NATIONAL CENTRE FOR RESILIENCE

The River Clyde as a Case Study into Building Community Resilience to Flooding

Research funded by The National Centre for Resilience

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List of terms

Deep Map: Deep Mapping is a research methodology that involves creating detailed and multi-layered representations of a place or environment. The aim of deep mapping is to capture the diverse and complex relationships between people, place, and history, and to create a more nuanced and holistic understanding of a particular environment. Deep mapping typically involves the use of multiple sources of data, including archival materials, personal narratives, and experiential knowledge. It can incorporate a range of different media, such as maps, photographs, audio recordings, and written texts, and often involves the participation of local communities and stakeholders in the research process.

Fluvial: (in terms of flooding) related to water level in a river, lake or stream that rises and overflows onto the neighbouring land.

GIS mapping: A geographic information system (GIS) is a system that creates, manages, analyses, and maps all types of data. GIS technology allows users to visualize, analyse, and interpret data from different sources such as satellite imagery, maps, and survey data. By overlaying different layers of information, GIS can help identify patterns, relationships, and trends in the data, which can be used for decision-making in a wide range of fields.

Nature-based solutions: Nature-based solutions (NBS) are actions that are inspired by, supported by, or mimicking nature to address environmental challenges and provide social, economic, and ecological benefits. NBS rely on the natural processes of ecosystems to provide a range of services, such as water purification, climate regulation, and biodiversity conservation, while also providing multiple co-benefits to human societies, such as health and wellbeing benefits, social and cultural benefits, and economic benefits.

Pluvial: (in terms of flooding) related to rainfall.

Spatial mapping: a spatial system that creates, manages, analyses, and maps all types of data.

Walking methodologies: Walking methodology is an approach to research that involves using walking as a method of data collection and analysis. It involves researchers walking through a particular environment or place, often with a specific research question or objective in mind. While walking, the researcher may observe and document various aspects of the environment, such as the built environment, social interactions, and natural surroundings. Walking methodology can be used in a range of research contexts, including urban planning, environmental studies, and anthropology. Walking methodology can provide unique insights into

the environment being studied, as it allows the researcher to experience the place first-hand and to document observations that might not be captured through other research methods. It can also be a more participatory approach to research, as it allows participants to contribute their own observations and perspectives while walking together with the researcher.

Water walks: applying walking methodologies to observe and study the relationship between people to water, and its various social, cultural, technological, economic, and spatial dimensions, in a place. A water walk methodology is a research approach that involves walking alongside a body of water, such as a river, lake, or ocean, in order to collect data and gain insights into the environment and its relationship to human and ecological systems. Water walk methodology can be used in a range of research contexts, including environmental studies, sustainability, and cultural studies.

Executive Summary

This report concludes the end of a seven-month period in which the authors (referred to as 'we' throughout) have conceptualised, researched, formed networks, and developed practical tools in a process that seeks to understand, represent, and communicate flooding related risks along the River Clyde in Glasgow to build awareness, knowledge, attention of these issues to various groups and help facilitate community resilience.

This project has involved the creation of a series of outputs to evaluate our various research themes, which include:

- Research and narrate Glasgow's flooding past and impacts on places and their communities.
- Gather representations of these events (visual, textual, etc) to better understand the communities that are most vulnerable.
- Compare and layer these onto physical/spatial digital mapping.
- Communicate and represent these to build awareness, knowledge, attention, and urgency.

The outputs are separated into three categories:

Mapping

- **Google Maps** to collate and map a rich account of the layers of multiple social, cultural, economic, infrastructural, and spatial assets in case study locations that communities use, value, and rely upon.
- **Google Earth Pro** to further represent this content (these are public facing but with layers of complexity that can be switched on or off).
- **QGIS** - Research/practitioner-based tool.

Multimedia repositories

- **Flickr** - to host images collated, to assign licensing, and allow for public access and social media sharing.
- **YouTube** - to host videos to link to Google Maps and allow for public access and social media sharing.
- **Website** - a host and space to bring together all the content, and as a single, updatable 'living' repository for sharing and engagement with various stakeholders. The website (as linked to above) has emerged as the central repository for the project - and contains details

on project context and networks, links to the various outputs, collates knowledge and links to other relevant external resources.

Witten outputs

- **Report** - research based output explicitly for use by NCR.
- **Blog** - public/practitioner facing output to communicate some of the outputs.
- **User manual** - guide to engage with, and potentially contribute, to the various tools and platforms.

A two-phase project

While the work undertaken so far (referred to as **Phase I** in this project) stands on its own, it more widely forms the foundations and initial structure for much more research to expand on the process, content, and outputs it has generated. The scope, scale and possibilities of the research extends beyond what has been able to be achieved in the 7-month timescale; from the outset the intention has been to use this initial period to work towards the formation of an external funding bid that allows for the development of a much more extensive piece of work to follow on from this initial piece. This report signposts to aspects of the research which would fit into this future work, referred to a **Phase II** of the project. It is important to recognise the work in this context - this is, by no means, a complete and conclusive representation of the research, but rather an expression of the initial development of a concept and process that can be developed further. The following report describes some of that process as it has emerged.

Rationale and status at end of Phase I - *August 2022 to March 2023*

We have continually undertaken fieldwork applying the use of "walking methodologies", whereby we have walked (and cycled) throughout the case study regions on various occasions to learn about, and document, the case study locations - gathering a range of multimedia content. We have taken these audio-visual outputs, integrated them with desk based textual research and reflection, as well as local knowledge of place, and used these as content for our case study maps, social media channels, and to create periodic blogs which can be found on the website[1].

[1] Based on initial user analytics, these media repositories have been successful - even without complex dedicated metadata- have had 1.5 thousand views on Flickr, and 800 views across the 22 videos on the YouTube channel by the end of March 2022.

A number of the outputs in the first phase of the work have been created with the explicit goal of being public facing, with the capability of ensuring long-term digital sustainability - adhering to the digital content lifecycle model. All these outputs have clearly defined copyright and licensing for the digital content created for ease of reuse for stakeholder groups.

We have been in communication with the GALLANT project communications strategist for the creation of multimedia outputs and ensure they meet the brand guidelines. We have also set up a strategy for migration over to the wider GALLANT website, servers, and repositories when these go live. This will ensure continued maintenance and availability to stakeholder groups for use and reuse.

Recommendations

- There is a need to develop communications of risk of flooding risk from the Clyde that recognises the significant impacts, but without creating fear or panic.
- Flood risk understanding and communication to the public as part of this process should extend beyond a focus on residential properties, and open-up the impact on communities and place more widely.
- Greater focus needs to be given to communicating to, and learning from, communities around flooding risks, as well as for approaches to build resilience.
- Modelling and spatial mapping (such as the SEPA flooding model referred to in this report) need to be contextualised in the context of the everyday lives of communities- from ways people live, work, move, access key resources, and undertake recreation.
- Develop and apply different interdisciplinary research methods and approaches, such as social-cultural mapping, to extend the content and communicative potential of flood risk information.
- Develop the long-term digital sustainability of research and content that is accessible and engaging to relevant communities.

1. Introduction & aims

1.1 Context and research approach

As the climate emergency intensifies, one of the major challenges facing communities in Scotland (and around the world) is flooding in river, coastal, and estuarine environments. This research project works alongside the NERC-funded GALLANT strategic programme that uses the latest river-estuary flood model (2020 TUFLOW) to test the feasibility of climate resilient, flood alleviating Nature-based Solutions along the River Clyde.

A criticism of conventional approaches to policy and social-economic discourse, understanding, management and decision making is that they can be limited in their capacity to consider wider values and relationships to social-ecological issues and their interrelationships - including flooding/water issues. To deal with this there is a need to 'open' up and employ alternative methodological approaches and ways to represent knowledge so that these wider issues can be understood and communicated.

Key point:
This necessitates a process of engaging with and learning from communities who are currently, or will be, affected by water and flooding issues- including the potential impacts of the flooding, as well from efforts to mitigate the impacts. The approaches covered in this work seek to gently provoke some of these conventions, through proposing alternative research approaches, and incorporating methods and practices to engage with, and represent, ways water and flooding affect place and societies.

In this research we seek to utilise a '**multimethodology**' approach to collate and represent various forms of qualitative information related to community risk and resilience to flooding. This includes social-spatial mapping of place using primary data collecting techniques (e.g., photography, videos, fieldnotes, etc.), as well as desk-based archival research to collate information related to community risk and resilience to flooding and open understandings of community relationships to these places. It focuses on a case study in the east end of Glasgow,

that has been selected in consultation with various project partners, including Sniffer and Climate Ready Clyde; an initial survey of archival research from Glasgow-based archives; and consideration of the SEPA Flood Hazard and Flood Risk Information mapping as an area at specific risk.[2]

As an output of this pilot research, we represent the collated data in a participatory mapping format (influenced by concepts of 'deep mapping').[3] This form of mapping seeks to complement other spatial and physical mapping techniques to represent flooding risk in the study area by providing alternative 'layers' of knowledge that represent social-focused relations to areas vulnerable to flooding. It seeks to highlight the multiple dimensions of sustainability risk and impact through representing areas and entities of social, cultural, infrastructural, ecological, and economic value and to recognise the importance that being able to utilise and access these to local communities.

As a primary output it seeks to represent this information in variety of online and publicly accessible platforms and social media channels (such as Google Maps and YouTube). By doing so we seek to widen knowledge, understanding, accessibility and interest in the multidimensional impacts and risks of flooding that extend across a range of sustainability related issues, as well as to practically integrate government/policy ambitions and commitments to community-focused stakeholder collaboration and consultation.

1.2 What is the GALLANT project?

Glasgow As a Living Lab Accelerating Novel Transformation (GALLANT) is a NERC-funded (£10.2M) partnership between University of Glasgow and Glasgow City Council and will use Glasgow as a living lab to trial new sustainable solutions throughout the city. GALLANT takes a whole-systems approach. While addressing the city's key environmental challenges, it will consider the co-benefits and trade-offs for public health, wellbeing, and economy. GALLANT aims to deliver the social priorities of the United Nations Sustainable Development Goals (UN SDGs) while remaining within the planetary boundaries of a 1.5°C world - using doughnut economics as a framework (Raworth, 2017).

[2] Scottish Environmental Protection Agency. 2022. *Flood Hazard and Flood Risk Information*. [Online]. [Accessed August 2022]. Available from: https://map.sepa.org.uk/floodmaps
[3] See, for example: http://www.deepmapscork.ie/deep-map-west-cork/deep-map-west-cork/

The programme brings together over 70 multidisciplinary researchers with 29 public and private sector partners across the city region. Together it aims not only to bring nature back into the city system, but make meaningful, lasting change that embeds sustainability across major policy decisions and empowers communities as stewards of their local places. GALLANT will work with local partners and communities to transform the city into a thriving place for people and nature and seek to help Glasgow achieve its goal to be carbon neutral by 2030 and accelerate its path to climate resilience.[4]

GALLANT in organised in five 'Work Packages' (WPs) and three cross cutting 'Workstreams'. These are as follows:

- The five work packages address the issues of flood risk, biodiversity loss, regenerating derelict, and polluted land, embedding active travel, and sustainable energy.
- The three cross-cutting workstreams consider systems science, community collaborations, and data and analytics.

While these are organised and defined separately there are clear intersections and interactions between the various work packages and workstreams. Flooding from the River Clyde, the focus of this project, directly, and indirectly connects across a number of these work packages and workstreams.

1.2.1 Placing our work in the context of the GALLANT project

From the outset this research has found itself situated between several work packages and workstreams - most notably WP1 ('Climate Adaptation') and WS2 ('Community Collaboration'). The focus of Phase I has been to develop the digital infrastructure and collate indicative content to communicate the issues around flooding aligned with WP1, while Phase II seeks to engage more in terms of the community collaboration themes that are the focus of WS2.

Furthermore, our work has naturally engaged with several of the other WPs – such as active travel (whereby it has identified active travel infrastructure and routes that are vulnerable to flooding along the river), to biodiversity (by collating images and knowledge about, for example, trees and wildlife on the Clyde). This is indicative of the interdisciplinary value of the research, opens opportunities for further content development, and help ensure the relevance to the wider GALLANT project. (In particular, the development of the digital infrastructure for the technical

[4] Project page on the University of Glasgow website: https://www.gla.ac.uk/schools/education/research/fromlocaltoglobalresearch/researchprojects/gallant/

aspects of this research have been recognised by the wider GALLANT team as benefit to the overall project.)

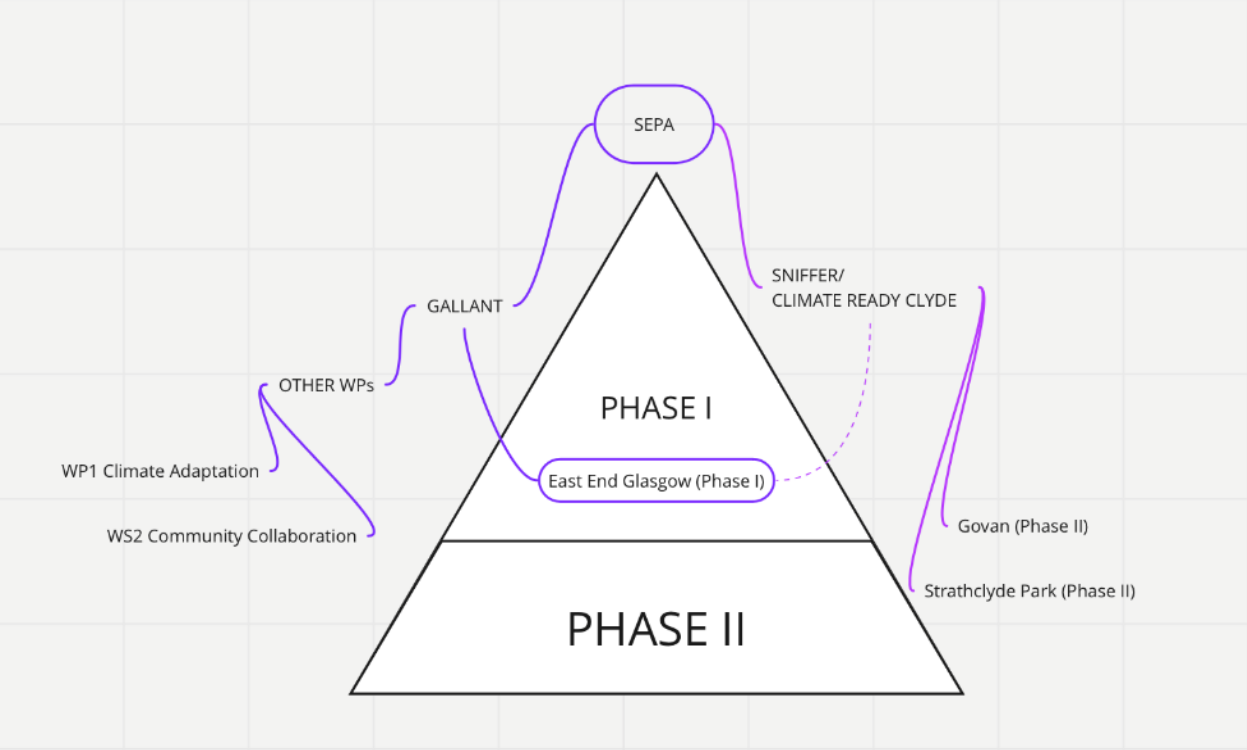

Figure 1: Graphic showing workflow of project and various streams of influence on the project in the planning stage.

1.3 Who is the Clyde?

The Clyde, at 170 kilometres, is Scotland's second longest river (after the Tay). It flows from the hills of the Southern Uplands in a general north westerly direction through the Clyde Valley to the Firth of the Clyde on the Scottish west coast, merging with the Irish Sea/Atlantic Ocean. With several historic settlements, including Scotland's largest city Glasgow, situated along its banks, it is often regarded as the Scotland's most famous, and important, river. It has maintained a significant impact on the social, cultural, ecological, and economic development of these settlements, as well as being influential nationally and internationally though the activities that have taken place on its waters over the centuries. From trade and shipbuilding, through to Glasgow's role in the industrial revolutions and British colonialism, the Clyde has had a geo-political reach far beyond it banks.[5]

[5] See a past exploration to the source of the Clyde by bicycle by James Bonner, one of this report's authors https://www.creativecarbonscotland.com/guest-blog-solstice-cycle-reflections-seeking-the-source-of-the-clyde/

Figure 2: Banner on Saltmarket near depicting images of the Clyde.

Figure 3: Map of the River and Frith of Clyde. 'Reproduced with the permission of the National Library of Scotland'. Site here.

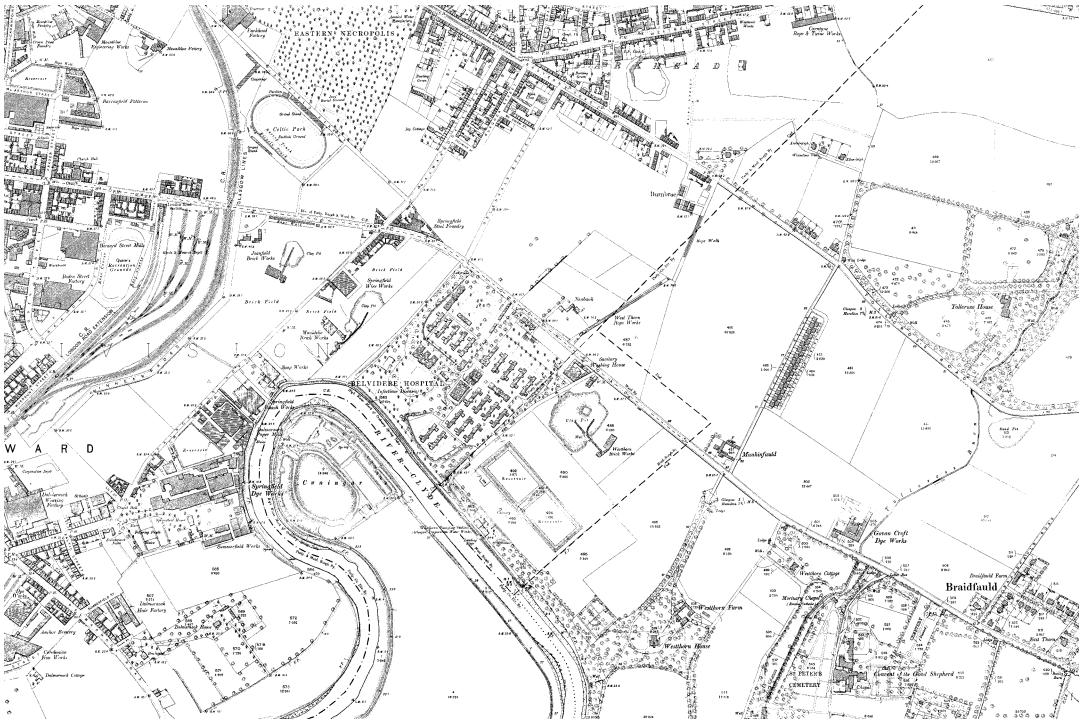

Figure 4: Example of data taken from DigiMap.

The Clyde forms a large estuary as it merges with the sea at Firth of Clyde, which determines the tidal nature of the river at its downstream section. Significantly the *Clyde tidal weir* bult in 1901 forms a barrier to mark the point at which the tidal influence of the river is controlled - and is a significant piece of infrastructure to maintain a fixed water level in upstream of its position. Its age and condition do make the weir vulnerable, as highlighted by recent incidents, and which have had significant physical impacts on some sections of the riverbank.[6]

1.3.1 Flooding on the Clyde: the past and recent present

There is a long history of flooding within the Clyde's catchment, including a well-documented history of major events in the 1700s and 1800s which impacted many properties and communities. These events, however, were prior to major catchment changes e.g., canalisation and widening of the river in the downstream extents of the catchment, as well as the construction of the Clyde Tidal Weir in 1901. The river has been subject to significant flood events in recent years, with notable events in 1994, 2002, 2015, as well as January 2020. Most major events are centred on the flooding of Glasgow City which is at the lower extent of the

[6] See more by Martha Wardrop: https://www.glasgowtimes.co.uk/news/19321606.clyde-tidal-weir-important-glasgow

River Clyde and can be significantly impacted by coastal storm surges below the Clyde tidal weir- reinforcing the significant role of this aging piece of infrastructure.

Figure 5: Clyde Tidal Weir from Albert Bridge looking east along the river Clyde with Glasgow's crest in foreground (photo by James Bonner)

Figure 6: Glasgow Tidal Weir from City of Glasgow College (2018) by AlasdairW. Link here.

Event Date	Source	Summary of Reports
1700s	Fluvial	Extensive flooding which led to severe damage in Glasgow City Centre at the Salt Market area.
1800's	Fluvial	Extensive flooding to Glasgow City Centre with numerous large- scale storm events throughout the Century.
11th Nov 1901	Fluvial	Large scale rainfall event which brought an end to a period of drought.
9th Feb 1903	Fluvial	Lower River Clyde caused destructive flooding in the Glasgow district with the river bursting its bank near Rutherglen. Dalmarnock Bridge was badly impacted including many factories and mills which were flooded out. Several thousand acres of land were left submerged.
17th August 1920	Fluvial	Serious flooding occurred along the whole of the Forth-Clyde belt, impacting Glasgow City Centre.
1941	Fluvial	Catastrophic flooding which led to the destruction of the River Clyde Weir and all riverside tenements on Adelphi Street in Glasgow.
8th August 1948	Pluvial	Pluvial flooding resulted in two deaths. There was also severe transportation disruption, with some homes and telephone lines impacted.
10th-12th December 1994	Fluvial	Major flooding occurred from the River Clyde and urban tributary water courses across Glasgow and surrounding areas. This was caused by a slow-moving weather system which delivered persistent rain over a 48-hour period. River Clyde recorded its highest peak flow and water levels for 150 years, with a total cost of damage of £100 million, with 700 homes and businesses affected in Strathclyde.
16th October 1998	Fluvial	Fluvial flooding in South Lanarkshire led to properties being evacuated in Kenmar Road, Kenmar Terrace, Auchinraith Avenue and areas of Hamilton with major roads affected and flooded and widespread loss of electricity.

27th October 1998	Fluvial	Major fluvial flooding due to the winter storm event caused extensive property damage and several properties were evacuated for 5 days.
Nov-Dec 2006	Fluvial	During a fluvial flood event emanating from the Rannie Burn residential properties impacted in Lennoxtown. The flood waters also heavily impacted areas of South Lanarkshire.
19th-20th November 2009	Fluvial	Significant rainfall led to numerous areas of significant flooding around the River Clyde catchment, which burst its banks in many areas.
21st October 2013	Fluvial	Extensive fluvial flooding from the River Clyde impacted properties and roads across the Clyde catchment, in particular north-west Glasgow.
8th-12th February 2020	Fluvial	A combination of high tides and prevailing poor weather conditions lead to localised flooding of low-lying areas around Ferry Road, with the Clyde Walkway flooded in Govan and King George V Bridge flooded within Glasgow City Centre.

Table 1: Historic flooding events affecting the Clyde and its catchment area. [7]

[7] Information collated from an independent report by JBA Trust of General Extreme Floods in Scotland was produced using information from the British Newspaper Archive, British Rainfall Climatological Observers Link, Great British Weather Disasters, and microfilmed newspapers from local libraries: https://www.jbatrust.org/wp-content/uploads/2020/09/Scotland.pdf

1.3.2 The Future picture and a starting point: SEPA mapping

Scottish Environmental Protection Agency (SEPA) have, with others, developed flood maps which show the risk for potential flooding throughout the country, including from the Clyde. This model has formed the starting point for our research to consider future areas at risk from flooding. At the case study selection phase of the project, this dataset was used to highlight several areas at potential risk across the city which could be viable areas for further research if they also aligned with other selection criteria from Scottish Index of Multiple Deprivation. The SEPA flood risk model interface also aligned with initial ideas of a concept of spatial mapping which developed into the deep mapping methodology. A point of interest at the outset was a lack of context for what each layer sought to actively convey prompting research questions about the context which should be provided within these types of public-facing tools.

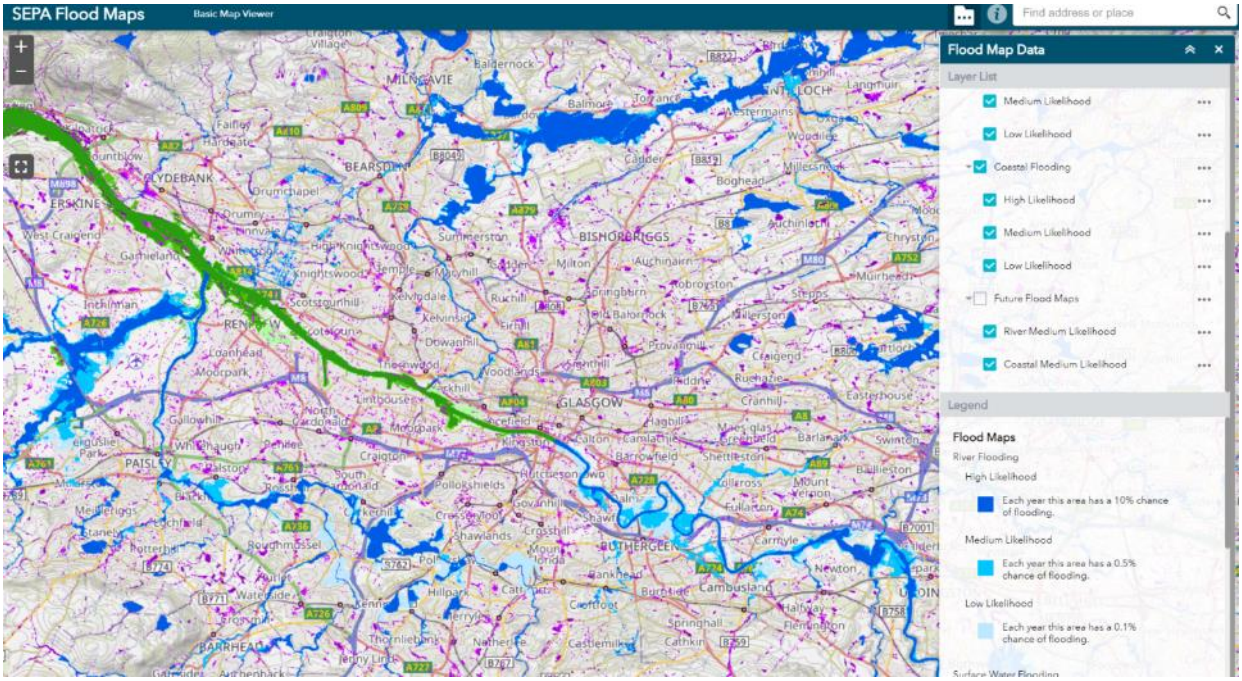

Figure 7: SEPA Flood Map of greater Glasgow area (https://www.sepa.org.uk/environment/water/flooding/flood-maps). Green and blue areas showing risk levels from flooding. The Clyde forms the green/blue watercourse flowing from top left to bottom right (Green is used in the model to convey tidal influence of the river

Intergovernmental/ regional agency

The case study area is located within both Glasgow City Council and South Lanarkshire City Council Regions. Through public avenues, there are different methods for obtaining zoning data and development plan data from these council entities. This zoning information aided in better understanding how people are using the case study area initially before we began our walking methodology data collection.

Figure 8: Glasgow City Council City Maps

Figure 9: South Lanarkshire City Council map

2. Overarching themes

This research project has several underlying themes from which we then build upon within the outputs.

- Researching and narrating Glasgow's flooding past and impacts on places and communities.
- Gathering representations of community assets in the case study areas (visual, textual, etc.) to better understand the places that are most vulnerable.
- Compare and layer these onto physical/spatial digital mapping.
- Represent these layers to build awareness, knowledge, attention, and urgency.

2.1 Community resilience & narrating Glasgow's flooding past

Major cities, such as Glasgow, face several intersecting social-ecological challenges. These include climate change, pollution, energy accessibility, land and water resource availability, biodiversity loss, health, cost of living, etc.[8] While these cross-cutting challenges are common to many cities, they occur at various spatial and temporal scales, and are often affected and shaped by specific aspects of each place. As such, city level management and governance are key to addressing them. Fostering community resilience to such social-ecological challenges is fundamental to achieving this, and which recognises that the knowledge and insight of local communities about the social-ecological contexts of places, as well as social networks and structures to address some of these challenges. It is vital to recognise and help build the

[8] See, for example, the Planetary Boundaries (Steffen et al, 2012) and Doughnut Economics (Raworth, 2017) - central to GALLANT WS1 systems approach. See Appendix.

capacity of local communities to gather and act, and to build relationships between local government bodies and community groups.

An initial step in the process has been to develop a resource for communities to bring to attention the Clyde's flooding past, which we have begun to develop in Chapter 1.

Glasgow has experienced significant flooding due to a combination of heavy rainfall, aging infrastructure, and urban development. However, the city has also shown remarkable resilience in responding to and recovering from flooding events.

Community resilience to flooding in Glasgow has been achieved through a range of initiatives, including flood warning systems, community engagement, and the development of flood management plans. The Scottish Environment Protection Agency (SEPA) has implemented a Flood Warning Scheme that provides advanced warning of potential flooding events, allowing communities to prepare and take action to protect themselves and their property.

Community engagement has also been an important aspect of building resilience to flooding in Glasgow. The Glasgow Flood Action Group is a community-led initiative that aims to raise awareness of flood risk and to promote community resilience to flooding. The group provides information and support to local residents and works with local authorities to develop and implement flood management strategies.

The development of flood management plans has also been critical in building resilience to flooding in Glasgow. Glasgow City Council has developed a comprehensive Flood Risk Management Plan, which includes a range of measures designed to reduce the risk of flooding, such as improving drainage systems, maintaining river channels, and investing in flood defences.

Overall, community resilience to flooding in Glasgow has been achieved through a combination of advanced warning systems, community engagement, and the development of flood management plans. By working together and taking a proactive approach to flood risk management, communities in Glasgow have been able to mitigate the impact of flooding events and to recover more quickly from the effects of flooding.

2.2 Deep/socio-cultural mapping

The process and outputs of our work is centred around developing maps - and 'deep maps'. Theoretically deep mapping (see also social-cultural mapping and social cartography) is an

approach that extends conventional mapping approaches that focus on objective representations of the physical features of a landscape to include narrative, history, and subjective experiences (see Springett, 2015; Roberts, 2016). Such forms of mapping incorporate gathering of multiple sources of information and narratives, in different formats (textual, schematic, image, photographic, numeric, etc.) (see Bonner, 2022). Deep mapping can involve the accumulation and layering of different kinds of geo-locatable media within a geographic information systems (GIS) environment to facilitate investigations of the material, discursive, and imaginative geographies that inform our conception of allocations topography and senses of place.

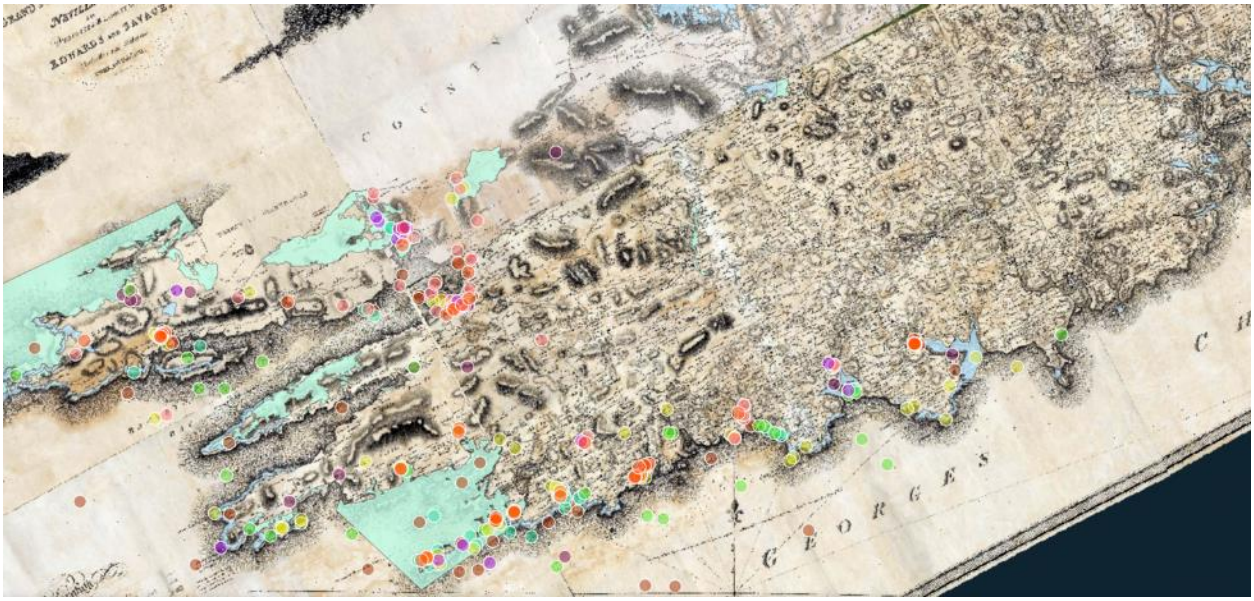

Figure 10: Deep map example http://www.deepmapscork.ie/. This deep map was used as an inspiring example that we used to build up our own map. (Explain points refer to different narratives, etc).

As a basis for developing a deep map of a place it is necessary to open-up, and explore the representation of the multiple social, cultural, ecological, characteristics of a place. This research seeks to develop a case study focused output to represent the multiple social, cultural, economic, and ecological risks associated with areas at flood risk along the River Clyde applying ideas of deep mapping. It seeks to highlight the multiple dimensions of sustainability risk and impact through representing areas and points of social, cultural, infrastructural, ecological, and economic value, and recognise the importance accessing these to local communities.

In phase I of this project, we investigate and develop a map of these various spatial assets in the context of the case study site as a foundation for expanding the map, with further details and representations in **phase II** - expanding to the inclusion of community sourced narratives of place, and other historical and subjective experiences. A phase II iteration of the map would also seek to represent the historical knowledge (see flooding events listed above) as a layer of content for the deep mapping - as well as incorporate various other archival material on narrative and arts-based representations of past flooding, including oral histories, community recollections of more recent flooding events.

2.3 Developing an urgency to act without panic

Flooding can have significant impacts on the quality of lives of communities - from degrading and damaging housing stock, community spaces, and key services- as well as undermining mobility and transport to access these various places of social and cultural value. Furthermore, flooding can create significant short, and longer-term, economic burdens on individual and society more widely through factors such as housing damage, house prices, insurance costs, land, and services - as well as impacting local businesses, places of work, and key infrastructure.

There are, however, opportunities to develop adaptation and mitigation approaches to reduce short term, and longer term, risks through technology, place design, and other engineering-based approaches (see **Nature-based solutions).** Aside from, and along with, these infrastructural approaches it is also vital to recognise and understand ways people can adapt to, and affect change, whereby different voices are included and considered. Herein the behavioural and social-cultural relationships to place, and those that are at risk from flooding, is crucial to developing future pathways to deal with flooding issues. The focus of our research is to open up understandings of these relationship in terms of flood risk on the River Clyde in Glasgow.

Methodology

The central aim of this research (across its two phases) is to understand, communicate and represent flooding related risks along with communities to build awareness, knowledge, attention of these issues to various groups, facilitating community resilience. Recognising the

interwoven social-ecological implications of flood risk with various other social, ecological, and economic issues and factors it is necessary to apply a methodological approach that can investigate and communicate these interrelationships- and expressed in the everyday context of people's lives and the places they live, work and play.

3.1 Interdisciplinarity

A key aspect of this work is its inherent interdisciplinarity, seeking to understand and represent relationships between people and water that cuts across ideas and methods from the social sciences, natural science, as well as the arts and humanities. It also reflects on the diverse backgrounds the authors; in social-ecological studies, and the digital humanities.[9]

WP1 Flood Adaptation & Creation of Riverscapes Team

WP1 represents our closest thematic partner and was able to provide key data sets through their parallel negotiations with intergovernmental groups, local authorities, and city councils. WP1 provided several datasets and files including zoning data via Digimap[10], SEPA Flood Risk datasets, and ESRI GIS 'basemaps' to overlay shapefiles.

Dataset/Model	Description	Generated by WP/WS or Data Owner Details	Approx size of dataset and known data challenges
Models needed	Numerical model of joint probability between tidal and fluvial impact on flood risk along the Clyde estuary considering the effect of future sea level projection (2100)	Fairhurst & South Lanarkshire	>8GB
Dataset needed	GIS layers (development plan, SEPA's flood risk map, SEPA's NFM shapefiles)	Local authorities & SEPA	>4GB

Figure 9: Relevant datasets that have been requested by WP1 that we use within the sub-project

WP 4 Active Travel

Recognition that key active travel routes, particularly along the Clyde (e.g., NCN75 following the river), are vulnerable to flooding risk restricting accessibility and inclusion, as well as potentially incurring future cots and attention to maintain.

[9] See author profiles at https://floodingcommunityresilience.wordpress.com/about/

[10] Digimap is a web mapping and online data delivery service It makes available on-line mapping and data download facilities which provide maps and spatial data from sources like Ordnance Survey – which was used in the research for this project. Site found here: https://digimap.edina.ac.uk.

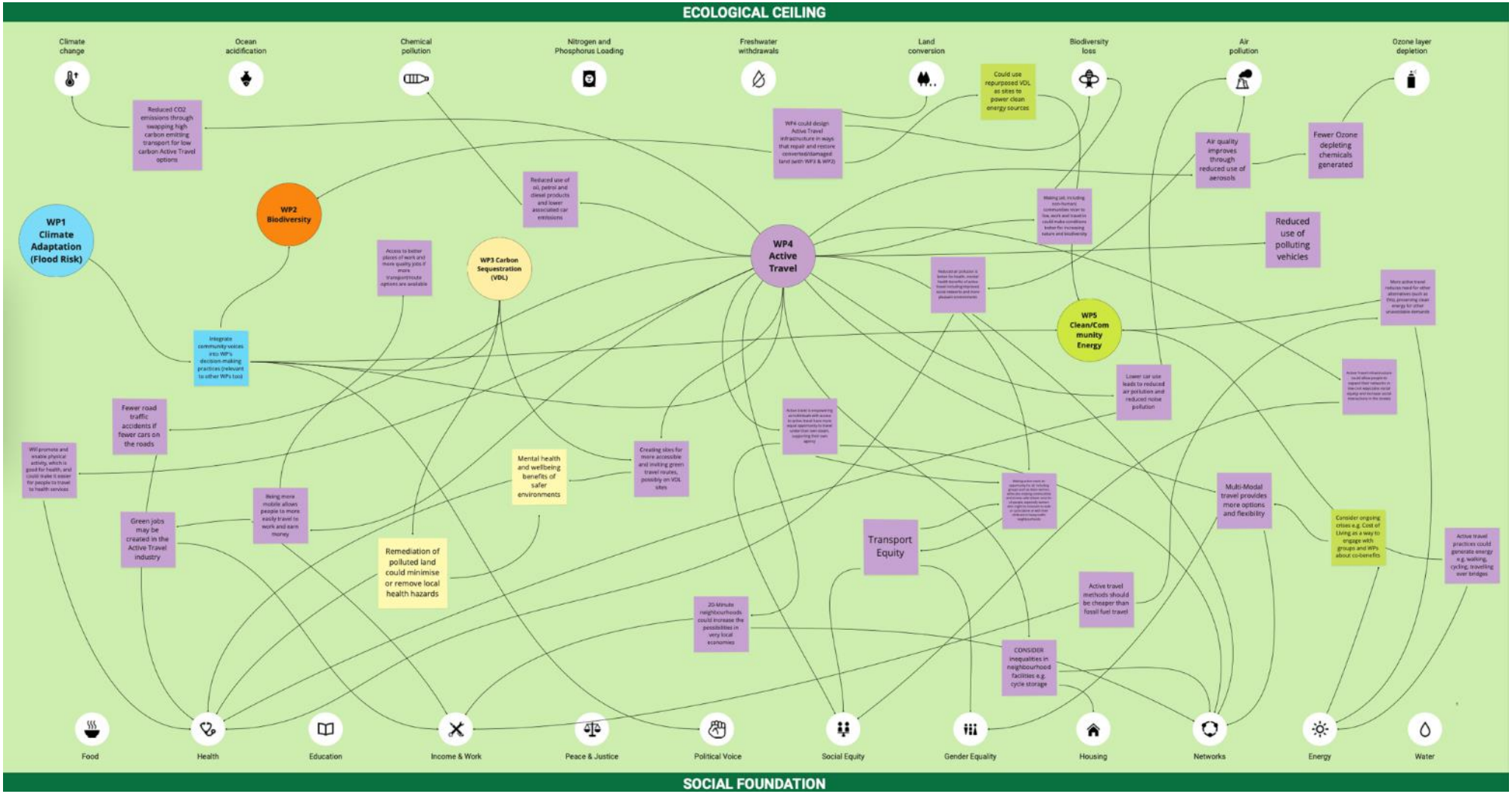

Figure 11: WP 4 Active Travel mapping to the planetary extent

WS2 Community Collaboration

Having developed initial scoping and mapping exercise a need to include (or at least propose) forms of community engagement through specific groups in the area to include and shape the outcomes. [Note Community WS definition of community on Teams].

Key point:
WS2 also determined the workflow as it related to conducting interviews with community members as they were in the process of undertaking ethical approval.

Investigating these complex and multifaceted problems requires diverse expertise and broad understanding of background context has been needed. Flood risk does not comprise one layer of complexity, but rather represents complex multi-hazards with cascading effects.

3.2 Multimethodology

This research uses a 'multimethodology' approach, incorporating different methods of qualitative research (this differs from mixed methods- which uses a mixture of qualitative and quantitative approaches). A multimethodology allows for a range of ways of investigating and communicating knowledge, as well as exploring novel ways of doing research, and draws on the range of methods and approaches taken by the authors in their other research. It reflects, and reinforces, the inter and cross disciplinarity of this research project.

The methods we use for data collection, and the methodological approaches that underpin them, combine both secondary desk-based research, as well as accumulating primary sourced data and content. Indeed, these reflect the overarching research backgrounds of the two authors- the application of desk based digital archival methodologies, and (auto)ethnographic place-based primary research walking methodologies.

3.3 Value of pilot case study

Short-term pilot studies can be a crucial point for good study design - they can be used to determine the best approach to research methods and methodological approaches and troubleshoot any issues that may arise from the methodology or data collection processes (Van Teijlingen, 2001). Pilot projects can also help to pre-emptively identify any potential single points of failure that could arise during the lifetime of the project, and mitigating action can be integrated in the planning phase.

Due to the short timescale of the initial funded project, we have focused our efforts to designing a scalable framework to approach research. The initial case study area works as a

proof of concept to the viability of deep mapping several social, economic, ecological, and historical aspects in a unique aggregation to evaluate community relationships to space, as well as evaluate resilience to changes to the geography due to climate change risk.

Through the pilot study, we hope to identify best practice for data collection, deep mapping, and GIS mapping to understand and mitigate any single points of failure or difficulties that may arise. Phase II of this project could expand the scope for the deep mapping layers using the same methodologies, while becoming increasingly rich and complex – adding in other types of qualitative data such as from semi-structured interviews and oral histories sourced from community stakeholders and various other audiences.

3.3.1 Case study selection

In this initial phase of the project, we focus on a pilot case study considering a section of the River Clyde in Glasgow from the Clyde Tidal Weir at Glasgow Green, extending along the banks of the river east through the areas of Dalmarnock, and along Cuningar Loop, to Junction 2A of the M74 motorway (see figure x). This pilot case study region (seen in Figure 11) has been selected using SEPA flood risk datasets as well as representing an area with notable levels of social-economic deprivation, agreed in consultation with external groups including Sniffer and Climate Ready Clyde (see contact list- does this still exist?).

Figure 12: Map of Glasgow city boundaries, with insert of case study area (Google Maps)

Figure 13: Focused case study area: from the Clyde Tidal Weir near Glasgow Green in the west, along the river past Dalmarnock and Cuningar Loop to the east.[11]

The SEPA flood map data was used to identify a case study area within the East End of Glasgow, between Rutherglen and Dalmarnock; this area was also selected to represent a case study area that has a higher level of deprivation.[12]

[11] Consider themes of 20-minute neighbourhoods; what areas should communities be able to access via active mobility.
[12] See Scottish Multiple Deprivation Index, with stats from 2020: https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/

Figure 14: Satellite image of case study area from Google Maps (downloaded 8 March 2023).

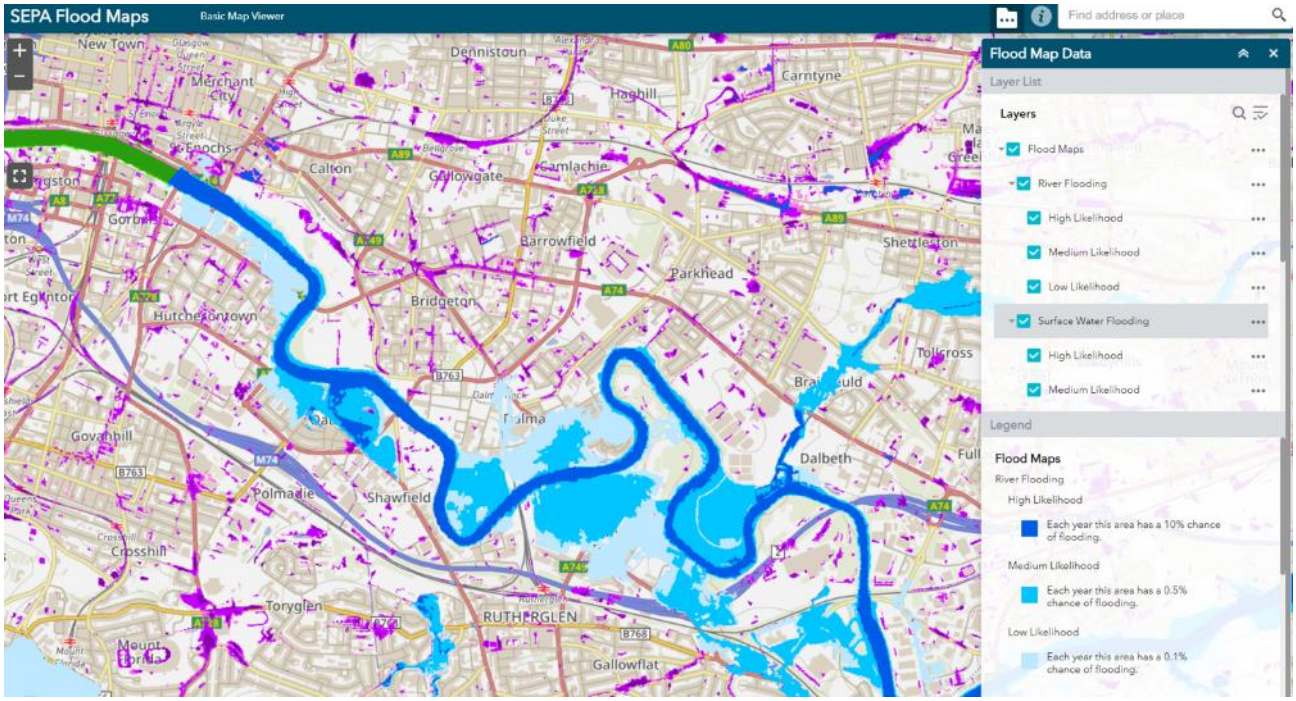

Figure 15: SEPA Flood Map representation of areas a risk of flooding along the River Clyde in the case study area

3.4 Data collection

Our multimethodology approach integrates the collation of various forms of secondary and primary data drawing on the backgrounds of the authors. The following section describes those approaches, and some of the data collected.

At the onset of the project, we spent dedicated time researching how flood risk was represented via modelling and how statistics were represented. This allowed us to better understand the SEPA dataset and fill our gaps in understanding about geomorphology and statical analysis of flood risk.

Fluvial Climate Change Allowances

SEPA provided an update on Climate Change implications and allowances for peak fluvial design flow estimates with the document 'Climate Change allowances for flood risk land use planning' from April 2019. This indicates that the allowances for Climate Change should be applied on a regional basis in terms of the river basin that the target catchment falls within.

River Basin Region	Total change to the year 2100
Clyde	44%

Coastal Climate Change Allowances

'Climate Change allowances for flood risk land use planning' from April 2019 also provides guidance on the implications and allowances for sea level rise and how these should be applied to coastal boundaries and water levels. Similarly, this indicates that the allowances for Climate Change should be applied on a regional basis in terms of the river basin that the target catchment falls within.

River Basin Region	Sea Level Rise (metres) by 2100
Clyde	0.85

This initial research was used to guide our understanding of the data sets that were presented within the SEPA flood risk tool, as the tool is presently with relatively little context. This guided our thinking in the design phase of our public facing deep map; identifying information that would be helpful for user groups to have.

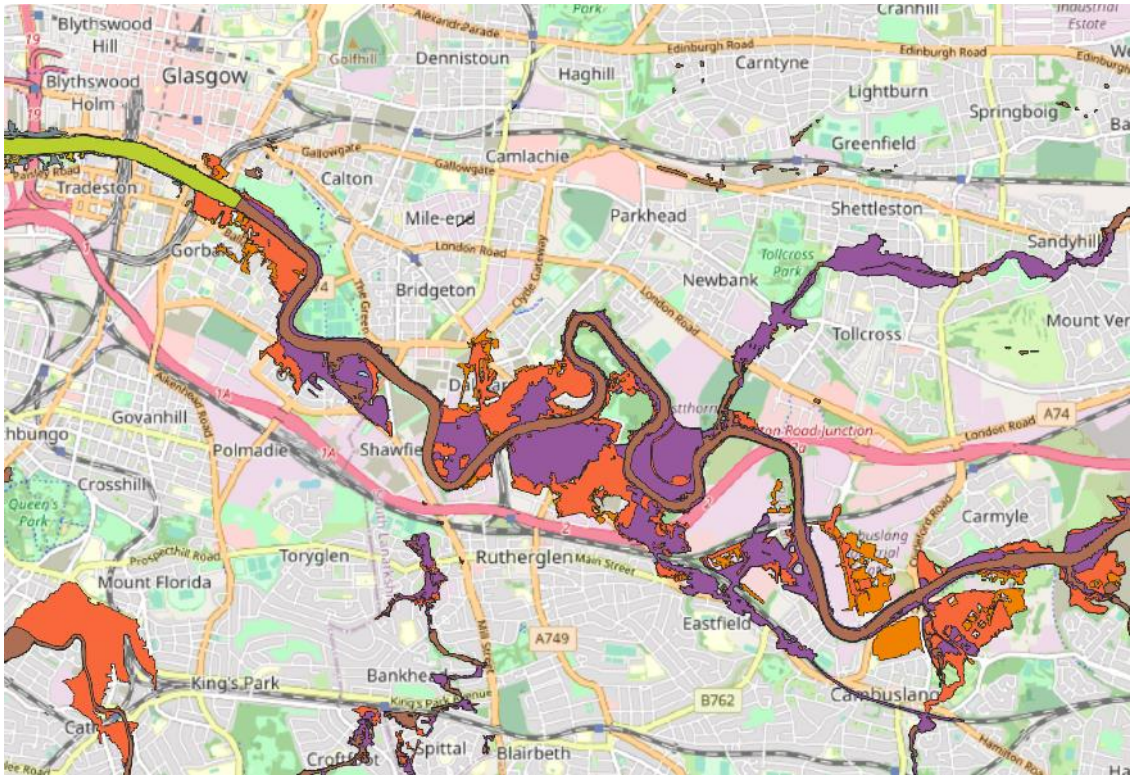

Figure 16: Future Flooding layer from SEPA dataset

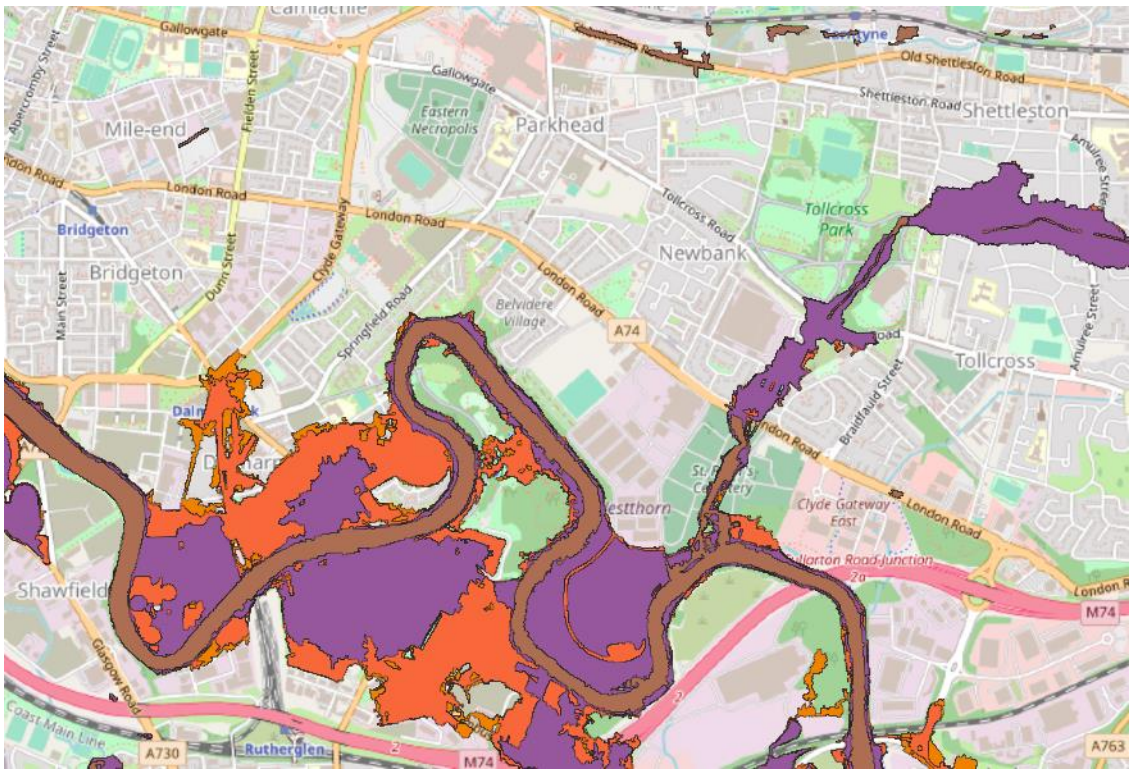

Figure 17: Future Flooding layer from SEPA dataset in case study area

3.4.1 Archival research

To gain a better understanding of historical understanding of flooding in Glasgow, we undertook desk based archival research from various sources (this has informed the some of the contextual information provided in Chapter 1). Several different resources were used in the initial survey of archival research.

National Library Scotland (NLS) has an online repository of map images that are searchable and georeferenced. They include historic maps, ordinance surveys, national grid references, and are searchable by keyword search metadata and controlled vocabularies.

To investigate historic maps in the case study region, initial searches focussed on Cuningar Loop, and called back 39 maps online, dates inclusive 1857-1970. This allowed us to investigate factors such as historic land usage, changing industry, movement of people through residential builds, and any deviation in the rivers path due to fluctuations in the fluvial water. We were also able to gain insight into cultural and social attitudes to the environment, based on how the region was utilised in terms of industry.

Some considerations for using this data include licensing for education use and permissions for sharing this information. NLS has very clear use and reuse guidelines for their available digitised map which guided how we used the information within our own Deep Maps.

National of Library of Scotland Moving Image Archive, was able to be searched through targeted metadata, "Flood", "Flooding", (Clyde). To avoid erroneous call-backs, a Boolean search[13] of (Clyde) was used where applicable. Though there were few results called back through this database search. Follow up in queries will be made to NLS Scotland staff at Kelvinhall are in process.

Some relevant sources include:

- Glasgow Floods 1936; National Library of Scotland; ref 2519; film: https://movingimage.nls.uk/film/2519

This media resource was used to search out viable archival footage that could be used within the Deep Map in the form of .mp3 or.wav files integrated into the map if the terms for licencing was loose enough to allow this derivative. At the point of Phase I, not enough sources were identified to be used within the map, but Phase II will seek out further resources for this layer.

[13] A query technique that utilises Boolean Logic to connect individual keywords or phrases within a single query

University of Glasgow Archives and Special Collections has city ordinance maps available within their collections that would be of value to evaluate changes in infrastructure, residential build up and changes in green spaces.
This aspect of the research represented a point of delay. My initial enquiry with the ASC team did not receive a response for 2 months so an in-person collections viewing could not be organised. As this barrier to access is in place, and currently digitised aspects of the ASC collections are not relevant for this aspect of the project, this avenue was not further explored for Phase I and will be explored again in Phase II when there is a longer time-scale for communication.

Collated research from British Newspaper Archive: An independent report by JBA Trust of General Extreme Floods in Scotland was produced using information from the British Newspaper Archive, British Rainfall Climatological Observers Link, Great British Weather Disasters, and microfilmed newspapers from local libraries. The dates inclusive for this report is 1749 to 2016 – related to the search term <Glasgow> and <<Clyde>>.

Relevant flooding events were collated within Table 1. From this data we can better understand the frequency of flooding events within the city and case study area. This research indicates that most flooding events have concurrent property damage risk, most notably damage to residential areas or areas of public transport.

3.4.2 Walking methodologies

The main approach we have used for collecting primary data has been through the application of 'walking methodologies'. Applying walking methodologies as a means for researching water aligns with political ecology water studies that foregrounds water relations in a time and place (see Linton and Budds, 2014) including to identify the variability, multiplicity, and dynamism of how societies interact with different types of water (see Elliott and Culhane, 2017). (Bonner, 2022).

This has involved undertaking a series of walks (as well as runs and cycles) along the river in our case study area- identifying, observing, and recording locations and activities of interest that we come across, recognising their potential value to local communities and place. The process for undertaking such 'water walks' involves some planning based around visiting some previously researched locations and activities on the river developed through local knowledge of place, interrogating digital maps, and considering other secondary resources such as newspaper articles. It also allows for emergent and unplanned observations as the walks are undertaken. Whether as a solitary pursuit (by James Bonner) or as both authors, we move along the river taking photographs, videos (using a camera phone and/or a DSLR

camera) and making reflective notes of their location and role- discussing and sharing these observations as we go (if undertaken by both researchers together).

The opportunity is also used to make unplanned observations on the river, especially of more dynamic, micro, or temporal events (such as encounters with wildlife, or incidences of flooding). Herein this information is considered and collated to be uploaded to the deep map and other social media channels as we gradually develop an emerging picture of the river.

Figure 18: Open gates at the Clyde Tidal weir signify a high-water level noticed while cycling past. Grassy bank to the left can be seen particularly close to the water level. Photo by James Bonner.

Figure 19: Clyde Tidal Weir with high water level

Figure 20: Moving to the grassy bank to observe and encounter the high river level

What resources were collected:

- Digital photographs: taken by James Bonner
- Videos: taken by James Bonner
- Other external resources: images from media reports and newspaper articles as part of desk research process.

Reflections

Where were points of delays and why?

- Waiting on data sets from WP1. There was a delay in getting access to Glasgow City Council flood risk data. In terms of the longer WP1 work, this was not a serious issue, but for the short term of our project, it meant a planned layer for the deep map had to be excluded.

4. Outputs

Mapping (deep maps)

- Google Maps and Google Earth Pro: (these 2 public-facing, but with layers of complexity that can be switched on or off).
- QGIS: Research/practitioner-based tool.

Multi-media repositories

- Flickr: images and to assign licencing.
- YouTube: videos to link to Google maps.
- Website: host and space to bring together content.

Witten outputs

- Report: research-based output from NCR.
- Blog: public/practitioner output.
- User manual: guide to engage with, and potentially contribute, to the various tools and platforms.

4.1 Deep mapping layer of social-cultural responses to flooding

The selection and development of each layer seeks to convey the multiple social, cultural economic, infrastructural, and spatial representations through different forms of multi-media to represent and communicate assets and activities valuable to communities.

4.2 Value of using public facing tools

For this phase of the methodology, we are using two tools to represent this narrative of place. Google Maps (and tangentially Google Earth for slightly more functionality) and QGIS (an open-source Geographic Information System software). The value in using Google Maps as a tool for spatial mapping is that it has easy to understand functionality for user groups. Most anticipated user groups will have previous experience using the Google suite of products and may have used Google Maps for other functions. The user interface (UI) is simple, while at the same time allows for the inclusion of a robust amount of data to be presented via various forms of digital media.

4.3 Google Maps

Google Map of Case Study Area: Cuningar Loop: here

More information on Flooding Community Resilience website: here

Google Maps allows for the user to access 10 layers of zoning data and specific locations identified from direct observation and primary data collection, as well as desk research. Each of these layers, a categorisation of the different social, cultural, economic, technological, spatial, and other assets that are of likely value and importance to communities- individually and collectively. Collected using our walking methodologies, as well as sourcing archival and external sources, these locations are described with a variety of multimedia formats (images, videos, press articles, etc). Phase I has incorporated multimedia content for most sites- a Phase II would expand on and complete this.

The layers available on the Google Map are:

- Green and Blue Spaces
- Public transportation and supporting infrastructure
- Problematic sites and observations
- Undeveloped land & car parking
- Health and social care and emergency services
- Business, work, and industry
- Residential
- Sport and recreation
- Culture and religious

Figure 21: Pins locating the various social, cultural, economic, and other community assets in case study site.

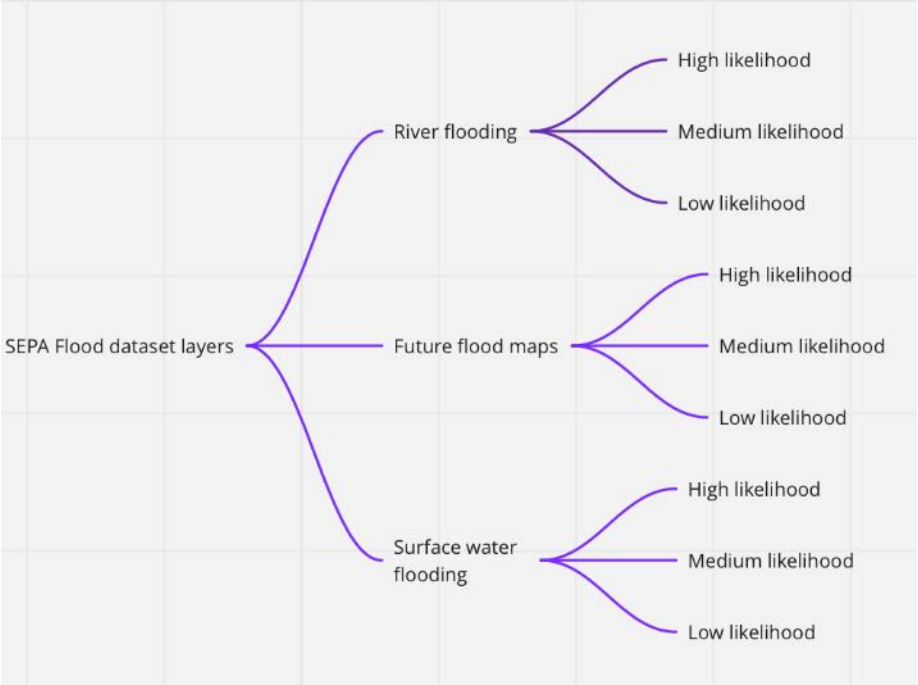

Figure 22: SEPA (Scottish Environmental Protection Agency) flood risk dataset layers. This the initial dataset we started with in the emergent design.

Uploading and sharing the data across several platforms has had a positive uptick in engagement with the materials. User analytics have indicated that the map has been viewed 350 times before being publicly disseminated through official communication means (via the GALLANT Communications Strategist)

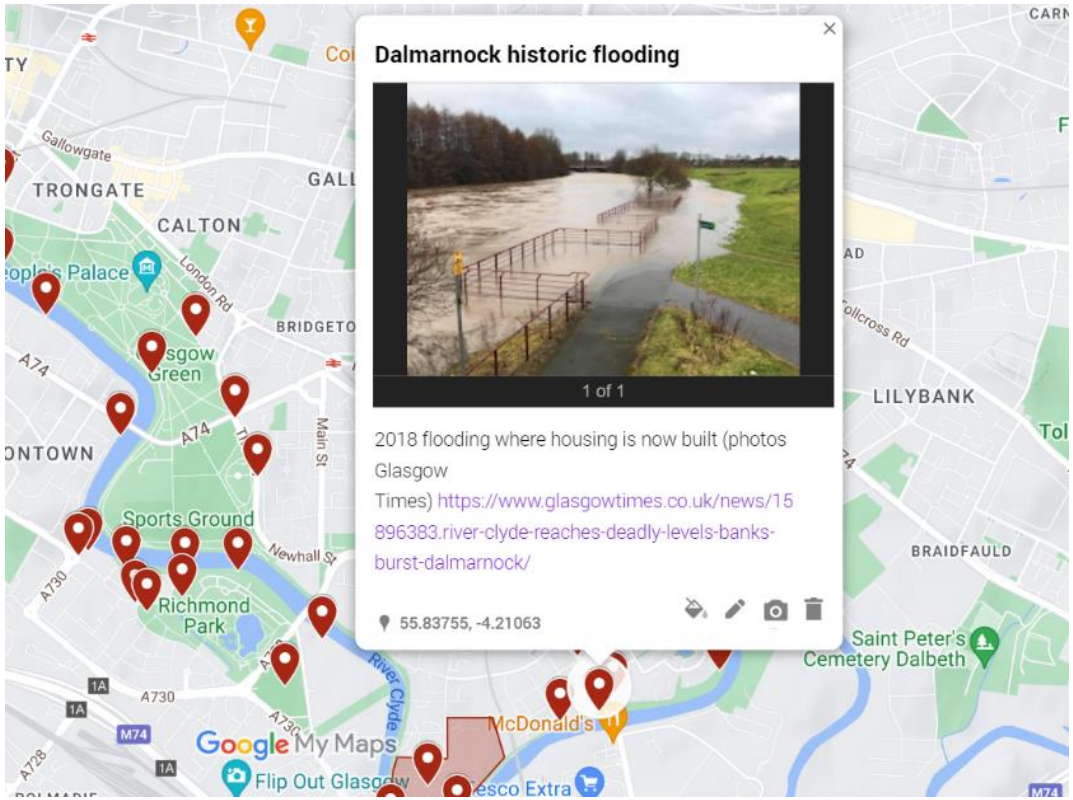

Figure 23: Layer of mapping with various locations of interest and risk

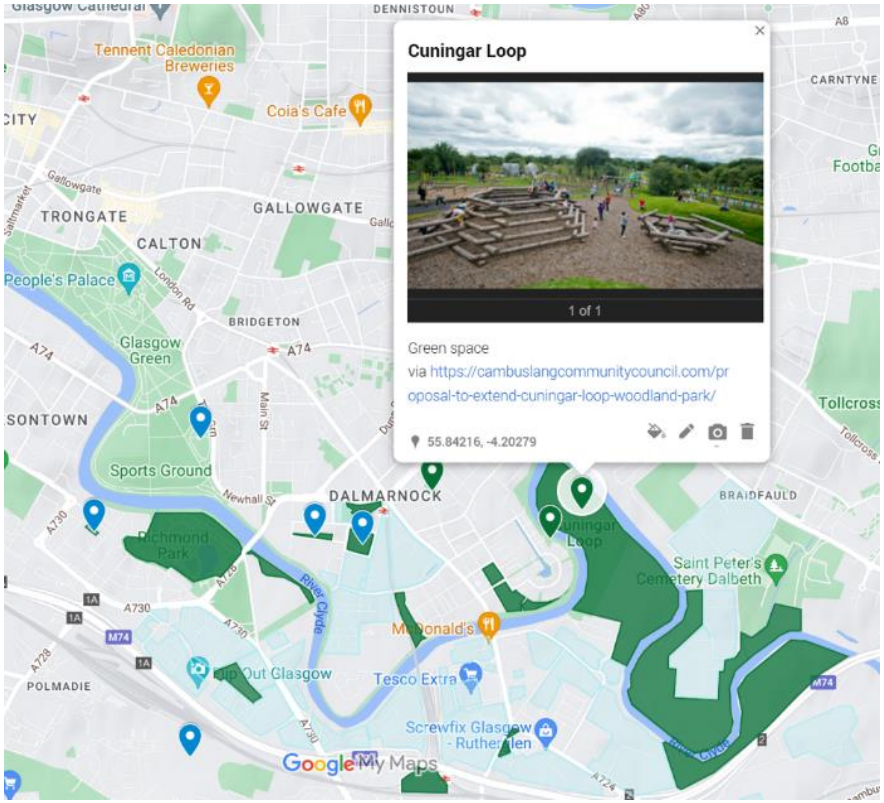

Figure 24: Layer of mapping representing green space

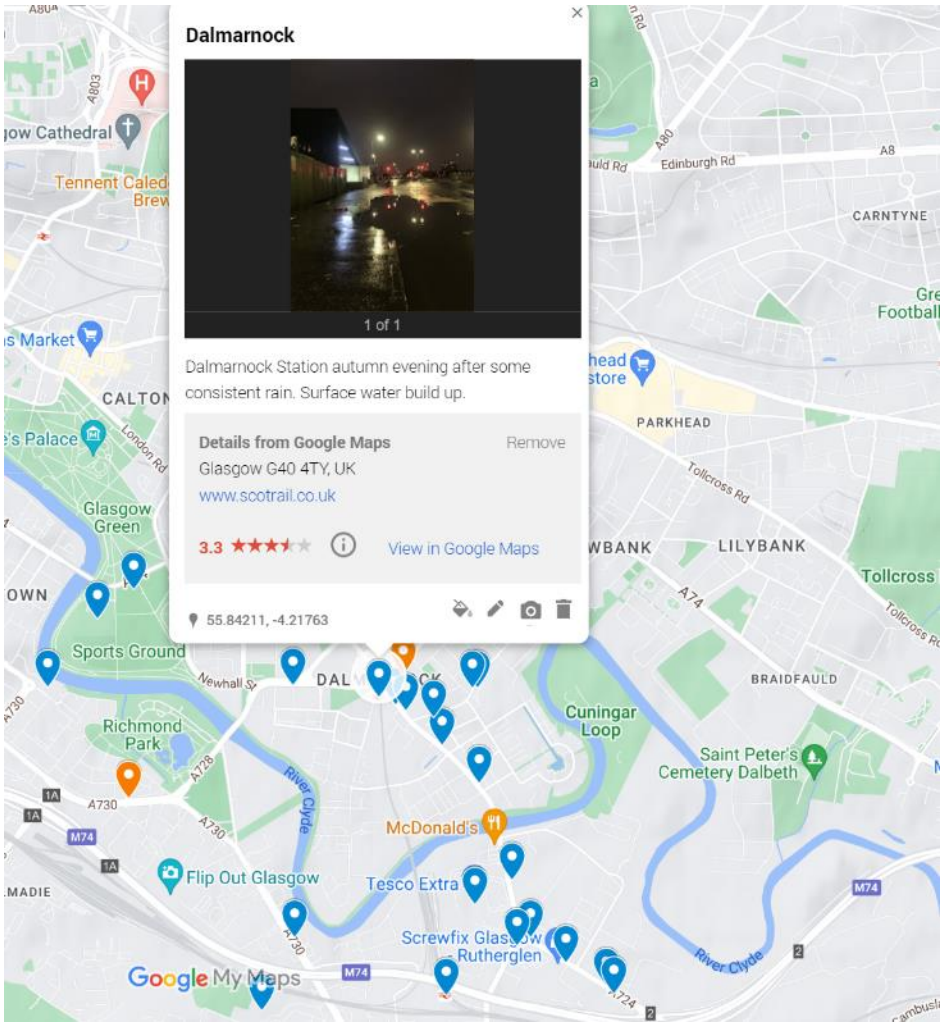

Figure 25: Layer of mapping showing public transport hubs and stops

4.4 Google Earth

Google Earth compilation of layers: here

Exporting and migrating the exported layer data via '.klm format' - the zoning layer information can also be viewed via Google Earth. This allows the user to have slightly enhanced functionality, including different base maps, 3D buildings, and enhanced topography. Users can also change environmental factors such as weather, trees, as well as various terrain options.

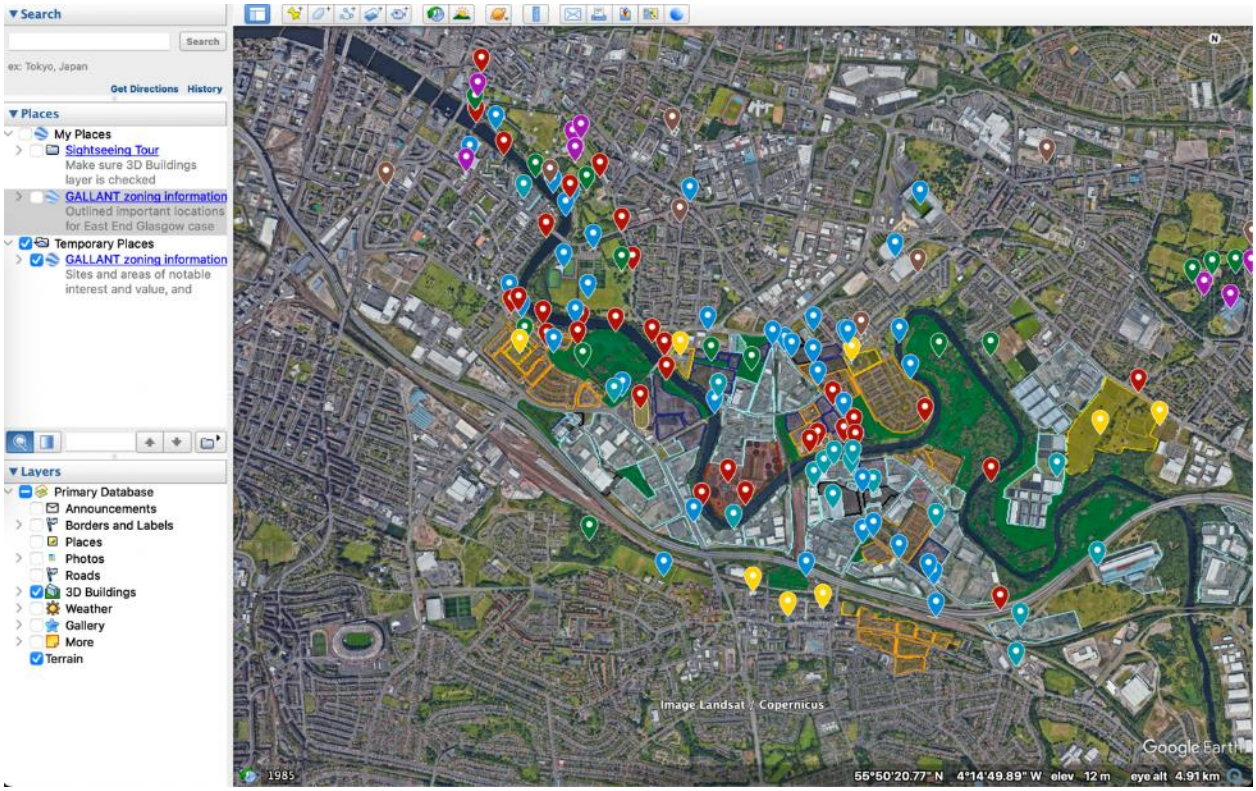

Figure 26: Google Earth version of case study site

By using the Google Earth Pro programme to collate multiple exported data sets the layer limit present in Google Maps can be mitigated. As Google Maps only allows for 10 layers to be used, multiple Google Maps data sets can be collated to create a web-based version of the collated data sets that is publicly shareable.

4.5 QGIS

Note: This resource has not been made publicly available in Phase I. This is due to the Cloud based service to upload QGIS maps is not a free service. This will be further explored in Phase II.

QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, printing, and analysis of geospatial data. The functionality of the software is flexible and supports formats shapefiles, personal geodatabases, dxf, MapInfo, PostGIS, and other industry-standard formats.

This platform allows for significant detail and professional level content, as well as including modelling data (from WP1) on current projections of flooding risk. This has been developed

significantly in the phase of the project (see screenshot in figure x) but has not been released publicly in this phase. Doing so should requires final checking of the modelling data (much of which has only just been accumulated), as well as aligning with the timeframes of the GALLANT work package that leads on this. A phase II would allow for this.

SEPA flood risk datasets

- Coastal extent - High (10%)
- Coastal extent - Medium (0.5%)
- Coastal extent - Low (0.1%)
- Coastal extent - Climate Change (0.5% @ 2100 worst case scenario)
- Fluvial extent - High (10%)
- Fluvial extent - Medium (0.5%)
- Fluvial extent - Low (0.1%)
- Fluvial extent - Climate Change (0.5% @ 2100 worst case scenario)

Historic Environment Scotland

- Historic Land Use Data
- Gardens and Designed Landscapes
- Listed Buildings
- Scheduled Sites and Monuments
-

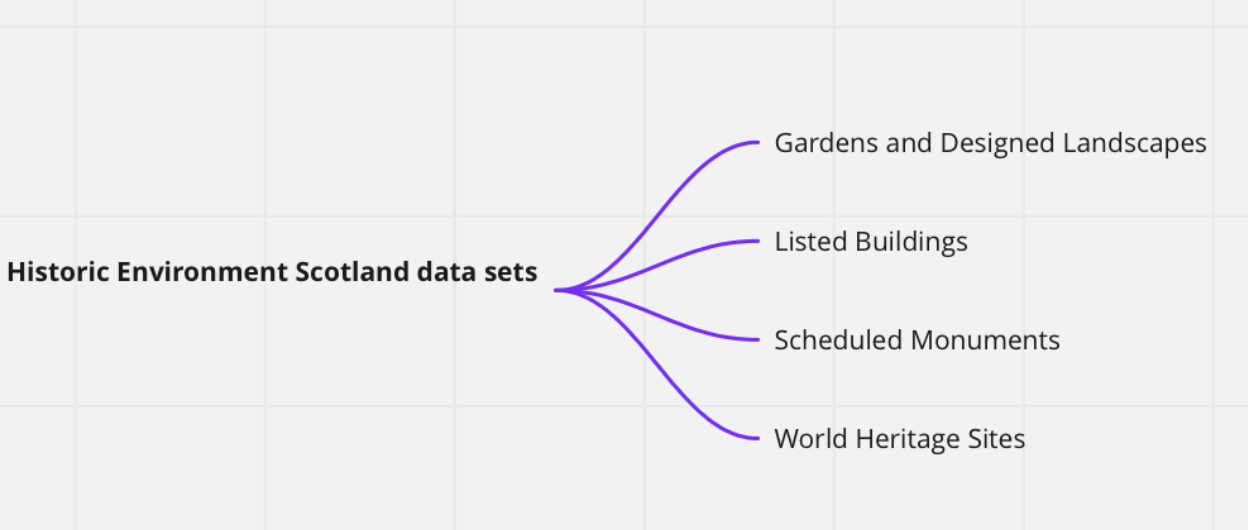

Figure 27: Historic Environment Scotland datasets to see if there are any relevant cultural heritage objects currently mapped within the case study area.

Exported .kml/.kmz google maps data

- Green and Blue Spaces
- Public transportation and supporting infrastructure
- Problematic sites and observations
- Undeveloped land & car parking
- Health and social care and emergency services
- Business, work, and industry
- Residential
- Sport and recreation

- Culture and religious
- Green and Blue Spaces
- Public transportation and supporting infrastructure
- Problematic sites and observations
- Undeveloped land & car parking
- Health and social care and emergency services
- Business, work, and industry
- Residential
- Sport and recreation
- Culture and religious

4.6 YouTube

Deep Map Glasgow YouTube channel: here

Google Maps has several methods to upload video files and link URLs for video playback within the Maps functionality. We found that it was easier to use links to YouTube videos for the Google Maps as the various methods of video capture we were using would produce digital outputs of varying file formats, of which not all were compatible with Google Maps. Rather than using external programs to export and reupload different file formats, a bespoke YouTube channel was created. We found that videos of 61 seconds or more could be linked to the Google Maps, as videos under 60 seconds automatically were formatted to "YouTube shorts" which auto created a different URL which are incompatible with the YouTube embed function on Google Maps.

By unloading the videos to YouTube studio, we are able to explicitly define a Creative Commons license so the copyright can be clearly defined as these media resources are being added to a deep map which has the capacity to be publicly available.

The YouTube channel comprises 22 videos of scenes from around the case study area highlighting several themes, including: Problematic sites, water scenes, non-human participants, and active travel routes. This media continues to foster the richness of the Deep Map tool by using more complex representations of space and relationship of place, while providing more context than is typically available in traditional mapping techniques. Copyright that is used falls under CreativeCommons - Attribution; CC-BY-SA 4.0, where the videos can be freely used, including derivatives, with attribution to DeepMapGlasgow who created the original videos. The "Like/dislike" function have been disabled for Google Maps videos, though YouTube shorts show the like/dislike metrics.

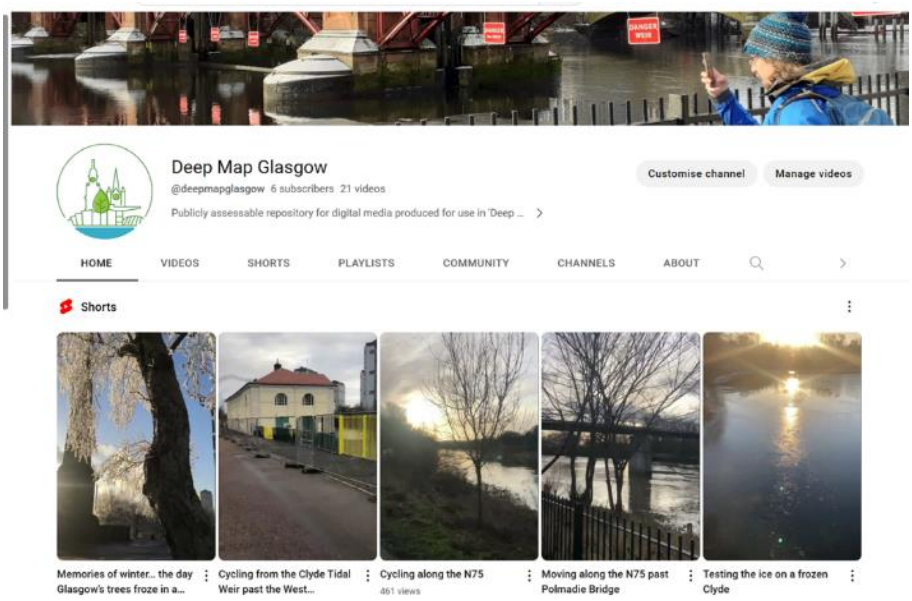

Figure 28: YouTube site: March 2023

4.7 Flickr

Flooding Community Resilience Flickr: here

Similar to the YouTube platform, a Flickr account was created as a digital repository for images taken during data collection where explicit copyright for use and reuse can be established. Copyright used for images is Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) where the images can be used freely, with derivatives, with attribution to Dr James Bonner who took the images.

Relevant descriptive tags have been added to all of the images to increase the discoverability of the images within the platform and Google Images. During Phase II, more dedicated metadata can be defined using Dublin Core via .XML.

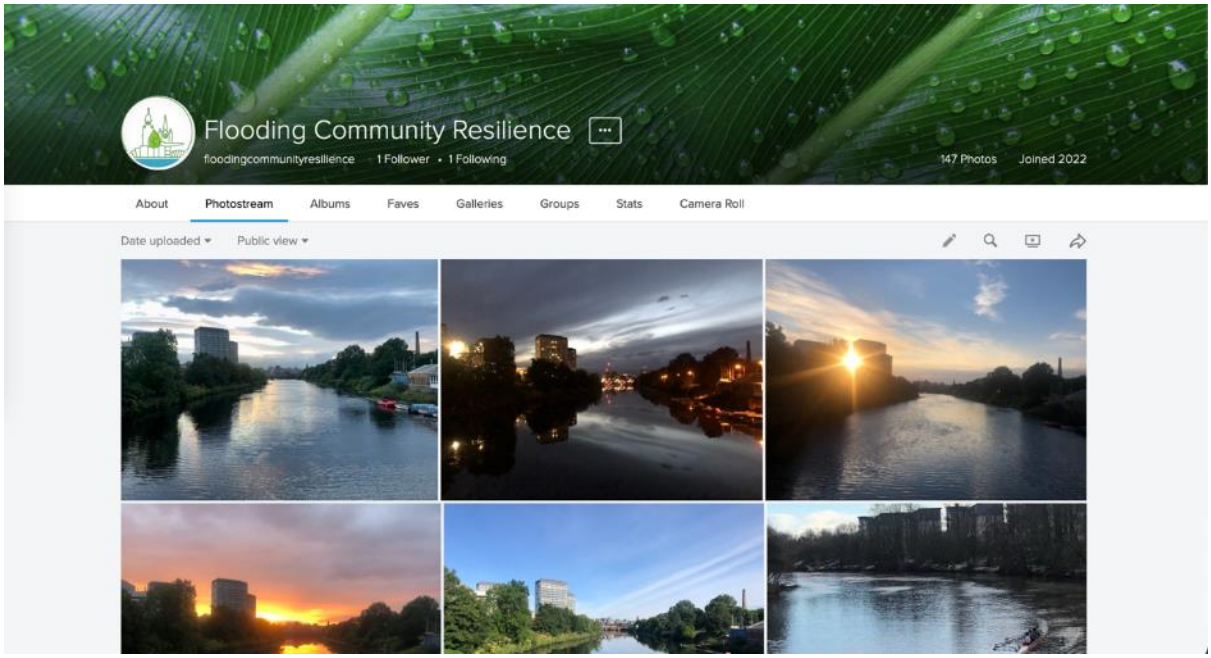

Figure 29: Flickr site: March 2023

The Flickr account has had relative success with engagement and discoverability even without promotion via the GALLANT web presence, with 1.7k views to the site since its creation in November 2022 (as of March 2023).

5. Findings & recommendations

Through our various methodologies and data collection of representations of place through our multiple digital media outputs we have several observations relating to relationships to space.

- There is a need to develop communications of risk of flooding risk from the Clyde that recognises the significant impacts, but without creating fear or panic.
- Flood risk understanding and communication to the public as part of this process should extend beyond a focus on residential properties, and open-up the impact on communities and place more widely.
- Greater focus needs to be given to communicating to, and learning from, communities around flooding risks, as well as for approaches to build resilience.
- Modelling and spatial mapping (such as the SEPA flooding model referred to in this report) need to be contextualised in the context of the everyday lives of communities- from ways people live, work, move, access key resources, and undertake recreation.
- Develop and apply different interdisciplinary research methods and approaches, such as social-cultural mapping, to extend the content and communicative potential of flood risk information.
- Develop the long-term digital sustainability of research and content that is accessible and engaging to relevant communities.

The Deep Map tool has proven to be a tool of value within the GALLANT project context as it has been an uptake of our methodology for Phase II. The model has the capacity to represent a co-productive participate model with stakeholder and community groups that was not possible within the first phase of the project due to delays in ethical approval. The tool will be used to better understand personal relation to place, communicate better understanding of flooding events and risk, and concurrently understand how single points of failure in city infrastructure can cause cascading effects that impact often hidden aspects to daily life, such as active travel routes.

6. Future scope for research

7.1 Phase II - April 2023 - 2027

In concluding Phase I of the project the authors ideas for follow-on funding for a Phase II of the work, which will have an explicit community generated content aspect - which we were unable to do in Phase I due to the short timeframe and likelihood of obtaining ethical

approval. The timescale of this piece of work has restricted the possibilities of fully developing the scope and content if the outputs that have emerged from it, and therefore much of what it has produced should be seen as 'work in progress' and the foundation for much more user generated content in the future. In particular, we would be keen to consider the potential for developing the methodological approach and the digital infrastructure we have created to develop case studies nationally and internationally, and with additional consideration of other interrelated risk and resilience related social-ecological factors.

7.2 Developing new case study sites

While the GALLANT project generally approaches its research through the lens of several work packages and workstreams, it is important to recognise that key findings are a recommendation for the wider project – we need to understand that there is value for each work package singularly, but they are interlinked more profoundly than was initially thought.

Some further research questions we would like to investigate are:

- Active travel routes, how seriously this is going to be affected by flooding events
- Biodiversity – non-human participants
- Conscious of the role of water and the Clyde and the river represents, will have on the capacity for the projects to come to fruition

As part of **Phase II** - based on the flexible and scalable methodology, there is room for expansion to include other sites within the Glasgow region where communities are subject to flood risk.

Recognising the various vulnerabilities from the SEPA flood mapping, initial thoughts include:

- Govan (we have undertaken initial mapping and content collation from this location- including undertaking a walk, and uploading content to social media channels)
- Strathclyde Park (initial scoping has identified this as areas at particular risk to extensive flooding)

We will continue to liaise and collaborate with SNIFFER to identify further case studies areas. Initial conversations with WS2 Community Collaboration colleagues have indicated several areas for overlap and need for deep mapping; we will continue these conversations as the project advances. There is also a possibility to extend this research methodology and the methods/practices it adopts to other social-ecological issues other than flooding (such as land use change).

We will also work in connection to the GALLANT WS 2 case study agenda that aligns with several planned case study areas to keep developing the deep map in Phase II. This will include Govanhill, Central, areas in West End and the East end for case study areas.

Key research theme: Conflicting data - can urgency be conflated?

Understanding for how flood risk is assessed is needed

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