HOW TO MAP YOUR WATERSHED PLANS

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ABSTRACT

New Zealand's renowned clean, green image is under threat from a multitude of environmental pressures, changing land use practices and human activities. Detailed watershed plans are one of the ways to identify and combat these pressures on New Zealand's freshwater and coastal environments. However, watershed plans can be difficult to share with a wider non-technical audience. Using the latest mapping technology is an effective way to break down complex watershed plans and disseminate these with the wider public.

This paper discusses the uses, benefits, and challenges of interactive mapping for watershed plans, and discusses some of the interactive mapping technologies available. It also highlights several geospatial techniques which can be used to provide additional benefits from spatial data and overcome some of the limitations of interactive mapping. Finally, it discusses the benefits of a Story Mapping, a modern technique used to share interactive maps supported by multimedia content and narrative text.

Auckland Council has recently begun developing stage 1 of its integrated watershed plan. This approach breaks the Auckland Region down into ten key watersheds and identifies the current quality state of the region's freshwater and coastal environments. Auckland Council has created an online tool for communicating watershed plans; the latest draft version of this tool is a series of interactive online multimedia maps which presents the current state overview of Auckland's watersheds and identifies the leading environmental and population pressure concerns. Where appropriate, examples will be drawn from this watershed planning tool and shown here.

For reference, the draft watershed plans are available via the link below.

https://arcg.is/11Hi58

KEYWORDS

GIS, Watershed Plans, Interactive Mapping, Public Engagement, NPSFM

PRESENTER PROFILE

Daniel Nutsford is a Senior GIS consultant at Interpret Geospatial Solutions. He has 5 years' experience working with maps and spatial data in the conservation, transport, engineering and water management fields. Over the last 12 months he has been working closely with the Auckland Council Healthy Waters Department developing an interactive map-based website to present Watershed Plans.

1 INTRODUCTION

New Zealand is well regarded for its clean, green image. Environmental pressures, changing land use practices and urban growth are threatening New Zealand's fresh water resources (Ballantine & Davies-Colley, 2013). Auckland Council is currently working to address these threats with the development of watershed plans. One tool which can aid communicating these plans is interactive mapping. This paper outlines the interactive mapping tools and techniques used in this project, and discusses the challenges, advantages, and applications of these tools.

2 BACKGROUND

2.1 AUCKLAND COUNCIL AND WATERSHED PLANS

In response to the National Policy Statement for Freshwater Management 2014 (updated 2017) (New Zealand Government, 2017), Auckland Council is currently generating watershed plans across the 10 key watersheds that drain into Auckland's harbours and major coastal waters.

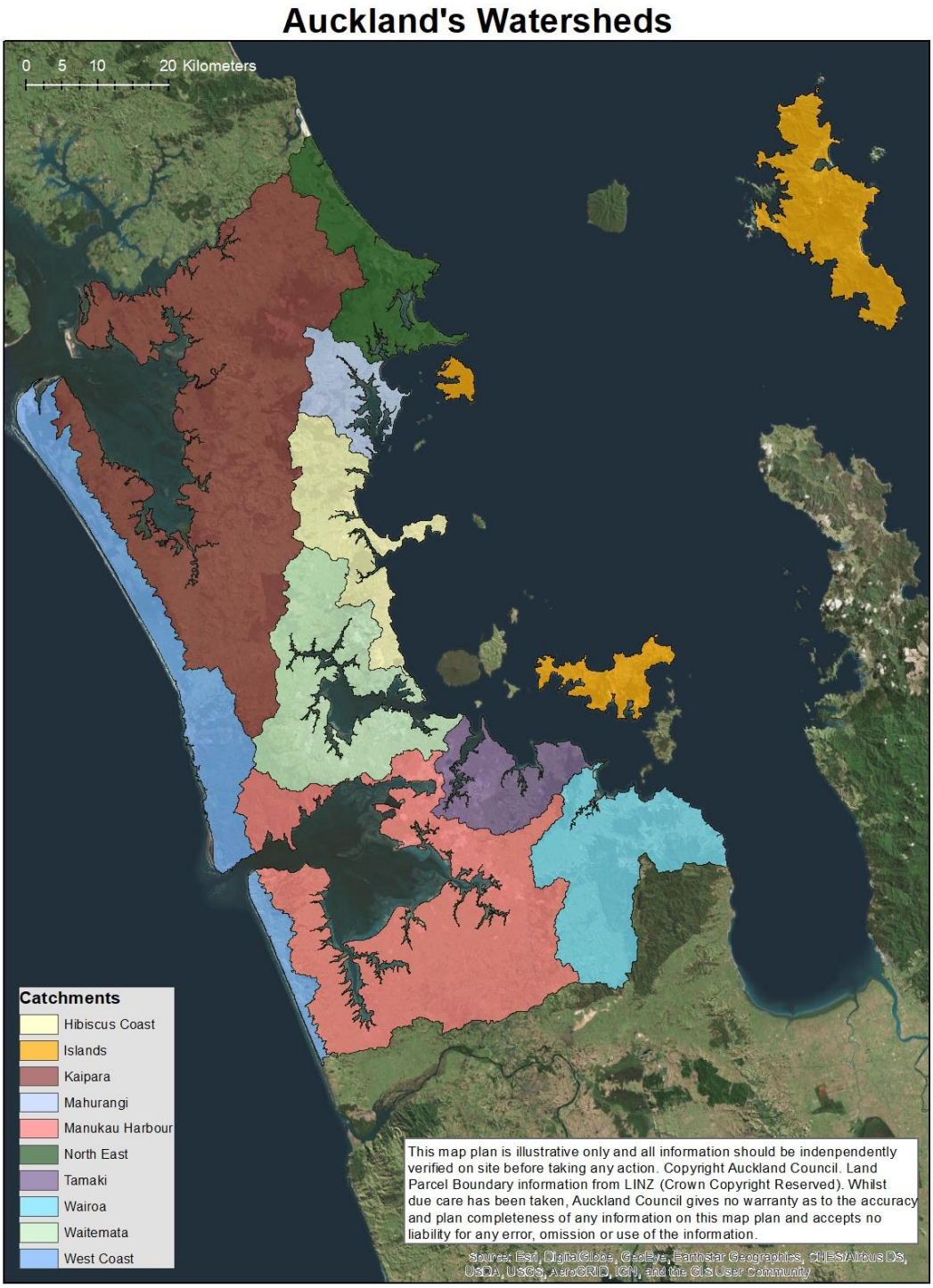

Figure 1 : Watersheds of the Auckland Region

Auckland Council's watershed plans are being developed in three stages (Auckland Council, 2017).

1. *Mapping the current state and key issues for each watershed.*
2. *Determining how to achieve the objectives and consulting the community.*
3. *Developing action plans to meet objectives, limits and targets set in collaboration with key stakeholders.*

Auckland Council are currently completing stage 1 above with an expected completion of all three stages by 2020 (Auckland Council, 2017)

2.2 WATERSHED PLANNING TOOL

Auckland Council has developed a watershed planning tool as part of Stage 1 above. The interactive map-based website will be used for communicating the current state and key issues for each of the ten watershed plans. The online tool disseminates the complex interactions between human activity and environmental change, identifies the value of freshwater and coastal environments to Aucklanders and presents the current state of each watershed environment. The tool was developed using Esri Story Maps and is hosted on the ArcGIS Online platform. The draft watershed plans are available at https://arcg.is/11Hi58.

3 STRUCTURE OF THIS PAPER

This paper discusses the use of geospatial techniques available for mapping watershed plans. The techniques referenced in this paper were implemented in the watershed planning tool maps developed by Auckland Council for sharing the results of Stage 1 of its watershed plans. Examples have been drawn from the watershed planning tool where appropriate.

The paper is divided into the following sections:

- Benefits of interactive mapping for watershed plans
- Interactive mapping techniques for watershed plans
- Map presentation for watershed plans

4 INTERACTIVE WATERSHED MAPPING

Watershed plans are complicated. They are derived from lots of datasets many of which are the result of complex analyses and modelling. Breaking these plans down into comprehensible sections proves a challenge. However, with modern mapping capabilities and geospatial data processing techniques, interactive mapping of watershed plans is an effective way to disseminate complex information to stakeholder groups and the wider public.

4.1 BENEFITS OF INTERACTIVE MAPS

Developing watershed plans is an iterative process and it can be inefficient to spend time and money mapping data when aspects of the plans are continuously changing. Mapping watershed plans with traditional static maps is a time-consuming process and requires high effort to update and reprint maps each time the underlying data is changed. Modern online mapping platforms allow data and maps to be updated *in-situ* without the need for recreating or reprinting. Processes can be established to ensure online maps automatically display the latest data available without the need for any manual intervention. However, authoring and managing complex interactive maps and spatial data brings its own challenges.

4.2 CHALLENGES OF INTERACTIVE MAPS

Authoring and managing online spatial content has its own challenges. Online maps are much easier to update than static maps as they don't require redesign or reprinting. However, an update process must be implemented to ensure that updated data, or new values yet to be mapped, are automatically added and displayed appropriately. This process is particularly important when dealing with a large volume of mapped content, as is often the case with watershed plans, as it minimises the amount of manual updating required. Map performance, or drawing/rendering speed is paramount to the user experience and care must be taken to ensure maps are fully functional. This is especially important when designing maps for both desktop and mobile applications. If the interactive maps will be accessed by the public, they must be hosted on infrastructure suitable for meeting high demand and this may come at a cost. Finally, maps must be readable and intuitive with clear messaging. Interactive maps allow for many approaches to displaying content and it is important not to over-saturate a map with information which may be confusing or misleading to the user.

5 BENEFITS OF INTERACTIVE MAPPING FOR WATERSHED PLANS

While there are numerous benefits of interactive maps over traditional static maps, the following are particularly useful in the context of sharing watershed plans.

5.1 ENGAGE WITH STAKEHOLDERS

Community involvement plays a key role in the successful design of any watershed plan. Stakeholder groups offer a valued insight into water management and should be engaged with early in the planning process to ensure their participation and support implementing changes (USEPA, 2008). Maps are a well-established medium for communicating watershed plans and are particularly useful for engaging with localised community groups. Interactive maps are especially engaging and make use of modern technology to break down the complicated aspects of plans. Platforms such as the watershed planning tool facilitate communication between stakeholders and planners and are an appropriate platform for feedback or for raising concerns.

5.2 EXPLORE RELATIONSHIPS

Interactive maps enable users to explore relationships and spatial trends within the data. This leads to a greater understanding of the interactions that are highlighted during the development of watershed plans. For example, the image below demonstrates how two interactive maps with linked displays can be used to highlight the impact of intensive land use practices on contaminant run-off.

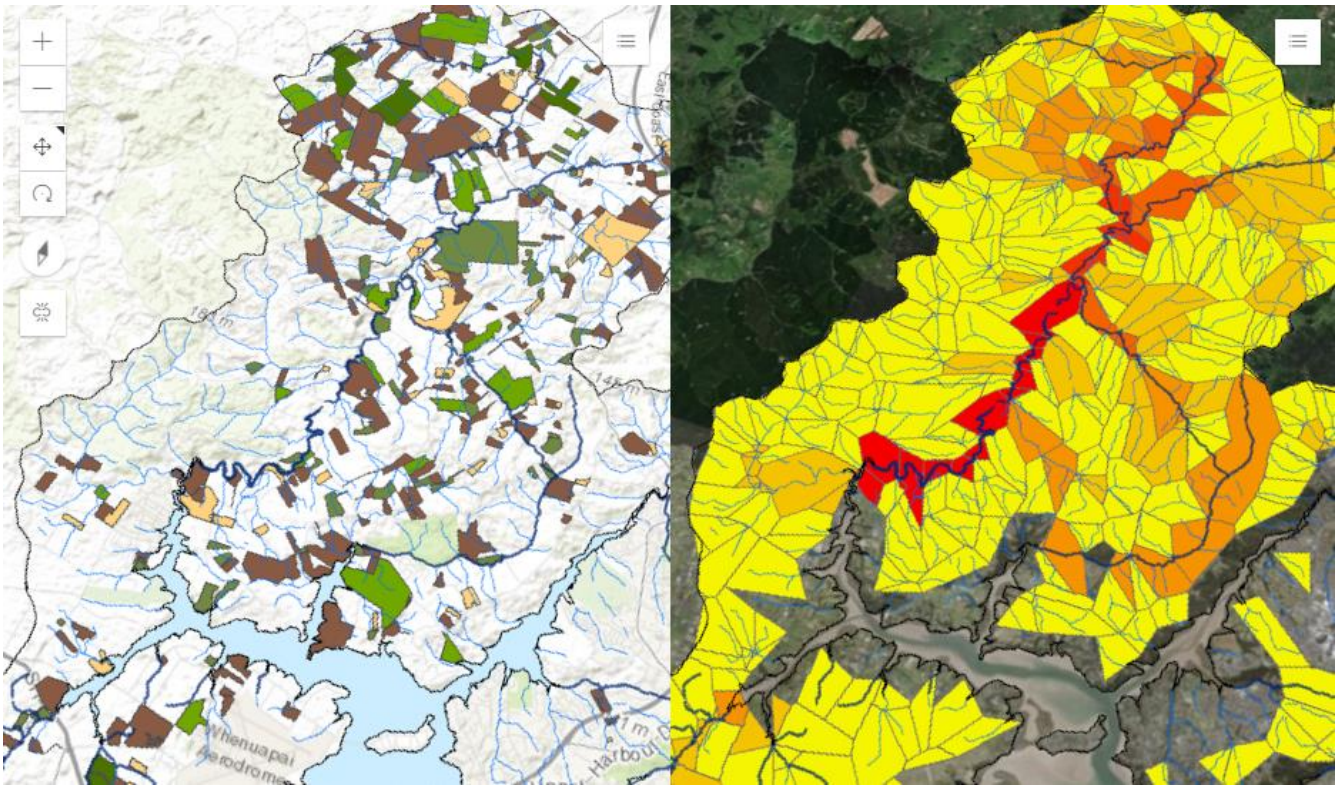

Figure 2: Linked interactive maps showing the relationship between intensive land use practices (left) and modelled contaminant run-off (right)

5.3 ISOLATE AND COMPARE

The ability to turn map layers on and off lets users isolate datasets and examine specific variables without the clutter of other map content. Similarly, users can see a single dataset in relation to specific contextual data. This lets users compare phenomena and is useful for stakeholder engagement interaction, where only some of the map content may be of interest at any one time. The ability to isolate and compare layers is particularly useful in stakeholder engagement and can be used as supporting material when discussing singular aspects of a watershed plan.

5.4 EXAMINE BEFORE AND AFTER SCENARIOS

Interactive maps are an effective way to visualize 'before and after' scenarios and can be used to assess the relative success of intervention projects. Visualising the estimated impact of intervention projects can help in the funding and decision-making process for future development. This is particularly important when discussing the impact intervention projects may have for specific stakeholder groups.

5.5 TIME-AWARE MAPPING

Developing watershed plans is an ongoing and iterative process, where data may be collected and reviewed for a period of months or years. Time-aware maps expose the temporal component of spatial data and are an effective way to view changes over time. The map below for example, shows the predominant litter category for each year (2009 - 2016) at various beaches throughout Auckland. Interactive time-aware maps allow users to examine how rubbish on Auckland's beaches is changing to reflect an increase in plastic (Figure 3).

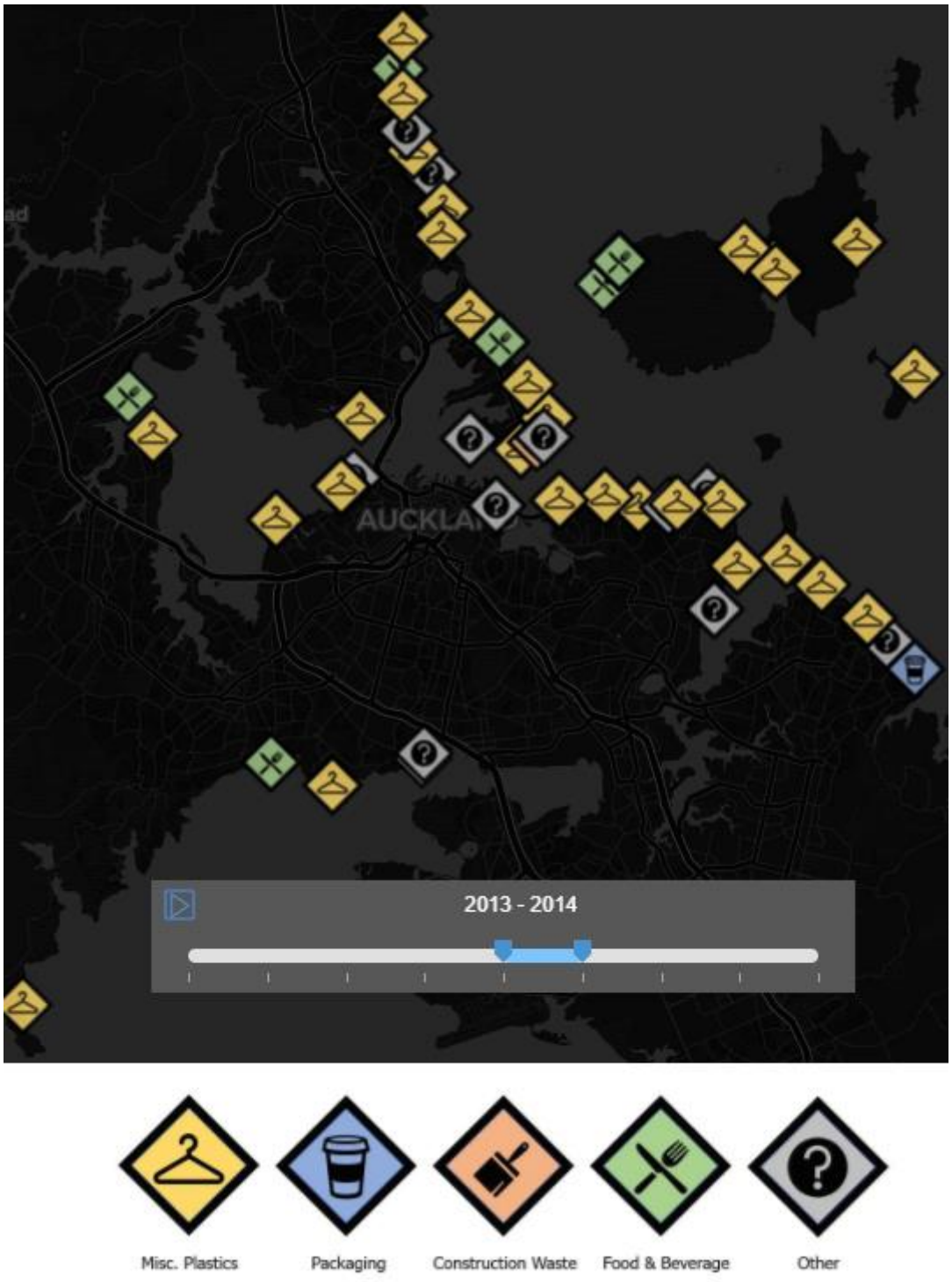

Figure 3 : Predominant litter category for each year (2009 – 2016) collected at various sites throughout the Auckland Region.

6 INTERACTIVE MAPPING TECHNIQUES

It is important that any map is simple, navigable, and intuitive with a clear message. Using a combination of interactive mapping techniques, authors can enrich maps with additional content, while maintaining map simplicity.

6.1 SCALE DEPENDENCIES

Scale dependent layers are an effective way to include multiple map layers on a single map without introducing clutter. While zoomed out, only the map content that is suitable at a regional level is displayed. As the map is zoomed in, layers are automatically turned on or off dependent on their suitability for display.

6.2 DYNAMIC LABELLING

Labelling features is an opportunity to highlight mapped data or to display further information beyond the mapped attribute. With interactive dynamic maps, labels are generated automatically and do not need to be manually configured to display the latest data. Custom labels can also be created using multiple pieces of information from the underlying data or even to display the result of dynamically created mathematical calculations. Labels can be set to turn off or display differently at different map scales, which helps to keep the map readable. Figure 4 below shows the impervious surfaces at a sub-catchment level for the Waitemata watershed. Labels are calculated dynamically as the percentage of impervious surfaces and are enabled automatically when zoomed in.

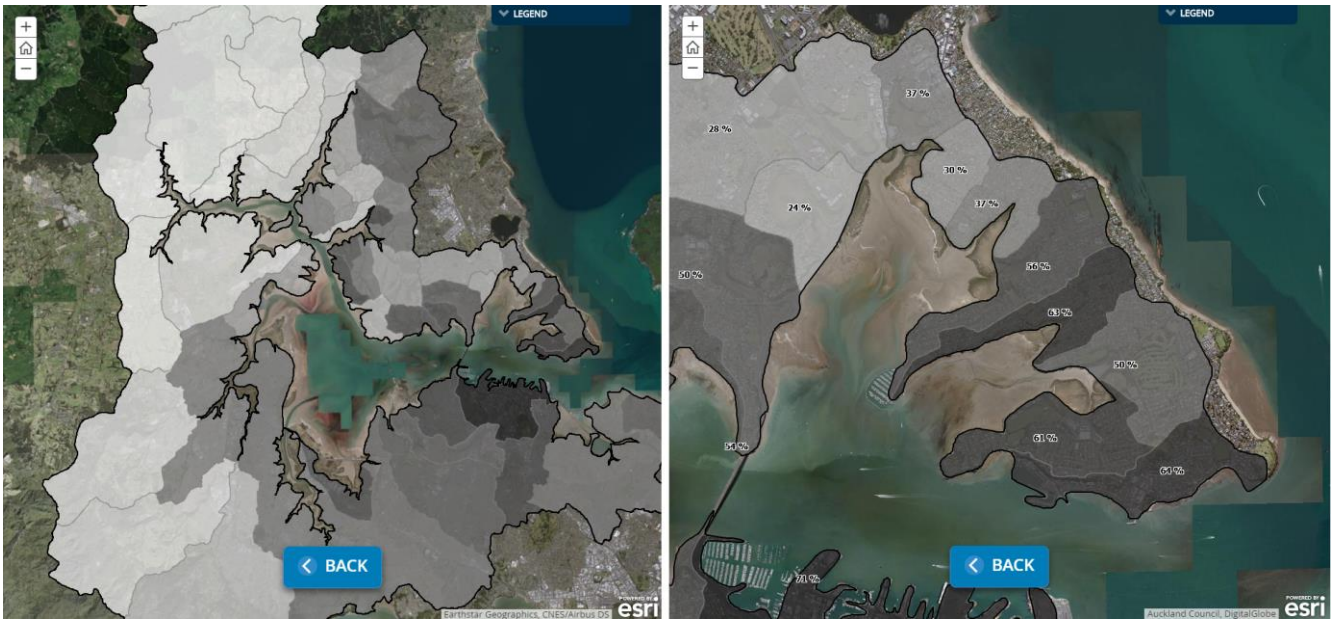

Figure 4: Map displaying impervious surfaces at sub-catchment level within the Waitemata watershed. Labels are dynamically calculated and make advantage of scale dependecies. As the map user zooms in labels are automatically enabled.

6.3 SYMBOLOGY

Interactive mapping provides the ability to automatically update symbology or map icons as underlying data changes. This is particularly useful for mapping data which is frequently updated. For example, the image below shows water quality throughout the Waitemata as indicated by the presence of *E.Coli* (Figure 5). Water sampling is conducted regularly, and the map is configured to display the latest readings as they are updated. No map publishing or manual updates are required.

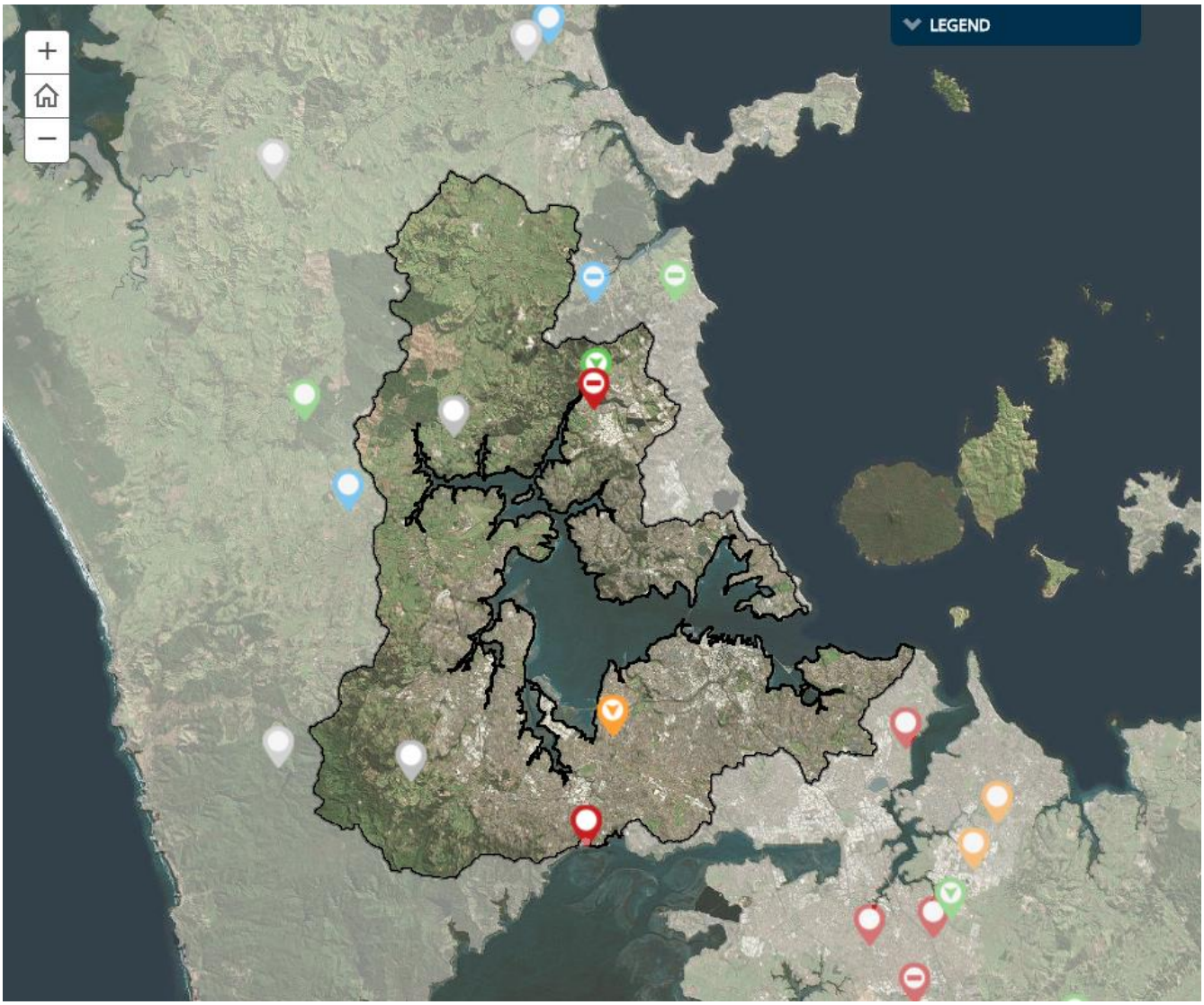

Figure 5: Water quality as indicated by E.Coli levels in the Waitemata watershed. Colour represents overall grade, while arrows represent the10-year trend. Icons are automatically updated when underlying data changes.

6.4 INFO-WINDOWS

Info-windows (also termed popup windows) return further information to the map user upon clicking or hovering over a feature. Most commonly this is simply additional information drawn from the feature, but can also include multimedia content, such as interactive charts, images or hyperlinks. This type of interactive mapping lets users drill down into datasets and further explore attributes. It also allows map users to understand the data beyond the way the features are visualized on the map. The watershed planning tool made extensive use of custom info-windows to display charts, hyperlinks and tables of attribute values. For example, Figure 6 shows earthwork consents granted between 2011 and 2015 throughout the Waitemata watershed. Charts graphically show the number of consents by year, and in this case, highlight the increase in construction projects within the CBD in recent years.

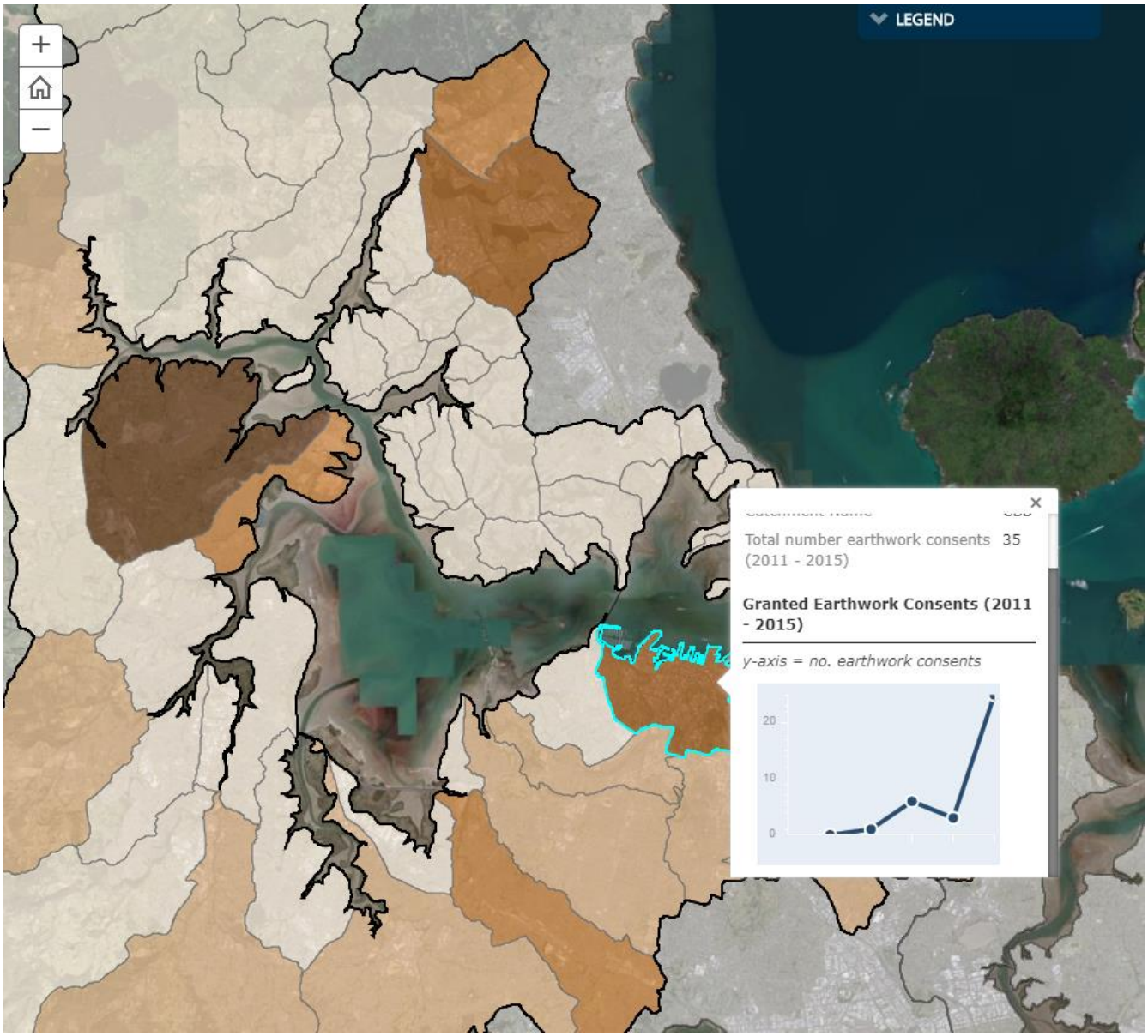

Figure 6: Number of earth work consents granted between 2011 and 2015 by subcatchment within the Waitemata Watershed.

7 MAP PRESENTATION

Creating interactive watershed maps for public consumption offers many challenges. Many datasets used in plans are derived from complex modelling and analysis and it may be necessary to simplify data so that it is easily interpretable. Furthermore, detailed plans often contain confidential or fine grain datasets that are not suitable for public release. There are also a host of considerations centered around the performance and user experience of interactive maps. Large or detailed datasets may need to be processed to ensure maps draw quickly. Finally, there are aesthetic aspects of mapping to consider. Different data processing techniques can be used to present data in engaging pleasing ways without comprising the spatial accuracy.

7.1 AGGREGATING DATA

A common way to simplify datasets is to summarise them by combining adjacent identical (or similar) features. Aggregation summarises the data in an easily interpretable way, anonymises the data and improves map rendering performance by reducing the

number of drawn features (see Figure 7). Applying the same aggregation process to multiple datasets allows for a quick and easy comparison between map layers.

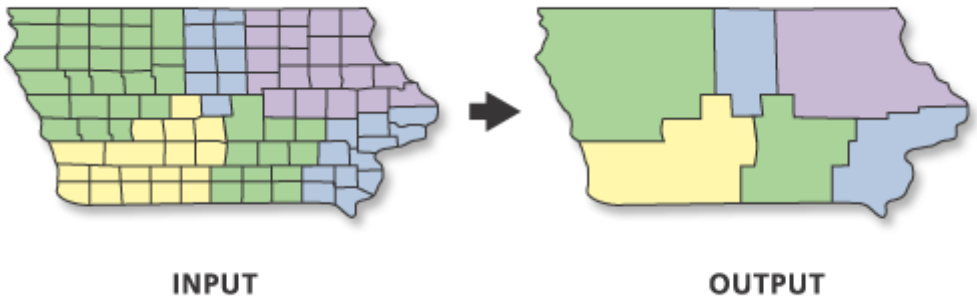

Figure 7: Common data aggregation technique available with GIS software (Esri, 2017)

Points can also be aggregated up to a larger geographical unit (i.e. number of point features per river catchment) or summarised as a clustered point layer where nearby points progressively display as a single aggregated feature when zooming out (See Figure 8).

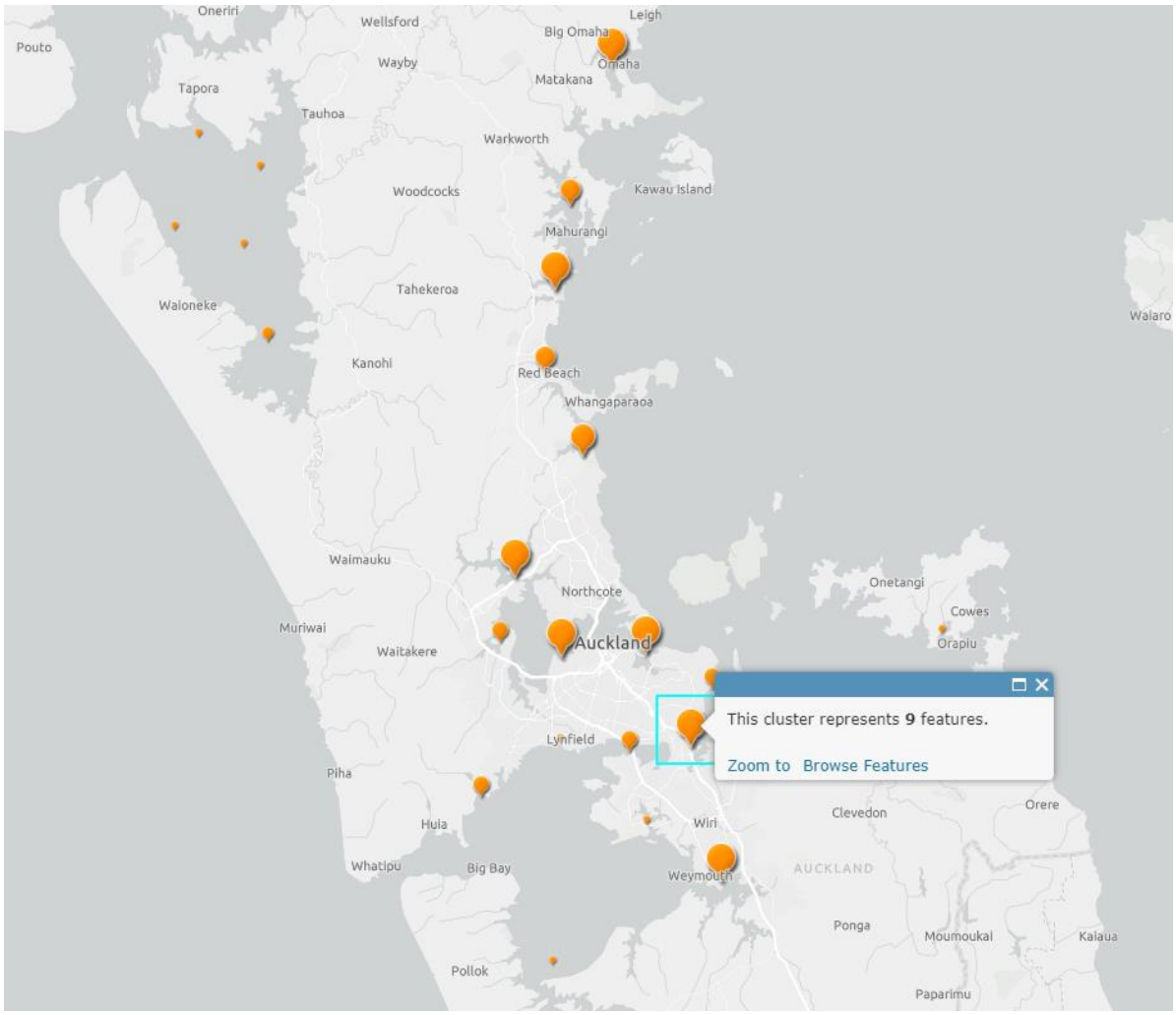

Figure 8: Coastal sediment monitoring sites in the Auckland Region. Nearby sites are aggregated to provide a generalised overview of regional coverage. As the map is zoomed in clusters are reduced to display real-world locations

7.2 MAPPING MULTIPLE ATTRIBUTES

It is possible to symbolise data by more than one attribute. This technique is useful for situations where there is a combination of attributes responsible for an outcome. For example, water quality may be assessed by measuring several water quality attributes such as *E. coli,* Nitrate or Ammonia. Another example (Figure 9 below) maps the results of rubbish collection programmes between 2009 and 2016. Litter type, collection year and litter volume are all represented by a single point using colour, transparency and scaling.

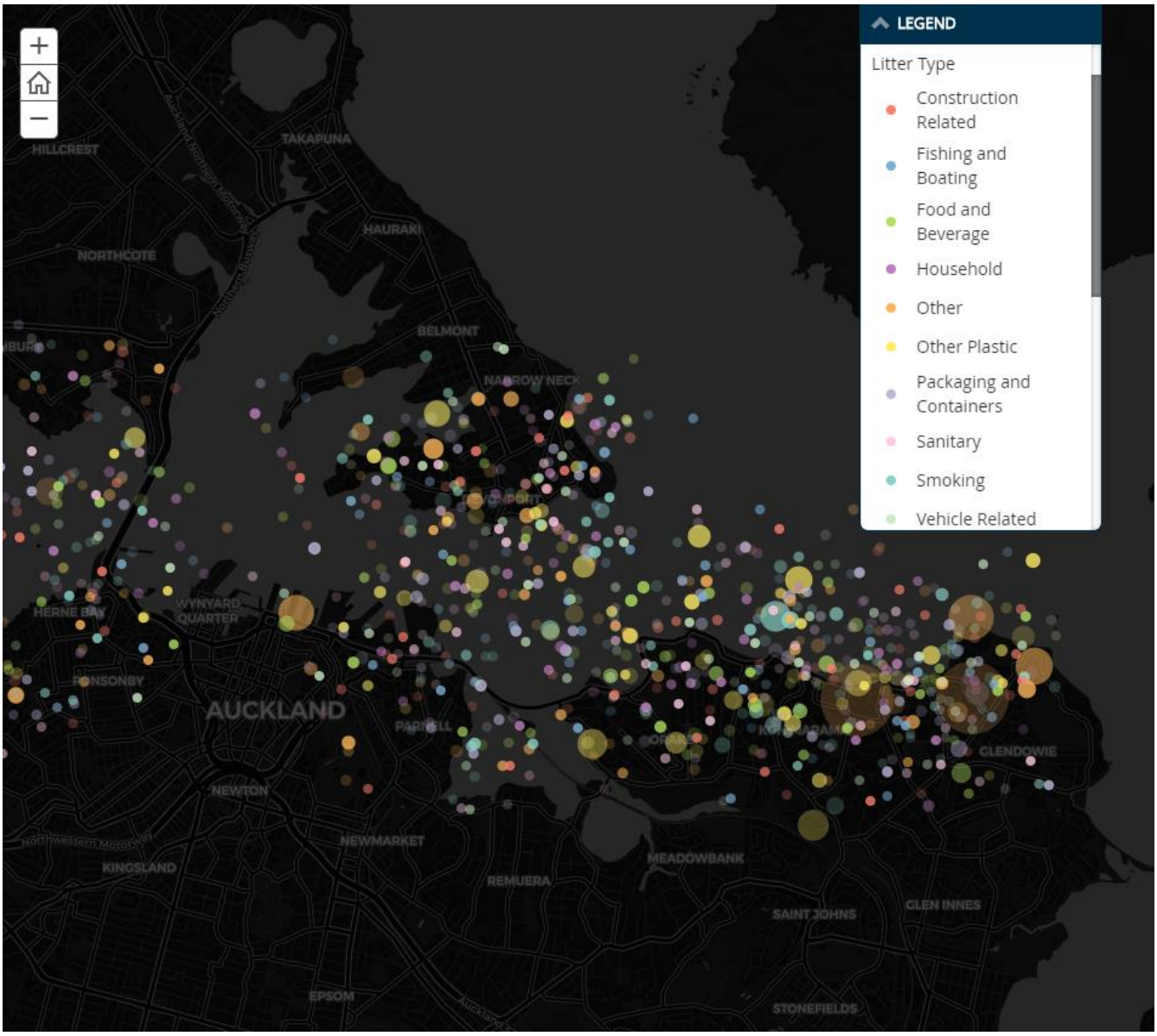

Figure 9 : Litter collection in the Waitemata from 2009 – 2016. Litter type represents colour, dot size represents the amount of litter collected in that year, dot transparency represents years since the collection date.

7.3 SIMPLIFYING FEATURES

Simplifying, or generalising, lines and polygons is the process of removing vertices from a feature while maintaining the overall shape (Figure 10). This technique is often a requirement to ensure map performance is preserved. For example, displaying an entire river network across a large watershed at its most detailed level would lead to map display issues each time the user moves the map. A simplified river network is much quicker to display, ensuring that poor map performance does not inhibit user experience.

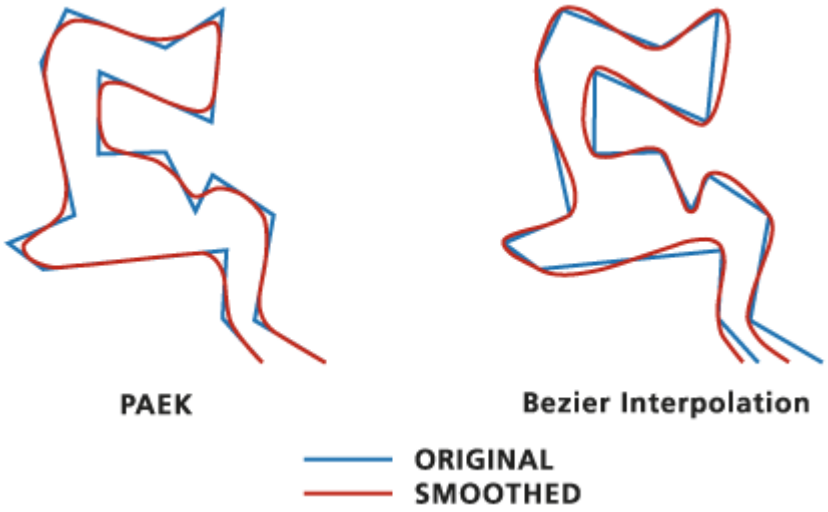

Figure 10: An example of two line smoothing techniques (Environmental Systems Research Institute (ESRI) 2017)

If it is critical to retain the original level of spatial detail, it is possible to use a combination of scale dependencies and duplicated map layers where the map contains both the original detailed data and a simplified copy. As the map user zooms in the simplified data is replaced with the detailed data where the smaller display extent means less features need to be rendered and map draw speeds are preserved.

7.4 STORY MAPS

Interactive Story Maps are a unique way to combine interactive maps, narrative text, and other multimedia content to create compelling stories (Esri 2018). Due to their complex nature and breadth of information available, Story Maps are a particularly effective method for sharing watershed plan maps. Content can be gradually introduced to the readers as a narrative and is readily understood. The watershed planning tool developed by Auckland Council was designed with Esri Story Maps and is publicly available on ArcGIS Online. Each watershed has been divided into four themes; 'Current State Overview', 'Ecosystem Health', 'Recreation', and 'Current Interventions'. Structuring the watershed plan maps in such a way allows users to access any of the four sections as a starting point and be introduced to the content as they move through the story. Additional content can easily be added to the existing Story Maps, without the need to take them off the web. In the next iteration of the watershed planning tool, the additional themes of 'Resource Use' and 'Cultural Health' will be added. This method of presenting watershed plans is appropriate for stakeholder engagement and can be used as supporting media for engagement meetings or used as a resource for individuals to look over unaided. The overarching purpose of this design is to allow non-technical individuals and groups to better understand the results of watershed plans, and therefore be able to make valued contributions to further developments. Figures Figure 11-Figure 13 below are taken from the Auckland Council watershed planning tool.

To view the full draft version of the watershed planning tool for all 10 watersheds, see the link below.

https://arcg.is/11Hi58.

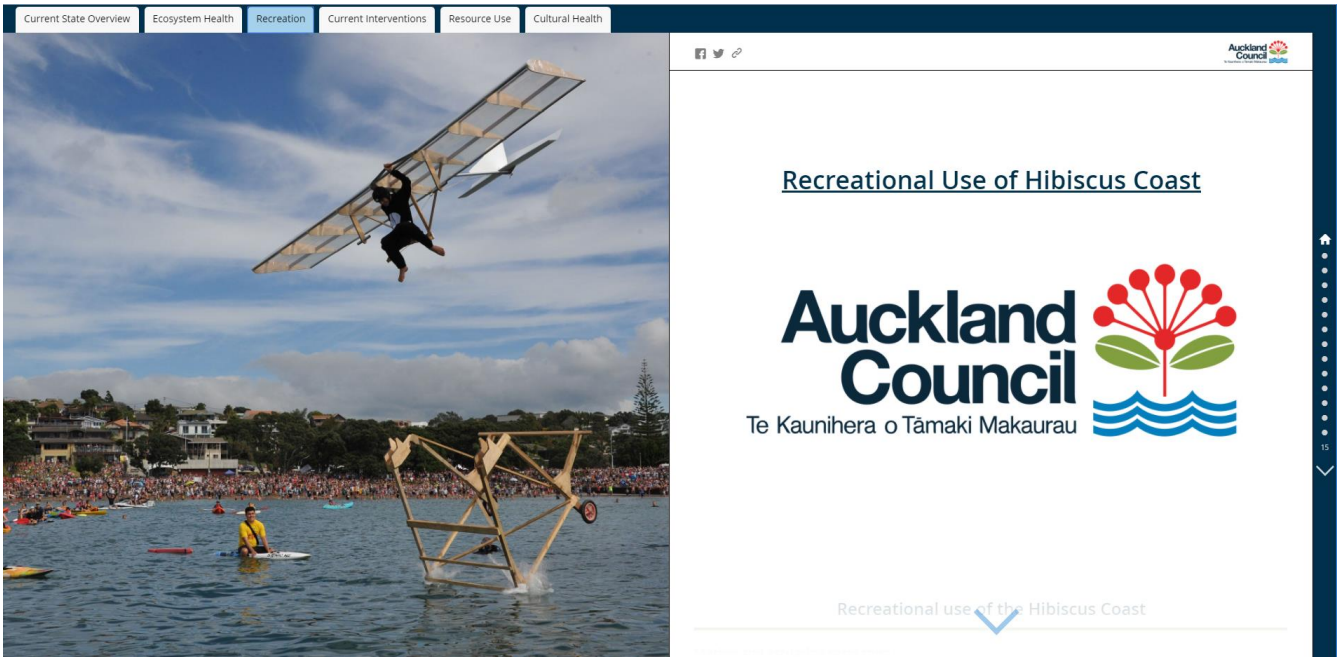

Figure 11: Imagery is engaging content used to support the narrative and storytelling aspect of watershed plans.

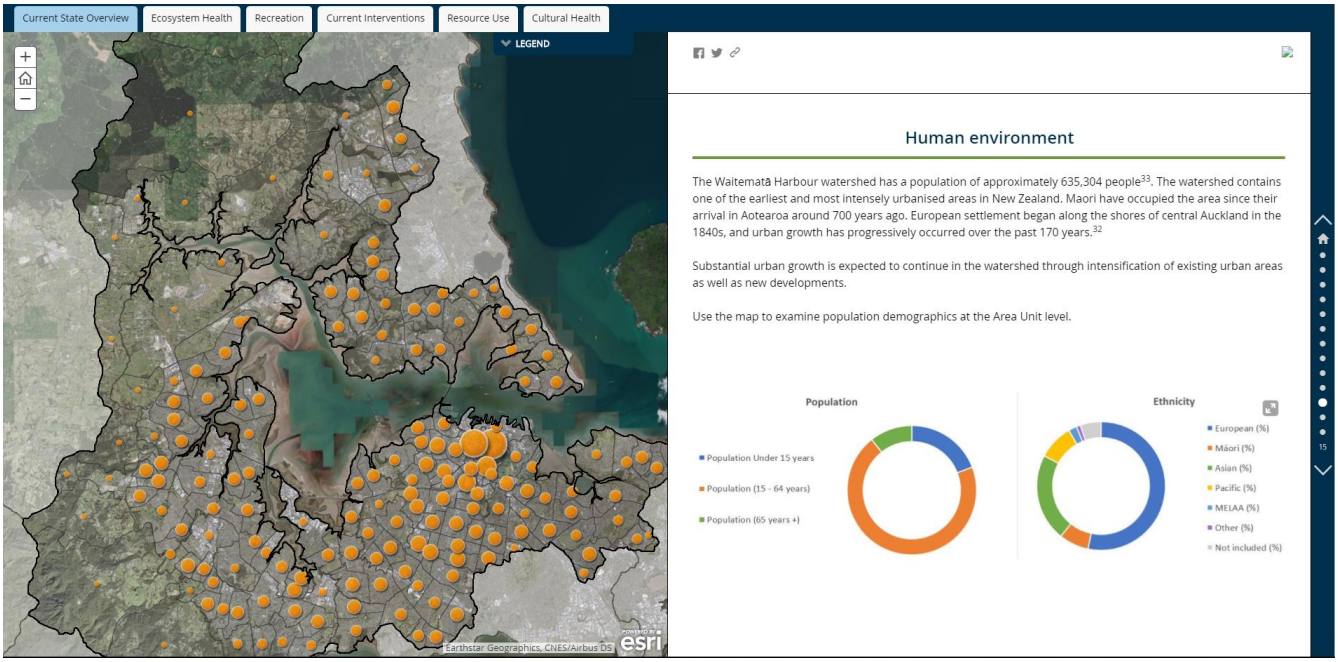

Figure 12: Population Density in the Waitemata watershed - Interactive maps can be embedded within the Story Map and are complemented by narrative text and other multimedia content.

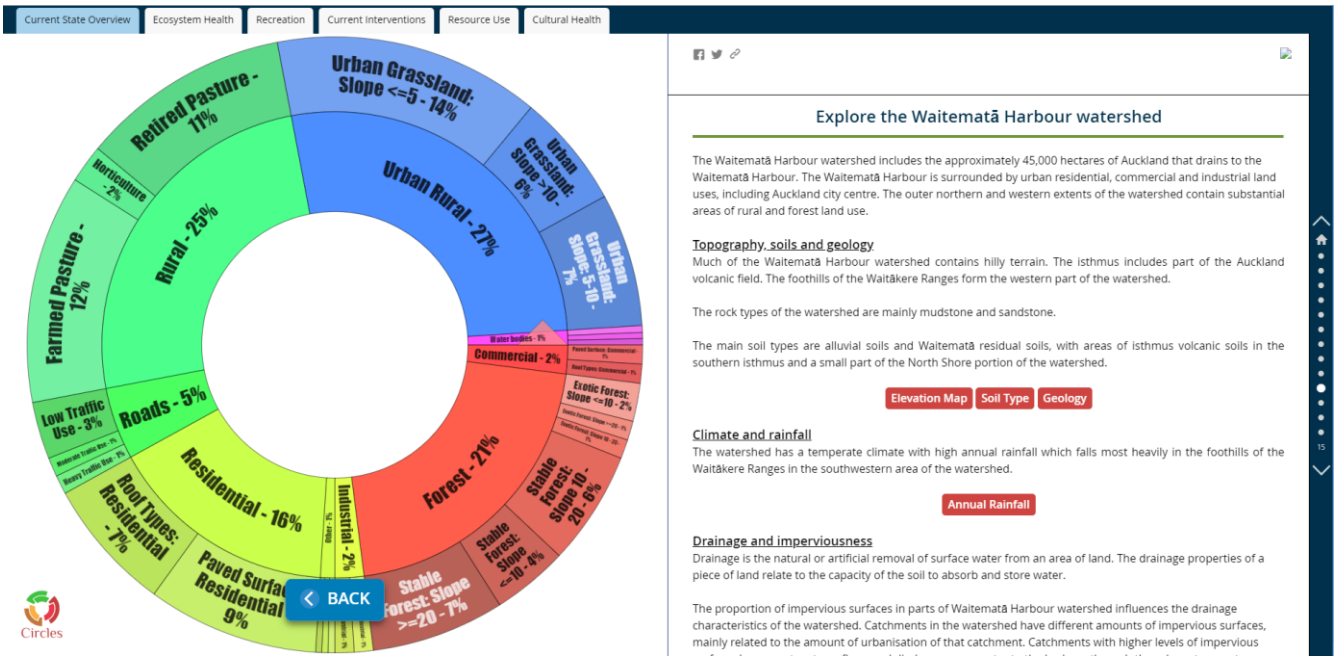

Figure 13: Landuse types in the Waitemata watershed - Multimedia content such as interactive charts can be embedded within Story Maps as an alternative to interactive maps.

8 CONCLUSIONS

Watershed plan maps have many benefits. They are an effective tool for disseminating the complex data, interactions, and outcomes identified in plans with non-technical audiences. Traditionally, static paper maps have been used as the map medium, however data currency and the duplicated effort of reprinting updates are significant drawbacks. Modern and interactive maps overcome many of the limitations of static paper maps and offer additional functionality to make watershed plans more consumable for stakeholders and the public.

An online, live, and publicly available catalogue of interactive maps is an effective way to present watershed plans. Information is easily accessible via the web and can be used by individuals, stakeholder groups or as supporting material in engagement meetings. The interactive functionality provides the map user with the opportunity to explore and interrogate the map content, revealing trends, patterns and linkages between datasets. Updating content is considerably easier than updating static maps and there is no need for recreating or reprinting maps.

The story mapping approach is a particularly effective way to disseminate the complex themes of watershed plans. This multimedia approach takes advantage of interactive mapping technologies, interactive charts, imagery, and narrative text to engage with audiences whilst gradually introducing aspects of the watershed plan.

The benefits of detailed watershed plan maps are that stakeholders and the wider public are better informed. Stakeholders can make valuable contributions to the planning process and these can be reflected in decision making to further improve watershed plans.

REFERENCES

Auckland Council (2017), 'Wai Ora-Healthy Waterways', viewed 27 February 2018, https://www.aucklandcouncil.govt.nz/environment/looking-after-our-waterways/Pages/wai-ora-healthy-waterways.aspx

Ballantine, D.J. and Davies-Colley, R.J. (2013) 'Water quality trends in New Zealand rivers: 1989–2009.' Environmental Monitoring and Assessment, 186, 3, 1939–1950.

Environmental Systems Research Institute (ESRI) (2018), 'Story Maps', viewed 27 February 2018, <https://storymaps.arcgis.com/en>

Environmental Systems Research Institute (ESRI) (2017), 'ArcGIS Pro Desktop Help 2.1 (Cartography Tool Box)', viewed 27 February 2018, http://pro.arcgis.com/en/pro-app/tool-reference/cartography/smooth-line.htm

New Zealand Government (2017). 'National Policy Statement for Freshwater Management 2014' (amended 2017)

Rabinowitz, Phil (2013) 'Geographic Information Systems: Tools for Community Mapping.' Community Tool Box, Work Group for Community Health Development, Retrieved from: http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/geographic-information-systems/main

United States Environmental Protection Agency (2008). 'Handbook for Developing Watershed Plans to Restore and Protect Our Waters'.