation given their role as intermediary to accurately communicate a view of how that information is presented. The original Beachbuoy took, in the reviewers opinion, a narrow view of those presentation needs (for various reasons), tidal modelling of impact widened that view but complicated the actual information delivery. Technical issues (transmission delays) also complicate the interpretation of that information delivery at the user interface. It is the opinion of the Reviewer that, given the actual governance process around the project delivery constraints, stakeholder management could be improved, mediated through the Working Group potentially via special interest groups committed to detailed involvement in the Agile process but accountable to the Working Group. Selection/election may be contentious, as would be the required time commitment.
	In addition a more passive approach would be via the app itself via encouragement of user feedback, comments, a rating system, etc.
2. Surfers Against Sewage safer seas app is a well trusted app used for many years. It uses just two colours RED and GREEN (Bad/Good) would it be reasonable/helpful for BB to adopt a simpler approach or whether the current approach is appropriate and there is sufficient confidence in the precision of the data	*Oceanographic Modelling* Although not an expert in this field, the writer did think this was appropriate on first reading about Beachbuoy. The concept of a 'traffic light' system is increasingly being used in flood risk assessment (but not so much in the UK) and in the writer's experience this is a simple and understandable way of presenting risk to the public. *User and Engagement* The web mapping interface of the Surfers Against Sewage shows bathing sites across the coast, with one the following symbols on top: a green tick (for no pollution alert), a red exclamation mark (for pollution risk forecast or incident alert), a red 'x' symbol (for sewage pollution alert). Some

further data provided for poor annual classification (x red symbol), out of season sites (snowflake symbol), maintenance alert (spanner tool). The icons are explained at the bottom of a map rather than using a map legend. Users can interact with each map point by clicking on it and read relevant information on a pop-up window. The pop-up windows are rather heavy in text, which might result in usability barriers. There is no information about the data sources or how forecasts are generated neither below the map nor in the FAQ section on the web-based version (this is a feature that generally violates trust heuristics). The mobile 'Safer Seas and Rivers Service' app provides information about data sources, and users can register to receive updates and report sewage pollution and upload relevant pictures. This service and the two-way information flows that enables is believed to be critical in terms of transparency and trust.
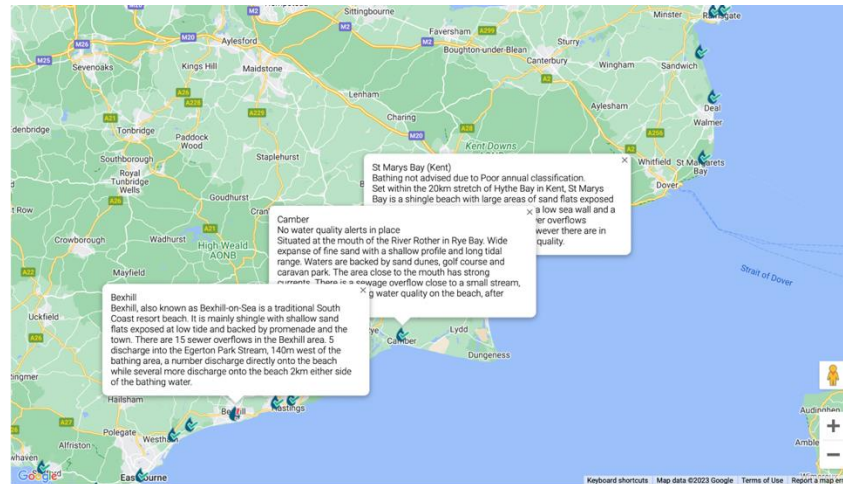

A similar colour scheme and symbol choice is also used by the Thames Water sewage release map[6] although, similarly to Surfers Against Sewage, it doesn't show the impact of the releases to water quality. A similar approach – i.e., Red/Green colour scheme with relevant symbols on top -

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[6] https://www.thameswater.co.uk/edm-map

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)

might be beneficial for simplicity purposes especially if the map is used to show both releases and impact to bathing sites at once as separate layers (as described in Section 2.2.2 issue #14) . If a significant number of Beachbuoy users have previously interacted with similar applications, the provision of a similar visualisation, offers a great opportunity to minimise any complexity in the learning curve, which is particularly important for novice users. An alternative way to visualise sewage is used by the Rivers Trust and Unearthed Greenpeace sewage map[7] (different size points to show number and duration of spills as shown on the screenshot below).
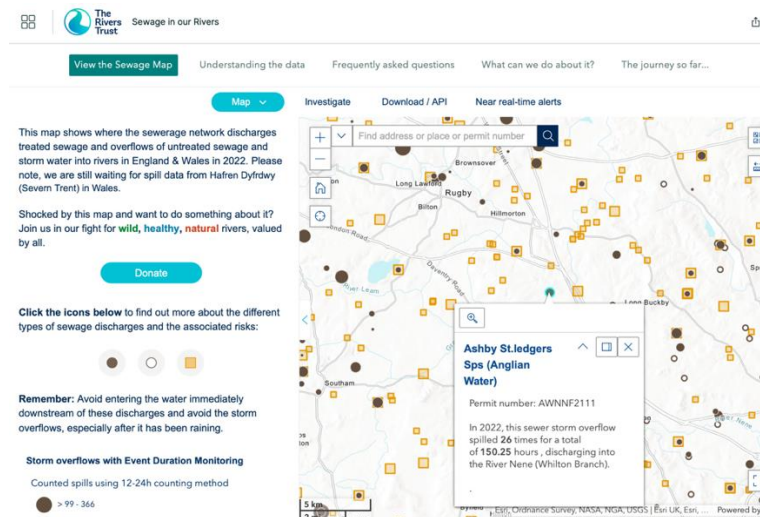
This study found that participants prefer Beachbuoy's interface, choice of colours and visualisation with the exception of the white 'unverified release' symbol. Nevertheless, and due to the small number of participants, it is recommended that additional usability user testing

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[7] https://theriverstrust.org/sewage-map

experiments or interviews are used to evaluate different visualisation approaches to identify and subsequently implement the most preferred by end users.

This review also found that beginners who interact with both Surfers Against Sewage and Beachbuoy believe that the two maps show the same data. It was clear in the interviews that participants ***do not understand that Surfers Against Sewage shows releases and Beachbuoy the impact of releases on bathing sites on the landing page.*** It is believed that, provision of two layers of information (i.e. view impact, view releases) (as recommended for issue #14 in Section 2.2.2) will solve this problem and address users' concerns of not being able to view all releases instantly.

With respect to trust, this review found that the users who tend to trust Surfers Against Sewage more is either because they are not aware that it uses Beachbuoy data, or they are aware, but they prefer that the map shows outfall releases instead of impact to bathing sites.

Recommendations

✓ Run usability testing to evaluate how easy are different visualisations to use by different types of users (i.e., beginners, intermediate and advanced competency levels) (low).

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3. Is BB reliable? Does it update metronomically every hour (no, it actually does not!) is this a problem from a user health perspective

Oceanographic Modelling

In the writer's experience Beachbuoy is an encouraging tool to inform the public in general terms about the potential health risks associated with bathing at a particular beach, on a particular day, and it should continue to be used. However, by improving the grid resolution, process modelling (particularly wind effects) and parameterisation in the coastal models currently being used would lead to more confidence in the predicted data upon which information is used within Beachbuoy. Furthermore, and into the future, a larger range of coastal model runs could be undertaken and, using hydroinformatics tools (such as ANNs and GAs), along with automated data collection etc., then real-time information could be provided to the public of the health risks of bathing in Southern Water's beaches on any particular day. This information could then be provided during the bathing season to regional TV and radio channels (e.g., BBC), along with regional weather up-dates.

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	User and Engagement

It is clearly indicated from the textual information that Beachbuoy data are updated in "near real-time". Below the map it is further shown that automated updates happen every hour. There is no explanation about the manual and automated update processes that it is easy to access, and which improves awareness of this feature.

When frequency of updates was discussed with interview participants, most of them felt confused. This is: i. due to discrepancies in the update timings across automated and manual updates; ii. the fact that manual updates vary in times, i.e. on several occasions, according to participants' feedback, updates timings vary significantly from hours to even days.

As discussed in *Expert Review Question #3* Beachbuoy updates have attracted a lot of attention and negatively impact users' trust perceptions into the system as well as perceived usefulness of Beachbuoy. This is directly relevant to its main purpose of informing people about when it is safe to enter the water, as interviewees identify and describe the purpose of the service. As a result, the reliability of updates is a significant problem from a user's health perspective (e.g., "*It used to be every eight hours, then two and now I think it is one hour. But it is not always working and therefore it is not trustworthy to make decisions about my health and safety*"; "*That's very worrying. I lose all faith on BB. Why have a system if it doesn't give me correct information. You better off without a system*"; "*The problem is that the manual review process will not happen until most likely the discharge is over. By that time the discharge will be yellow or even green. How is this helpful?*" – interview comments).

There is an urgent need to inform Beachbuoy users about updates and most importantly to be consistent with how long manual updates take to appear into the system. The roadmap set internally for manual updates needs to be simplified with the main aim to provide accurate information ***as quickly as possible***. For this reason, a threshold needs to be set for manual updates, to set users' expectations towards the right direction in terms of how long they should wait for manual updates to appear to make an informed decision about accessing the water or not.

Recommendations

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	✓ Provide clear explanations of how updates work (critical).
	✓ Provide clear explanation of Beachbuoy update times (i.e. both manual and automated) (critical).
	✓ Set threshold for manual updates (e.g., no less than two hours) to improve reliability and help users efficiently manage health risks (critical).

Software and Systems

Beachbuoy updates every hour on the hour using Quartz scheduler and a stored procedure to poll data from Aspire tables to Beachbuoy tables.

User health is a difficult term to respond to by the Software & Systems Reviewer and is outside of the Reviewer's terms of reference. Beachbuoy is advisory on spills not pollution levels as these may be affected by other factors outside of the control of Southern Water.

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
4. Is BB reliable? Are the software updates seamless, well tested and problem free (no! See DMI introduction 12/9/22) should users expect properly tested software updates to keep them safe and well informed.	*User and Engagement* In addition to what already discussed in *Expert Review Questions #3 and #8* above, Beachbuoy data reliability is influenced significant by the following: i. Unverified releases communicated through the white symbol are also relevant in terms of influencing the system's reliability and having an impact into users' decisions to access the water or not. As explained in *Expert Review Question* #Q3 these are treated by most users as actual releases, in terms of taking relevant action. The way unverified releases are manually checked and the way relevant data are updated are of significant user concern. A decision therefore needs to be made about how unverified releases are communicated in the future and the significance of setting a threshold value for a manual check to confirm the situation, in as close to "near real-time" as possible.

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	ii. The time zones for the start and end timings in the 'Historical and current releases' Table are not specified. Several users report that most likely these are in GMT, which means that timings are off during summer months, which several users may not realise.
	iii. Confusion with respect to the duration of some releases. For example, participants mention that frequently a longer release is broken down into multiple releases: *"Another weird thing that I noticed is that lots of multiple releases may happen almost back to back. A 20 hours release may consist of three releases which actually happen only one or two minutes apart. Why are they presenting data like that?"* (Interview comment).
	As further outlined in *Expert Review Questions #6 and #10* this review found that Beachbuoy in its current form it is neither perceived as reliable nor it fully meets the needs and expectations of users with different experience and competency levels. Stakeholder mapping and an approach which enables the engagement of a much broader yet targeted (for end users characteristics) spectrum of stakeholders, with an emphasis on local users, and further analysis to collect user functional/non-functional requirements will potentially improve the service and how people interact with it.
	Recommendations
	✓ Explain why some longer releases are described as multiple smaller releases even when these are just a few minutes apart (critical).
	✓ Specify time zones for start and end release times (critical).
	✓ Explain in lay terms on Beachbuoy information page the 'unverified overflow release' feature and the reason it exists in the first place (critical).
	✓ Set threshold for manual updates that verify a release (critical).
	Software and Systems
	See the previous Report sections detailing the testing processes. Testing is carried out on User Stories and Sprint delivered product, Tests include Sanity Tests, see table 4 reproduced below.

| Review Question – User Engagement | Responses (as provided by the reviewer – details in Section 2) |

Test Phase	Proposed	Responsible	Expected Delivery
Unit Test	Y	Development	Before moving Story to 'Ready for Test'
Sanity Testing	Y	BTS Test Team	2nd day of the Sprint (Week1)
System Integration Test (Sprint)	Y	BTS Test Team	Sprint closure date
User Acceptance Test	Y	Business Users	After Sprint Review Meeting

Testing is support currently It is also understood in the by the Jira Zephyr tool. Bugs are prioritised and if low priority rolled into the next Sprint backlog for remediation and retest. All test results are documented and subject to acceptance by the Test Manager. Sprint Test Exit reports are available and auditable Examples are available). In addition, there are pre-production PEN tests for security, Regression tests, and APIs are stress tested for performance. The CAB release check is extensive and fully auditable with certification.

In terms of process, execution and recording this is, in the opinion of the Reviewer, industry best practice. It is also understood that enhanced testing tools will be deployed for the new development, however, these were not specifically identified.

Acceptance of the end product by the public as a third party is a different matter.

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5. Has BB Stakeholder involvement been effective. Historically this has been dysfunctional; there is very little representation from actual users and these are often side-lined. How can stakeholder involvement be improved so that user requirements for improvements and enhancements should be openly debated and prioritised in a Beachbuoy Stakeholder user forum to ensure that both functional and nonfunctional requirements are addressed to optimise benefit for both Southern Water and the user community

User and Engagement

Water companies across the country provide relevant information to report on environmental performance, which includes information about releases. Southern Water's Beachbuoy service launched in 2018 to communicate openly outfall releases and their impacts to bathing sites across the South-East coast. Since then Beachbuoy was updated in May 2021 to cover *"all 83 of our region's designated bathing waters and two non-designated recreation harbours, along with more details about each release"* (Southern Water, 2021). The innovativeness of this service is on the fact that Beachbuoy data are linked to Aspire (i.e. Southern Water's spill reporting system) so data are updated on the map in near real-time. The Beachbuoy stakeholder working group was formed in October 2020, which included stakeholders from different organisations as well as local people from the entire region, who met regularly to provide input which informs the development of Beachbuoy services and visualisation.

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	Between November 2021 and January 2022, the Customer Insight Team launched the Beachbuoy feedback survey to get further insight into how users use the service, the interface design and other features they like and dislike and their recommendations as for how the service could be improved. Subsequently the website was updated in September 2022; the main change at this stage involved showing on the map an assumed impact of releases on bathing waters, instead of simply showing the location of all releases. Since September 2022 the website is updated on an hourly basis, as opposed to two-hours, before. The collection of user feedback to further improve the service and tailor it more to the user needs is an ongoing effort, which will subsequently inform the launch of a more sophisticated version to accommodate a wider range of user needs and improve user interaction.

This expert review found that the changes that were made in September 2022 generated public suspicion and reduced people's trust in the data provided. Some participants expressed a view that *"Beachbuoy was great before the changes in September 2022…now it shows less releases, which doesn't make sense…we don't know much about the impact models and we don't necessarily trust them"* (interview comment). Videos and textual information to explain how Beachbuoy impact models work in lay terms are essential and should have accompanied the changes which took place in September 2022. Such information needs to be transparent and relevant functionality should provide people with an option to ask questions and get further support when they require it. A forum has been further suggested by several participants for two-way communication; e.g., people can use it to raise an issue or ask a question and get a response, give feedback and so on.

Despite the ongoing efforts of the service provider to engage with a wide range of stakeholders there are still significant gaps especially in terms of reaching out to members of the public and specific groups which use Beachbuoy on a regular or occasional basis. One participant mentioned, *"we know that sewage and storm overflows is the biggest issue for local residents"* and most people agreed that there is great potential for local people to be involved in this process as *"there are so many who could benefit from Beachbuoy but they are not aware of its existence"* (interview comment). Participants, referred to various swimmers' groups, surfer and sailing clubs, |

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	fishing groups, farmers, local business as well as various individuals who access the sea across the South-East coast and who would benefit from being more involved in this process. Stakeholder engagement, including the involvement of local people, should be ideally supported through different mechanisms for synchronous and asynchronous communication channels, face-to-face but also online methods which support two-way information communication flows. This is to accommodate people's needs more effectively (e.g., time, availability) and be inclusive towards a more diverse population group. Traditional engagement approaches have been criticised for introducing new forms of participation barriers and exclusion, and for not considering people's views and opinions into decision-making processes. For this reason, methods such as surveys, stakeholder roundtables, focus groups and discussion panels should be further combined with other activities such an online forum where people can discuss issues and provide feedback asynchronously. Although engagement approaches so far have been targeting a diverse range of stakeholders, the stakeholder working group mainly consists of local authorities' representatives, politicians, and environmental organisations and groups (e.g., Environment Agency and Surfers against Sewage). Some local people have been also participating but in very limited numbers. To make stakeholder engagement more efficient a stakeholder analysis and mapping (e.g. see Skarlatidou et al., 2019) should be carried out by the service provider as an instrumental tool to guide decision-making and inform organisational practices with respect to stakeholder and public engagement when it comes to Beachbuoy. This will help raise awareness of Beachbuoy services, get more diverse user feedback and opinions for improving it, identify appropriate communication mechanisms to support and sustain engagement and subsequently maximise Beachbuoy impact so that local communities can fully benefit from it. In this context campaigns to attract a wider audience can be helpful as well as the provision of incentives to compensate people for their time and input in engagement and consultation processes.

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
	Recommendations
	✔ Perform stakeholder analysis to map all relevant stakeholder groups across the South-East coast (critical).
	✔ Emphasis should be paid on improving awareness about Beachbuoy and engage more actively with members of the public who might benefit from it (medium).
	✔ Provide incentives or other mechanisms to encourage participation (medium).
6. How can BB be more responsive in managing field defects and new features. The agile software process lends itself well to this kind of thing - but product management seems to be blocking this and fixing things that users don't really care about.	*Software and Systems* Not sure what is meant by 'field defects'. With regard to new features yes Agile/Scrum does support adaptability and change via adding new stories to the backlog in principle although in actuality the danger is the product can morph uncontrollably without tight control by the Product Owner as mediated by the product vision and business requirements, the 'three Amigos' step in 'grooming' the requirements also helps. The perception that 'Product Management' seems to be blocking innovation should be addressed by the up-front requirements elicitation. It is necessary to also understand that in the Aspire Beachbuoy Enhancement Work, Aspire, as a SW internal business critical application necessary for timely Environment Agency reporting, has requirements that are not necessarily relevant to or communicated to or understood by the public stakeholders in Beachbuoy. One recommendation by the Reviewer is separation of Aspire (and other internal systems) from Beachbuoy in terms of project definition and management. Another Beachbuoy specific aspect is in terms of greater and more nuanced stakeholder engagement with improved communication channels to the Product Owner (and Project Board) more transparent prioritisation of Beachbuoy specific requirements

Review Question – User Engagement	Responses (as provided by the reviewer – details in Section 2)
7. BB Emails are currently worthless. This could be improved by appending the event data to which it pertains. This request has been outstanding for years!	***Software and Systems*** The Reviewer assumes this comment refers to the email content and as such should be directed to the User Interaction Reviewer. From the current technology view it would appear the email interface as part of the notification functionally is technically correct, especially in terms of spam differentiation. Data and information is available in the database, what is deemed appropriate and necessary as content could be configured.

B.6 Software Aspects

Table 6-6 – Software Aspects Review Questions & responses (as provided by the reviewers).

Review Question – Software Aspects	Responses (as provided by the reviewer – details in Section 2)
1. Have industry standard software development and test processes been used in the creation of BB	***Software and Systems*** Yes, see previous section in the report and a previous answer.
2. How is the software properly validated against the system requirements and the system test specification at every software update (unambiguously not the case). Consider the potential benefits to Southern Water of including a 'User Acceptance' test phase as a standard element of the release schedule. User testers should be drawn from the Beachbuoy Stakeholder community.	***Software and Systems*** From the evidence provided yes the software is adequately tested against the User Stories and validated for release by the CAB based on other testing and confirmed checks. See previous report sections and answers above. For the tidal impact release (Sept 12th 2022) see the CAB Change Request and approval form ref. CHG0003941 (ref. [33]). User acceptance testing and review for Sprints is carried out by the Product Owner as delegated user representative with apparent reporting to the Working Group (see example Working Group Minutes as of Feb 2023 re the Tidal Modelling release and further requirements capture, ref. [3]). System testing (and Unit Testing, and Regression Testing, and Pen Testing, and API stress testing) is carried out and signed off by the Test Manager with stored and auditable reports.
3. Why are users are finding serious problems with the software on "upgrades" What can be done to improve BB public health information software in this regard	***Software and Systems*** Without specific information on these problems the Reviewer cannot provide a response. The Reviewer has made extensive comments and recommendation as to how the map interface functionality can lead to misinterpretation of the spill data being provided (see previous answers and the report). These issues are not problems with the software, it works as specified and has the necessary assurance that it does work. Inevitably some unforeseen bugs will occur and there is an established process for reviewing reported bugs, planning and remediating these bugs (via the Sprint backlog) and rolling the fixes into future planned releases (standard software engineering practice for both COTS and bespoke developments). Potential improvements are recommended to the requirements elicitation and stakeholder communication.

Review Question – Software Aspects	Responses (as provided by the reviewer – details in Section 2)
4. How are ALL icon state transition diagrams validated against specification (there are currently serious faults with them	***Software and Systems*** No, the Reviewer has not seen any state transition diagrams. See the Reviewer's partial icon state transition matrix for some insight into how these work in a partial sense. The display works as implemented without 'faults', however, how it works and the interdependencies is not transparent to the public end user. There are spill and BWS entity state attributes with an added layer of rules re how these are to be displayed as icon colours. There are a number of interacting factors in how spill states change, how consequential bathing water site states change and how both sets of these entity states are rendered on the map as coloured pins. In addition these entity state changes (which are affected by where the entity record is stored, how it is time dependent updated and as a consequence of other factors changing such as tidal state) that complicate how icon colours represent these states (the web page update process will also have an effect). In the Reviewer's opinion these state transition steps should be detailed in different scenarios related to: - Spill (outfall) and BWS relationships mediated by tidal state and spill duration - Spill data supply chain delays (polling, review updates) - Map display rules for pin colours - User web page interaction effects (auto refresh) It is difficult to see how the specific dynamic complexity and dependencies that underpin the map display when opened by a user (and left open) at a point in time can be conveyed to give understanding (and trust) but this needs addressing.
5. What process is reasonable to protect user health and safety should software upgrades demonstrate software behaviours potentially harmful to its users (as occurred Sept 12th 2022)	***Software and Systems*** The Reviewer has not seen any evidence that the Sept 12th release of Beachbuoy demonstrated behaviours potentially harmful to users and from observation the map interface works as specified, albeit in a non-intuitive way. The Beachbuoy app is remitted to delivery information about overflow spills that may impact bathing water sites. There is no information as to the potential health risks other that the red/yellow colour coding to indicate the time since the spill ended based on the give 72 hour duration for bacteria to degrade in sea water. These aspects are better addressed by the other

Review Question – Software Aspects	Responses (as provided by the reviewer – details in Section 2)
	reviewers. It is assumed a Safety Case (and Safety Impact assessment) is not required as the Reporter has seen no reference to these in the design documents made available, but this requires confirmation from Southern Water.
	It is the opinion of this Reviewer the substantive changes implemented in the Sept 12th release should have been extensively piloted with a cross section of stakeholders based on the remit for the change (and chain of accountability raising and approving the change) with rework if necessary based on a consensus as to acceptability and usefulness.
6. Review the user experience of BB on mobile phones, is it fit for purpose what could be improved as most users will be accessing BB from mobile devices.	***Software and Systems*** Beachbuoy has never had a mobile app in scope although this is under consideration for the new development. The interface was always a web page with access via a browser, so from a design and build perspective the technical issue was browser compatibility (Chrome, Microsoft Edge, etc.). The web page design should have followed good practice for browser access on multiple devices but this Reviewer cannot comment as these considerations sit with the User Engagement Reviewer

B.7   Documentation

Table 6-7 – Documentation Review Questions & responses (as provided by the reviewers).

Review Question – Documentation	Responses (as provided by the reviewer – details in Section 2)
1. Is current supplementary BB information in the public domain misleading or inaccurate. This needs to be corrected	**Water Quality** I have read the descriptions of Beachbuoy on the Southern Water www site accessed at https://www.southernwater.co.uk/water-for-life/beachbuoy/information. The statements made there are, in my view, correct and balanced, indeed the specific criticisms of the overall project are made possible given the openness and candour with which elements such as (i) the prediction of EC rather than IE; (ii) the lack of confirmatory sampling and enhanced precision enumeration (of IE) to validate the SWS predictions in particular. If the recommendations coming out of the water quality review are acted upon, then documentation and statements on the site can be updated. This candour augers well for the development and improvement of Beachbuoy into the future. **Oceanographic Modelling** In the writer's opinion the Beachbuoy information in the public domain is not intentionally misleading or inaccurate. However, based on the comments made in sections 2 and 4 of this report[2], it is the writer's view that there is scope for improving the accuracy in the results obtained in future coastal modelling studies and thereby leading to more confidence in the information being presented to the public and key stakeholders via Beachbuoy. However, in the meantime it is recommended that Beachbuoy continues to be used by Southern Water but advising that the accuracy of Beachbuoy is expected to be improved once refined and improved coastal models are set up and operational. These modelling studies would include higher grid resolution, improved turbulence representation and would have been fully calibrated and validated against ADCP data, along with existing current data. **Software and Systems** This question has been answered by other reviewers.

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