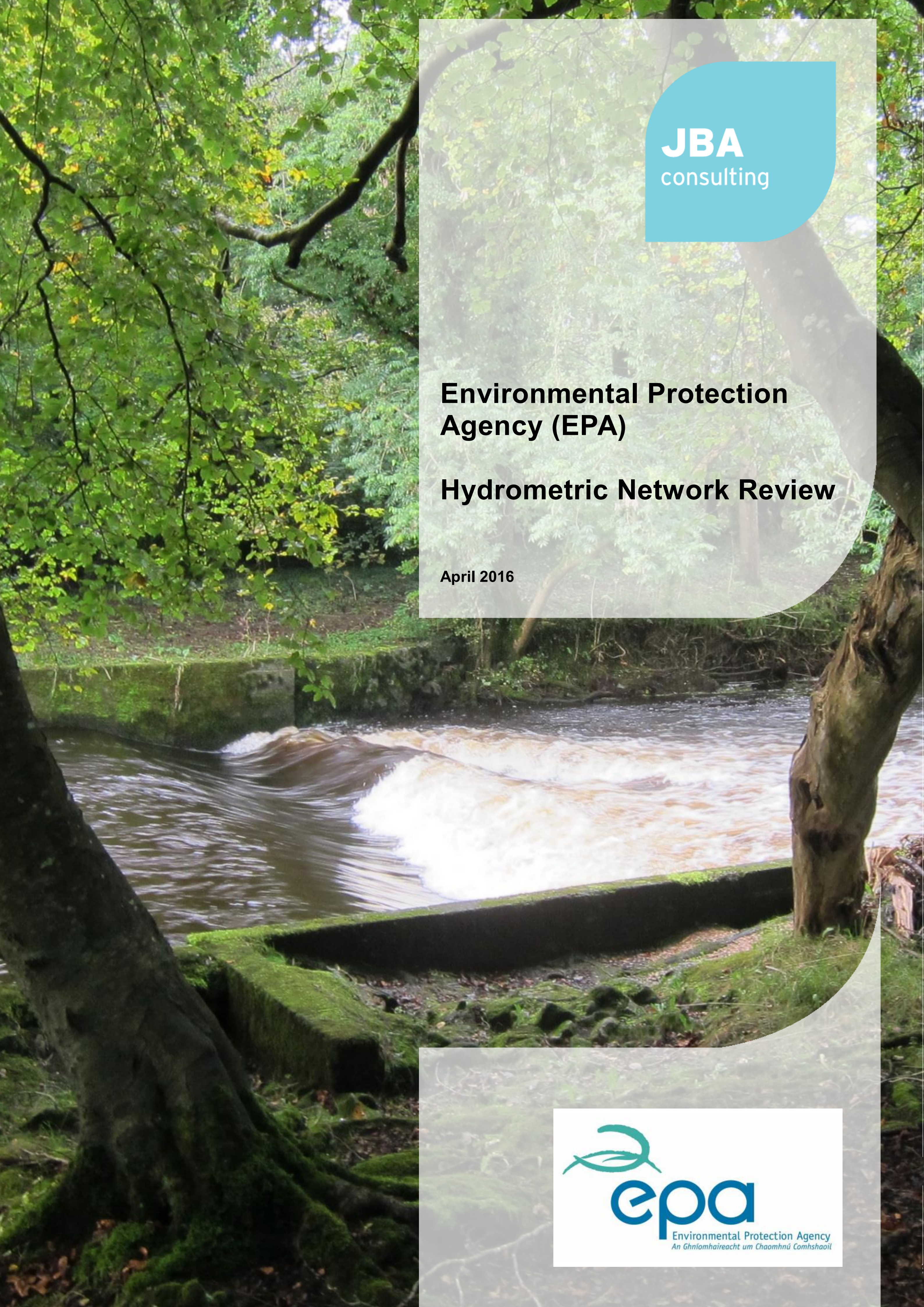

JBA consulting

Environmental Protection Agency (EPA)

Hydrometric Network Review

April 2016

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
v1.0 / October 2015		Conor Quinlan, EPA
V2.0 / December 2015	Updates following client review	Conor Quinlan, EPA
V3.0 / April 2016		Conor Quinlan, EPA
V4.0 / August 2016	Update requested from ESB to Table 5-2.	Conor Quinlan, EPA

Contract

This report describes work commissioned by Matthew Craig, on behalf of the Environmental Protection Agency (EPA), by a contract agreement signed 06/08/2015. The EPA's representative for the contract was Conor Quinlan. Maxine Zaidman, Barry Hankin and Tom Sampson of JBA Consulting carried out this work.

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Acknowledgements

JBA wish to acknowledge hydrometric specialists, managers and representatives from New Zealand, Wales, Scotland and Ireland whose input into this review has been essential. Specific mention to Alison Hanson of NRW, Richard Brown, Nigel Goody and Grant Kennedy of SEPA, Jeff Watson and Brent Watson from Horizons Regional Council, Jason Donaghy of Northland Regional Council, Kent Steel of Auckland Council, Martin Doyle of Tasmin District Council, Mark Harkness of Wellington Regional Council, Pete Stevenson of Otago Regional Council, Lisa Naysmith of Bay of Plenty Regional Council and Jochim Schmidt of NIWA.

We also wish to acknowledge the EPA and OPW staff who have provided information to this review. Matt Craig, Conor Quinlan, Anthony Mannix and Rebecca Quinn from the EPA and Peter Newport from the OPW.

1 Introduction

1.1 Background

The Environmental Protection Agency (EPA) is an independent public body established under the Environmental Protection Agency Act 1992. Its mandate relates chiefly to environmental protection and regulation, and specifically includes water quantity and water quality assessment, as well as broader duties related to air, waste and environmental management. Its jurisdiction includes the 26 counties that make up the Republic of Ireland.

As part of its duties under Section 64 of the Environmental Protection Agency Act (1992), the EPA is responsible for "a national programme for the collection, analysis and publication of information on the levels, volumes and flows of water in rivers, lakes and groundwater in the State". This role is undertaken by the Office of Evidence and Assessment (OEA) within the EPA, and implemented on a day-to-day basis by the OEA, Hydrometric and Groundwater Section.

The EPA is not the only organisation within the Republic of Ireland that undertakes the collection of hydrometric data, however. In line with their own objectives and regulatory drivers, the following bodies also maintain hydrometric networks:

- Local Authorities
- The Office of Public Works (OPW)
- The Electricity Supply Board (ESB)
- The Geological Survey of Ireland (GSI)
- The Marine Institute
- Met Éireann (raingauges only)
- Waterways Ireland
- Northern Ireland Rivers Agency

For some time the EPA has been working towards maintaining and operating a national hydrometric programme involving all the above organisations. Hydrometric network reviews are fundamental to this process and, under Section 64 of the 1992 Act, are required to be completed every five years. The EPA is now approaching completion of the most recent network review. Having established what monitoring is currently in place and coming to an understanding of the drivers and fitness for purpose of individual gauges within the existing networks, the EPA is now looking more holistically. Next steps will focus on establishing whether the network as a whole can be considered as fit for purpose in the context of international best practice, provide a better understanding of resilience, and evaluate how future requirements can be anticipated and accommodated.

1.2 Study aims and objectives

JBA have been commissioned to provide consultancy services to the Hydrometric and Groundwater Section relating to completing an assessment of three other comparable national hydrometric programmes and preparing recommendations regarding the configuration and governance of the Irish national hydrometric network.

The scope of the review includes river flow, river level and lake level measurement. Groundwater level measurement and sea/tidal measurement are not being considered within the context of the comparison. Rainfall gauge network governance is excluded from the scope of this study, however the potential benefits of increased integration of rainfall and surface water gauge networks are briefly considered.

The EPA provided some general criteria against which the Irish and case study networks should be compared (Table 1-2). The main objective to be drawn from the review is a better understanding of desirable and achievable features (governance, representation and management) of a representative and modern hydrometric network. Or more specifically to establish, for each of the case study countries, the following:

- Governance structures and resources employed to manage hydrometric networks.
- Hydrometric network densities to meet operational and strategic requirements.
- Common challenges faced by hydrometric network operators, and to gain an idea of the range of strategies that have been employed to address them.
- How the hydrometric network contributes to a wider environmental evidence base.

1.3 Case study countries

New Zealand, Scotland and Wales have been selected as the three case study countries as they have broadly similar population sizes, spatial extents, physical and climatic settings, and land use patterns to those seen in the Republic of Ireland.

The preference for "island nations" is based from our experience that hydrometric networks in many continental countries, even where those countries are small, are often focussed along major rivers that are much larger than those which might be seen in Ireland. Navigation and large-scale hydro-electric power generation are often the main drivers for hydrometric monitoring on such systems, and these are not necessarily as important from an Irish perspective, where the focus is more often on Environmental Protection, Flood Risk Management and Water Resources Management. A further consideration was the ease of obtaining the necessary network data and information on network governance, a focus being on collation of data within the timescale required for this project.

A summary comparison of their geographical characteristics with those of Ireland is provided in Table 1-1. Ireland and all three case study countries have very variable rainfall, land use and population distributions. Population and industry is concentrated around the main towns and cities, most of which are located on the coast. Many of the cities have developed at major river estuaries (e.g. Dublin, Limerick, and Edinburgh) or in sheltered bays (e.g. Galway, Cork, Auckland, and Cardiff). Rainfall is generally higher in upland areas and lowest in lowland areas sheltered to the leeward side (in relation to predominant direction of weather systems) of upland regions. The wetter regions tend to have less dense population in all countries. A more detailed table is presented in Appendix C.

Table 1-1: Characteristics of case study countries in comparison with Ireland

Characteristic	Ireland	Wales	Scotland	New Zealand
Area (1000 km^2)	70	21	79	270
Average rainfall (mm/year)	1120	1430	1520	1300
Population (million)	4.7	3.0	5.3	4.6
Population density (people/km^2)	67	143	67	17
Climatic Setting	Maritime influenced warm Temperate	Maritime influenced warm Temperate	Maritime influenced Temperate	Maritime influenced Temperate
Sources: various including Wikipedia and World Bank indicators (http://data.worldbank.org/indicator/)				

1.4 Approach to review

The review has been approached in three parts:

Part 1: Case Studies (New Zealand, Wales, Scotland).

An understanding of the governance and networks in the three case study countries was gained by carrying out detailed interviews with the local measuring authorities and regulatory bodies. The outcomes are reported in Part 1.

Part 2: Status and Requirements for the Irish Network

The current status and governance of the Irish network has been summarised in Part 2 in order to provide context for a comparison with the case study networks.

Part 3: Recommendations

Part 3 of this review has involved the development of recommendations for future management of the Irish network. These are focussed on sensibly aligning network governance with strategic and operational requirements for Ireland whilst remaining realistic about what is achievable practice based on experience elsewhere.

Table 1-2: Considerations as stated in the scope

- History of and reasoning behind existing network configuration (including number of organisations involved and nature of relationship between them, powers of direction to collect data, ownership of sites);
- Spatial configuration (number of sites, location relative to climate, topography, land uses);
- Configuration relative to population sizes;
- Data requirements (i.e. strategic and operational requirements including statutory, research, public information, recreational, OSPAR, European EA State of the Environment reporting, representivity for modelling purposes, Water Framework Directive, climate change etc.);
- Configuration of data collection within the networks (how hydrometric data is collected, size, number, configuration and workload of hydrometric teams, management structure and division of labour within hydrometric units, telemetry, existing and emerging stage and flow measurement technologies, outsourcing and insourcing, existing procedure for dropping or adding stations and at what level such changes are decided on);
- Data management and dissemination (central archives, open data, protocols);
- Plans for future developments and future requirements (especially within the EU and including Natura 2000 sites and appropriate assessment, barriers to migration such as control structures, future requirements of Eflows, hydromorphology, bathing water, planning issues and future equipment upgrades);
- Resourcing (including funding mechanisms, volume and target of resources employed, who pays for the network stations and data collection, is funding central, local or both, are stakeholders charged, water supply companies input, cost of stations and networks);
- Governance of hydrometric data collection (legal framework underpinning national hydrometric network between all organisations involved); and
- Network review processes and methodologies (how often are networks reviewed and is there an accepted methodology in each case).

2 Case study: New Zealand

2.1 Context

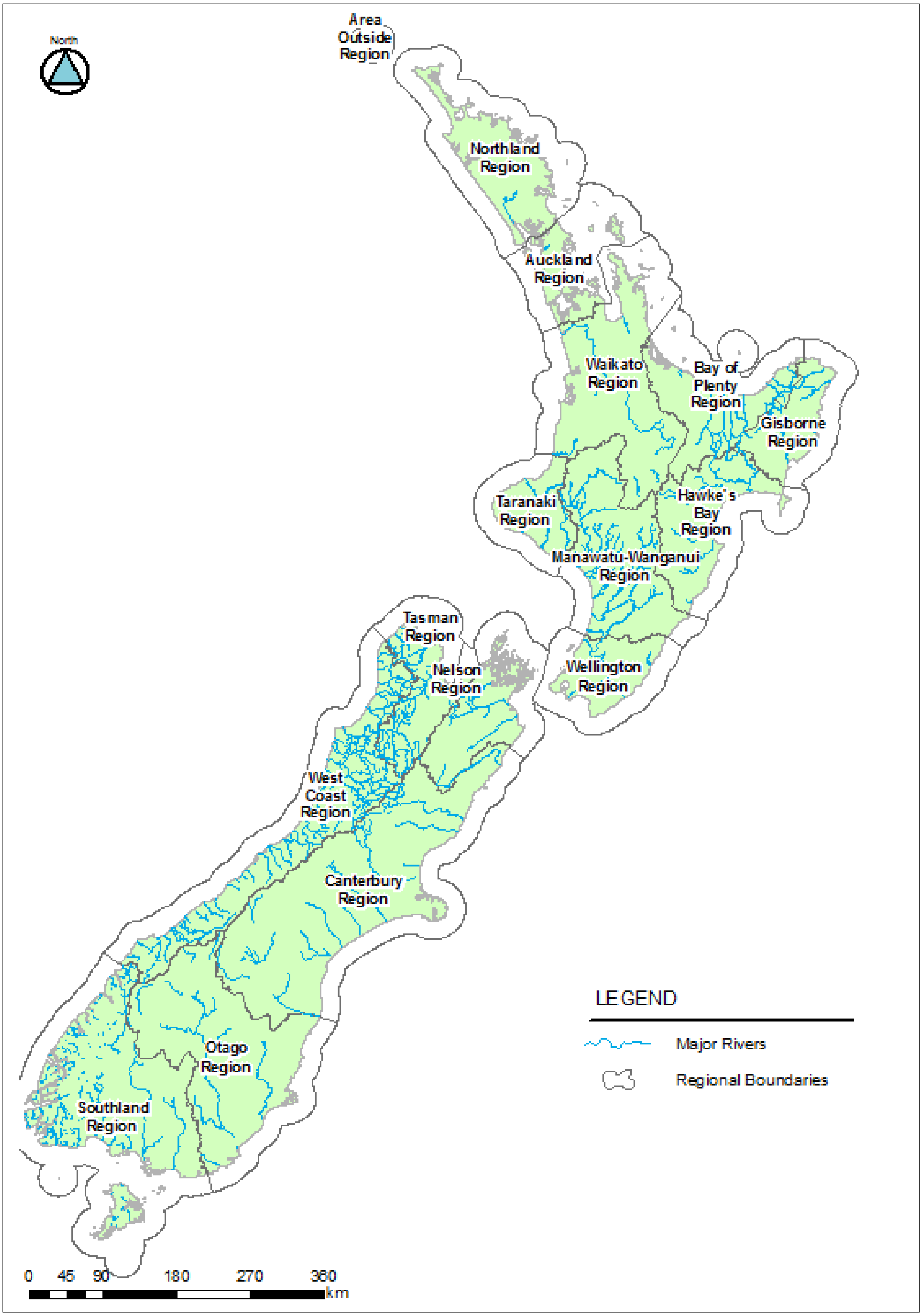
2.1.1 Geography and socio-economics

New Zealand is made up of two narrow, mountainous islands located to the south east of Australia. Overall it experiences a temperate maritime climate, but North Island leans towards a warmer more subtropical situation than the South Island, which has a cooler climate. However, the day-to-day weather is determined by wind and pressure patterns across the country and can be very variable. In particular the various mountain ranges provide a barrier for the prevailing westerly winds, producing a strong rainfall gradient which ranges between 600 and 1600mm per year. In addition, phenomenon such as El Nino and La Nina, directly affect the weather type and influence the variability of the climate. Rainfall is highly variable in New Zealand; annual average rainfall ranges from 440mm in Central Otago to 12000mm on the Southern Alps. Most of the central divide (North and South Island) receives in excess of 6000mm/annum.

The "taming" of New Zealand's water environment started in earnest when it became established as a colony of the British Empire in the 1840's, although the indigenous Maori cultures had been there at least 500 years previous to this. Many of the areas initially settled were in lowland coastal floodplains of ephemeral rivers, the rugged terrain preventing urban development of more mountainous regions. The initial focus was on providing security from flooding (through engineering schemes), the need for power (hydroelectric installations) and provision of irrigation, themes that still apply today. Less than 1% of the land area is currently urbanised and there is a significant positivity within the country towards environmental protection. Much of the 4 million population is centred on the larger cities of Auckland, Wellington, Christchurch, Hamilton, and Dunedin. At least half the land area remains as native vegetation, although a large proportion of the remainder is used as pasture for cattle and sheep.

New Zealand is a unitary state with, in addition to central government, sixteen regions for devolved local government, nine on North Island and the rest on South Island. The majority of these regions are run by Regional Councils (the top tier of local government), however five regions are administered by unitary authorities, which are district or city councils (the second tier of local government) that also perform the functions of Regional Councils. Regional and Unitary Authority boundaries are closely aligned to catchment watersheds (Figure 2-1), which facilitates the execution of the council’s resource and environmental management duties.

Figure 2-1: New Zealand Regional boundaries for local government



2.1.2 Regulatory framework

The Resource Management Act (1991) sets out the legislative regulatory framework for environmental management in New Zealand. The Minister for Environment has the responsibility for national policy statements, setting environmental standards[1] and monitoring progress of the implementation of the act. The New Zealand Environment Protection Agency (EPA-NZ) is the government agency responsible for regulatory functions concerning New Zealand's environmental management, although its remit relates only to "major projects". The EPA-NZ a relatively new agency that took over some activities previously carried out by the New Zealand Ministry for the Environment (MfE), although the MfE is still responsible for reporting on the state of the environment in New Zealand and advising government on environmental issues. However, neither the EPA-NZ nor the MfE carry out environmental monitoring, largely relying on other organisations to provide this data including hydrometric measurements.

Under the New Zealand Resource Management Act (1991) the 16 Regional Councils/ Unitary Authorities have a statutory duty to manage surface and groundwater (allocation, resource use consents, water quality and the management of flooding). The councils therefore carry out hydrometric monitoring for operational purposes in line with their duties under the RMA. Regional Councils operate independently and own all components of their networks (although gauging stations are viewed as public assets). Despite the separate governance it is understood that there is strong technical and strategic cooperation between councils, issues of national importance being coordinated either informally or more formally through initiatives like the National Environmental Monitoring Standards (NEMS) Programme. As Council boundaries are almost universally catchment boundaries there is no shared responsibility for river basins, however there is close cooperation around what is monitored and who is monitoring at or near council boundaries, as well as with regard to setting monitoring standards, sharing data and resources, and training.

The National Institute of Water and Atmospheric Research (NIWA), a Crown-owned but stand-alone company established to undertake scientific research and related activities, also maintains a limited hydrometric monitoring network at national level. In addition to unitary authorities and NIWA, private enterprises maintain a minor number of hydrometric monitoring stations. These include hydroelectric/energy companies, which maintain their own sites for consent monitoring and water management purposes and other industries which may also monitor in relation to water use management (e.g. irrigation).

2.2 Current hydrometric network configuration

2.2.1 Flow and level networks

Each Regional Council and the NIWA hold their own independent hydrometric network data. Direct comparison is difficult as attributes are not consistent between Regional Council datasets. There are approximately 850 river flow gauging stations within New Zealand and a further 130 level-only stations. The vast majority of these are telemetered. About 90% of these sites are maintained by Regional Councils and the rest maintained by NIWA.

For most of the 20,000 water abstractions nationally data is telemetered to regional councils directly or via third party service providers as hourly total water use. Automated compliance checking is increasingly put in place to ensure that extraction rates do not exceed consent limits and that abstractions cease or reduce when minimum flows are reached.

Some of the sites are located in remote locations or in reaches that are geomorphologically unstable, which can bring practical and technical problems in relation to frequent gauging to refine rating equations, equipment robustness, power generation, installation and maintenance. There are some locations that can only be inspected on an annual basis as access is by helicopter only. Given the above issues, a range of different methods are employed for stage measurement in New Zealand, and these include:

[1] http://www.lawa.org.nz/learn/factsheets/(nems)-national-environmental-monitoring-standards/

- Float and counter weight operated shaft encoders in stilling wells
- Submersible pressure transducers
- Pressure transducers (dry pressure transducers using a range of gas purge systems)
- Radar
- Acoustic sensors

There is no national benchmark sensor type, although there is a high level of dialogue between practitioners as to what works well and what doesn't. Devices from a range of manufacturers are utilised including Handars/Waterlog, Parascientific, Sutrons, Ott, Hydrological Services and Vagapuls instrumentation. Some key flood-warning sites have a second back-up sensor to improve resilience against failure.

For most councils measurements are recorded using a solid state data logger (typically IQuest or Campbell Scientific), but the majority of sites are also connected to telemetry system. The means of telemetry provisions varies between councils however. Most rely either on the mobile phone network (either via CDMA/calls or via GPRS/internet connections through a mobile phone or VHF/UHF analogue and digital radio networks). Landline connections, WIFI/ADSL and some satellite communications are also used where appropriate. For very important sites there may be two alternative forms of communication (e.g. radio with GPRS as a backup) to help reduce telemetry downtime. Some key flood warning sites have dual sensors and up to three communication options.

Flows are mostly derived using open channel approaches (i.e. stage-discharge ratings applied to level records). Spot flows are captured via wading with mechanical meters or flow trackers, meters suspended from cableways and ADCPs (either on a slackline, towed on a kayak or on a jet boat) depending on the site conditions. A number of instrumentation brands are used including RDI, Sontek and OTT. Spot gauging can occasionally be outsourced, although most councils have their own kit. Unstable bed controls (e.g. mobile gravel-bed rivers) means frequent gaugings are required to maintain ratings. At some stations velocities/flows are measured directly by acoustic devices.

2.2.2 Rainfall networks

There are around 1180 automatic rain gauges in New Zealand. The vast majority of these are operated by the Regional Councils however the New Zealand Meteorological Service also operate a network of about 80 automatic weather. Regional Councils provide hourly updates of rainfall data from their own stations to the Meteorological Service, which use the data for short term rainfall forecasting.

Real-time rainfall data is collected using tipping bucket gauges connected to solid state data loggers and telemetry. A range of different gauge makes are employed (OTA, Hydrological Services, Rimco) but these are all either 0.2mm or 0.5mm capacity buckets. Most councils have a preferred type of gauge manufacturer. As is standard practice, the majority of Tipping Bucket Raingauges (TBRs) are co-located with a check gauge (monthly or daily read gauges), except where it would not be practicable (e.g. no access to observer) or for some flood warning gauges. There are also a small number of standalone daily read gauges.

Figure 2-2: New Zealand regional council surface water network - North Island

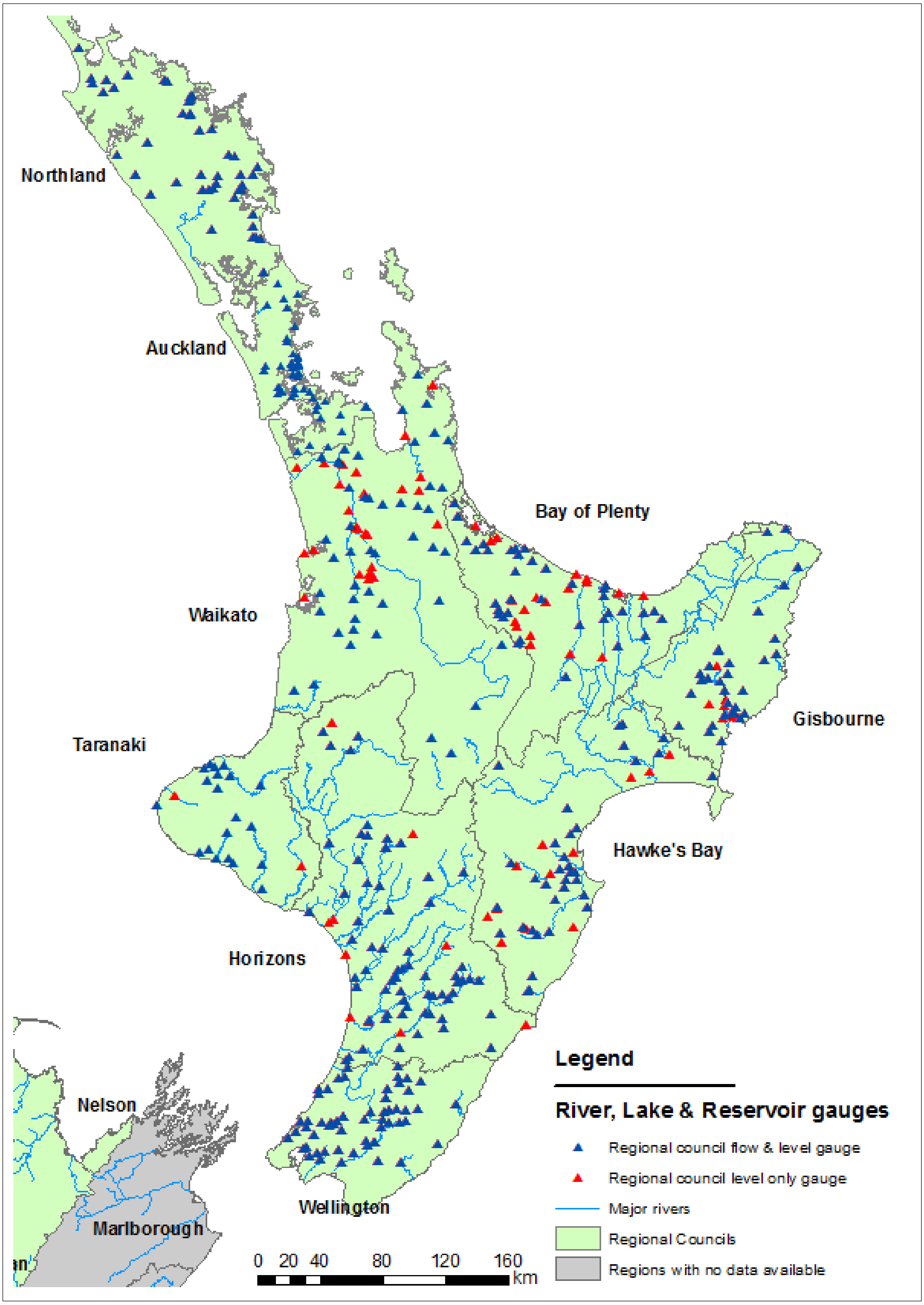
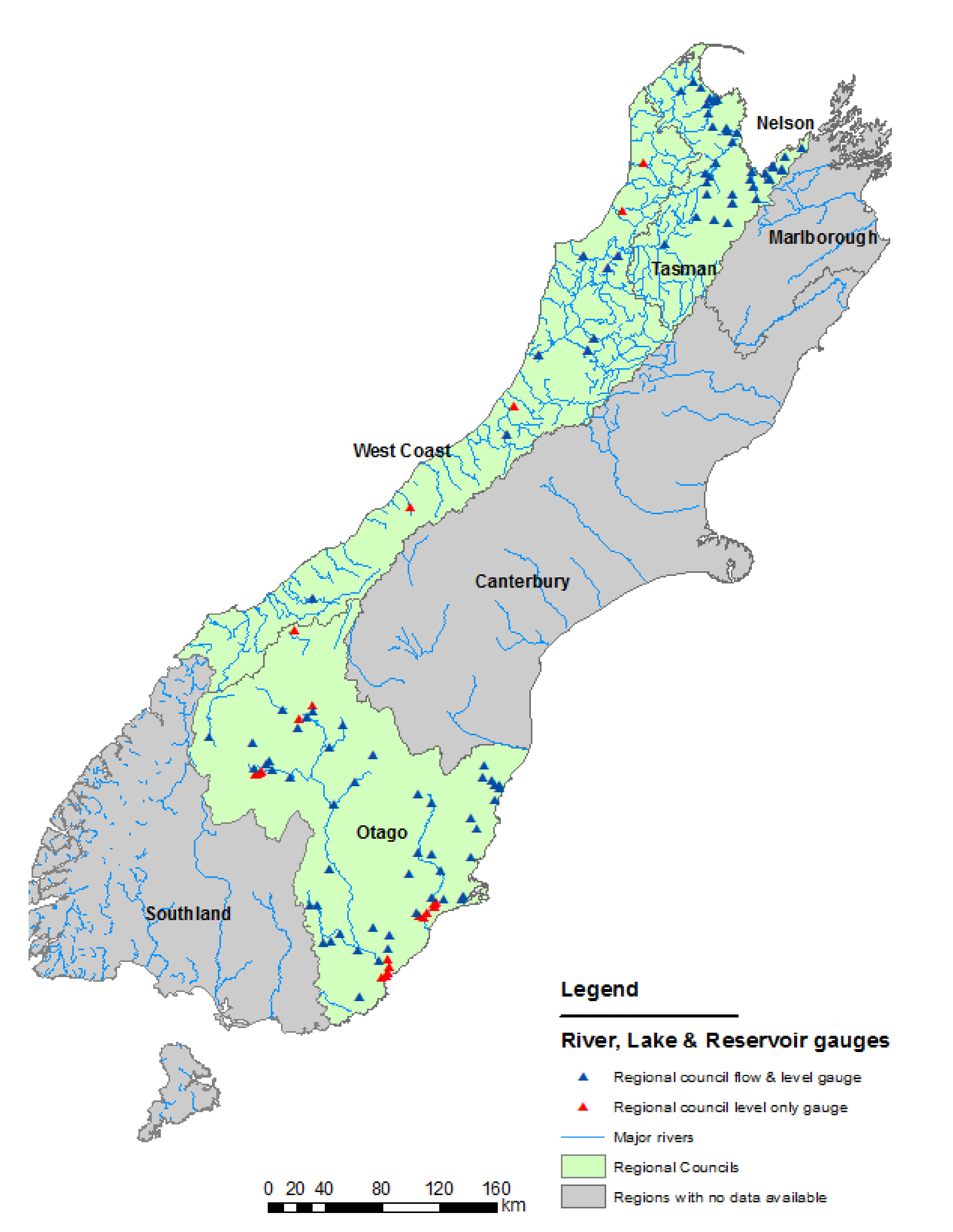


Figure 2-3: New Zealand regional council surface water network - Southern Island.[2]



[2] Excluding gauge date for Canterbury, Marlborough, Nelson, Southland and West Coast regional councils (spatial GIS data not received).

2.3 Hydrometric network governance

2.3.1 Operation and maintenance

Across all the Regional Councils, there are on the order of 125 staff working operationally in hydrometry. Team and staff arrangements vary between different councils and the information below summarises some of the team formation in selected regional councils.

- In Auckland the Environmental Monitoring and Reporting team is situated in a Research Unit that branches from a planning sector of the wider council. The team is made up of 16 cross discipline staff, of which 7 have more of a hydrology focus. Sites of similar geographic location are allocated to a single staff member, for example one staff member might have 10 flow sites and 10 rain gauges to manage, which would include planning site visits, undertaking of maintenance and completion of any relevant work relating to the allocated site.
- Northlands Regional Council has a team of six hydrologists who run approximately 20-25 sites. River sites are visited at a frequency of between six and eight weeks, the remainder of the time is spent or processing and cleaning data to archive quality. Rainfall sites are visited less frequently, every 2 to 4 months.
- Otago Regional Council's Environmental Monitoring team includes 10 staff spread over three offices. Each office services in the order of 14 water level, 10 rainfall and 11 groundwater sites. Environmental Monitoring staff are also involved in a number of short term science investigation projects and water quality projects. This set up is common across many councils.
- Westlands, which have only 14 gauges, have 1.5 technicians, each with their own set of sites they are responsible for maintaining. Site maintenance is carried out six week intervals at sites with vehicular access and annually at more remote sites where access is only by helicopters. Assistance if given by other staff within the environmental monitoring team.
- Horizons Regional Council has four teams. Three field parties that each have responsibility for sites within the region with the workload approximately shared and a data team responsible for the majority of data processing, archive maintenance and data analyses and information delivery internally and for external requests. There is a total of 16 staff plus one manager. These resources are responsible for 72 river gauges (of which 67 are flow gauges, the remainder being level-only) and 87 rainfall gauges (many of the raingauges are located at level and flow sites).

It is unusual for Regional Councils to outsource. Most councils have the expertise in house to maintain all hydrometric stations independently. Some councils use specialist skills for example telemetry/power installation needing specialist aerials or solar panels. Structural work is often contracted out (i.e. constructing new recorder towers or cableways. Occasionally gauging of large rivers and high flow gauging might be outsourced where H&S issues associated with use of boats and gauging from bridges which requires significant traffic management plans to be in place. This may be other publically funded organisations and private companies.

2.3.2 Funding sources and budget allocation

Each Regional Council is responsible for setting local rates and allocating budgets to regional priorities. Hydrometric networks are funded from an array of stakeholders, and rates. In Auckland council controlled organisations that use or rely on hydrometric data (e.g. Storm water, Consents, Civil Defence, Environmental Services, Natural Environment Strategy, Rural Fire) help to fund the capital and operational costs of the network through Service Level Agreements and even "own" some of the sites. For example a large portion of Auckland's network is owned and funded by the Council's Storm Water team. Some councils levy those protected by flood alleviation schemes, with elements of this funding being directed to maintenance of the hydrometric network. In Otago funding is primarily from general rates with only 3 flow sites part funded from consent holders. The majority of the council networks works are funded by rates.

In Horizons residents and organisations who abstract water are levied an annual charge which makes up about 30% of the Council's surface water science costs of which a substantial proportion is applied to hydrological monitoring.

Councils are required to plan funding for environmental and hydrometric monitoring well in advance. All councils are legally required to have a Long Term plan encompassing the next 10 years as a minimum. Some minor changes are made annually and the LTP undergoes a major review every three years. For example, the hydrological programme in the District of Tasman has funding planned to 2035 and allocated until 2025, which is a time frame well-aligned with an acute awareness of the values of long periods of uninterrupted record.

In terms of funding for NIWA sites, central government funding is not readily available for data collection unless that collection links into a specific research project. NIWA's hydrological activities are funded via central government the energy companies and other commercial clients.

Horizons Regional Council's operating costs for flow stations range between NZ$11,374 and NZ$18,654[3] per station per year. These costs include:

- Corporate and management overheads
- Depreciation on equipment and infrastructure
- All operational costs
- Travel costs and vehicle running costs
- Maintenance of our UHF digital radio telemetry network
- Equipment calibration
- Check gaugings
- Consumables, repairs and maintenance.

The exact figures depend on site location, site complexity (which can influence how many gaugings are required in a year to ensure all rating changes are identified) and vulnerability to damage from floods and vandalism.

2.3.3 Data management and quality assurance

There is not necessarily consistency in data archiving across the Regional councils. Some councils have specialist Data Services sections that have a specialist focus on data collection, management and quality assurance. In some cases quality assurance is governed by service level agreements that exist between the data section and end users (this often specify budget and resourcing requirements and are directly linked to funding requirements).

The Local Authority Environmental Monitoring Group (**LAEMG**) has been involved in the development of a set of National Environmental Monitoring Standards (NEMS) with the goal of maximising standardisation of data within the industry. These cover office and field work practice.

2.3.4 Dissemination of data

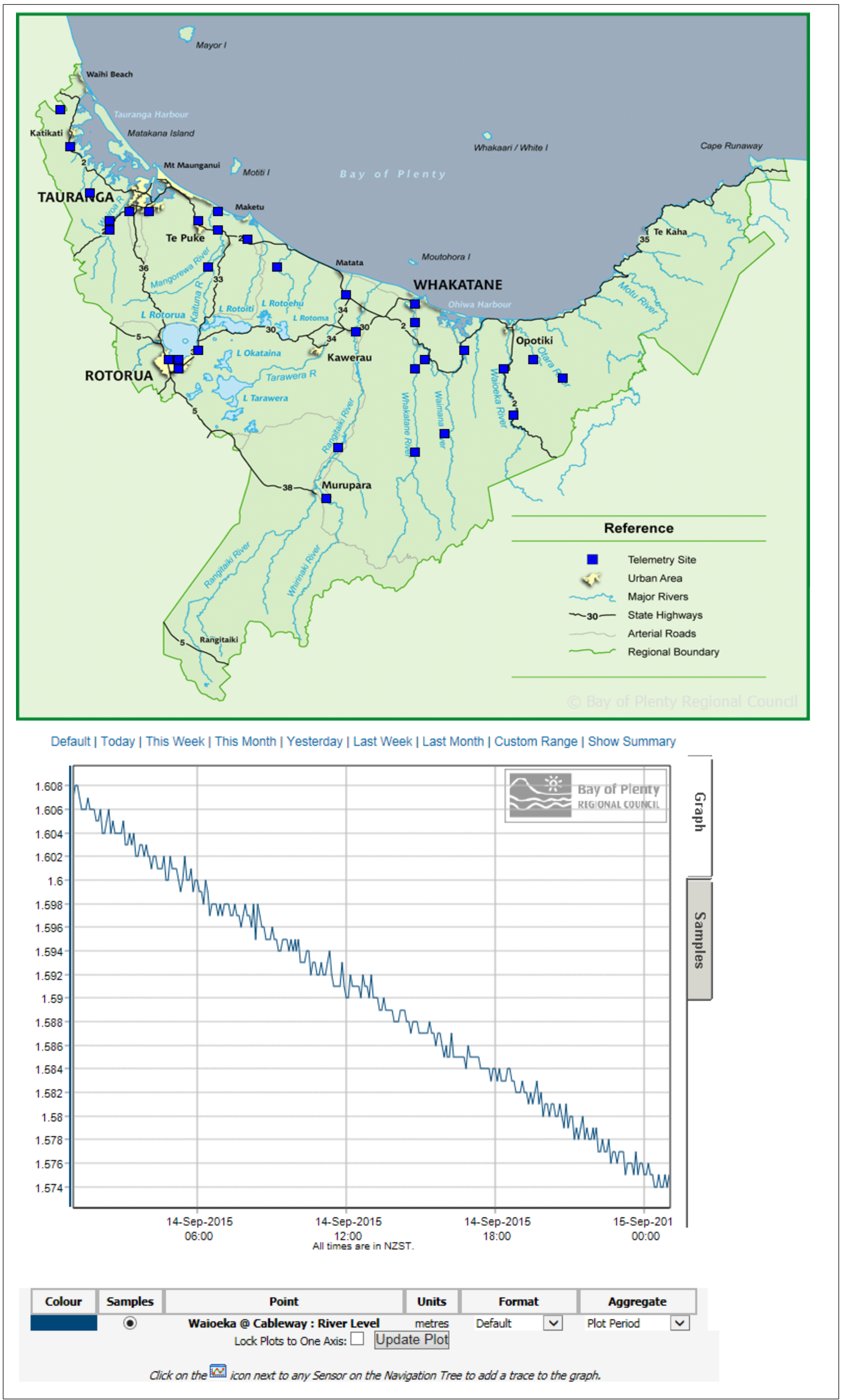
Public access to data seems to be the de facto position in New Zealand. All the Regional Councils provide access to hydrometric data, mostly in near-real time, via their websites. An example is provided below for Bay of Plenty Regional Council, from which a range of variables/sites can be interrogated. Historic data is also available for most of the stations presented.

The ability to deliver data publicly in near real-time allows informed decision making by other users; and increasingly data is being used to inform/control how resources are used in real-time (however this real-time use puts additional pressure in terms of quality, timeliness and a need for future funding in support). Also of note is that while some councils used to contribute some of their hydrological data to NIWA to enable them to maintain a national hydrometric archive this practice is decreasing and the focus is now on Open Geospatial Consortium (OGC) compliant federated data systems rather than on a single centralised archive. New Zealand has

[3] Based on an exchange rate of 1 NZ$ = 0.6Euro, this range is equivalent to 6,825 to 11,192 Euro.

made a lot of progress in this area over the last couple of years. The LAWA web site has been a strong driver for federated data systems and all of the near real-time data shown on the LAWA website is provided by such a system (http://www.lawa.org.nz/explore-data/manawatu-wanganui-region/water-quantity/surface-water-zones/manawatu/).

Figure 2-4: Bay of Plenty's interactive website[4]



[4]http://monitoring.boprc.govt.nz/MonitoredSites/cgi-bin/hydwebserver.cgi/districts/details?district=3

2.4 Hydrometric network drivers

2.4.1 Past influences

New Zealand has a long established hydrometric monitoring network, despite this being neither owned nor managed by a single agency, or as a single entity. To appreciate the current situation some understanding of network history is required. Nationally consistent standards for field hydrometry and data monitoring in New Zealand were pioneered in the 1950s after establishment of national hydrometric survey teams in 1951 within the Ministry of Works. During the 1960's Catchment and Regional Water Boards took responsibility for water management and maintained local hydrometric networks. A later consolidation exercise saw hydrometric monitoring responsibilities previously undertaken by the Ministry of Works passed to the National Institute for Water and Atmospheric Research (NIWA), a Crown-owned but stand-alone company established to undertake scientific research and related activities. However this was accompanied by a 20% cut in central government funding for hydrometric monitoring. This lead to local authorities (Regional Councils) further developing their own networks to meet operational drivers. However, the extent to which they choose to monitor was variable. Over the period leading up to the issue of the new Environmental Monitoring Bill in 2014 greater emphasis was placed on national consistency and improved regional council monitoring. It was therefore natural for Regional Councils to gradually take on a greater responsibility for hydrometric monitoring within their own areas. Regional Councils therefore presently undertake the majority of flow, level and rainfall measurement in New Zealand (currently about 90% of the total network), with NIWA in a supporting role. Further background is provided by Keane (2011).

2.4.2 Current network functions and drivers

The main regulatory obligations that influence Regional Council strategies for hydrometric monitoring are summarised in Appendix A1. Regional Councils have the responsibilities for integrated management of natural and physical resources, including decision making on:

- discharges of contaminants to land, air or water,
- water quality and quantity,
- the coastal marine area,
- soil conservation,
- land use to avoid natural hazards,
- investigating land to identify and monitor contaminated land, and
- preparing regional policy statements.

Regional Councils are also responsible for flood warnings, flood management and flood recovery as part of their emergency management function under the Civil defence Emergency Management Act, 2003.

Regulatory obligations are reiterated at local level, through local authority targets and plans. Specifically, the hydrometric network aligns with the council's obligation to monitor water quantity and disseminate the data effectively, which is achieved via state of the environment report cards, technical publications and a range of other tools.

From an operational perspective there are a wide range of drivers for maintaining networks. Unitary Authorities have a wide range of responsibilities that are dependent on accurate and reliable hydrologic information including:

- design, construction and life-cycle management of public infrastructure such as roads,
- potable water supply,
- stormwater and wastewater management,
- flood warnings,
- drought management,
- environmental protection, and
- water resources allocations.

The most important drivers vary from council to council, depending on local issues. For example:

- In Tasman District, water shortages in summer droughts and environmental quality of coastal waters supporting shellfish are two key concerns.
- In the Manawatu-Wanganui Region, which is governed by the Horizons Regional Council, there has been a substantial intensification within the agricultural sector, which has put pressure on water resources for irrigation, and also led to water quality problems primarily due to an increase in nitrate leaching. Hydrometric data also supports flood protection schemes, water allocation and hydroelectric assessments.
- In Northlands flood forecasting expectations continue to grow and this has resulted in a number of new level and flow installations
- In Auckland, there is a focus on flood warning provision, especially to urban areas which are rapidly expanding. Raingauges and flow gauges provide this surface. Other sites have origins in other functions such as storm water, water care and rural fire.

A primary driver for operational growth across all councils in recent years has been to provide public information for consent holders to manage to minimum flows through the Water Plan process (a large number of rivers and streams have minimum flow thresholds at which water abstraction must cease or reduce). Some hydrometric monitoring is undertaken in support of The Resource Management (Measurement and Reporting of Water Takes) Regulations 2010, which were enacted to ensure consistent measuring and reporting of abstractions and also to[5]:

- *"enable water users and regulators to easily determine compliance with water take consents*
- *provide accurate information about actual (consented) water taken in any catchment (including the catchments of groundwater resources)*
- *improve allocative efficiency through accurate measurement of water abstracted for consumptive uses*
- *ensure the comprehensive uptake of water measuring in a cost effective and timely way".*

These regulations require measurement of all abstractions greater than 5 litres/second, in terms of record keeping, water measuring system and devices, verification and reporting.

Due to the hydrologically complex landscape data transfer between catchments is extremely difficult and inaccurate. With the increase in water use catchment managers in New Zealand rely upon accurate real time flow estimates to manage water abstraction with a high degree of confidence. The current understanding is that restricting irrigation or abstraction for an urban water supply based on modelled flows would not be acceptable. Water abstractions are required to reduce when minimum flows are reached and this is the case for most Regional Councils. It is the responsibility of the District or City Council to instigate and enforce reduction in consumer consumption as they deem necessary to ensure that they can maintain adequate supply.

2.4.3 Environmental reporting

Environmental monitoring is strongly championed in New Zealand and traditionally many hydrometric sites are co-located at freshwater monitoring sites where other water quality or ecological monitoring is undertaken. The idea of an integrated approach was strengthened by the Environmental Monitoring Bill in 2014, in which greater emphasis was placed on national consistency and improved regional council monitoring, and by the creation of Land Air Water Aotearoa (LAWA), which is a collaboration between Regional Councils, Ministry for the Environment and research institutes. Hydrometric data strongly underpins environmental reporting activities, through the data provided directly to LAWA by Regional Councils, but also through the NIWA network.

National state of the environment reporting includes a number of freshwater topics (Table 2-1), which are driving what data needs to be captured within the environmental evidence base, including hydrometric measurements. A review of the river environmental monitoring network

[5] http://www.mfe.govt.nz/fresh-water/regulations-measurement-and-reporting-water-takes#3

in 2014, by the Ministry for Environment recommended 80 new river monitoring sites for water quality and ecological monitoring in order to improve the representativeness of monitoring of River Environment Classification (REC) in New Zealand. The review made no comment on the number of hydrometric gauges in the network.

Table 2-1: Draft freshwater topics for national state of the environment reporting

Type	Topic
Pressure (human activities that affect condition)	• Contaminant discharges to freshwater • Land cover in freshwater catchments • Landscape and form of freshwater catchments • Climate effects on the freshwater environment
State (condition of)	• Condition and physical characteristics of freshwater habitats • Presence or abundance of freshwater plants and animals • Biological productivity of lakes and rivers • Chemical properties of river water, lake water and groundwater • Freshwater sediment, clarity, quantities and flows • Organisms that cause disease or illness
Impact (of condition on ecology)	• Impacts on biodiversity
Impact (of condition on economy)	• Economic impacts related to primary industries • Energy generation and mineral extraction • Urban freshwater use • Impacts on tourism
Impact (of condition on public health)	• Acute health effects related to fresh water quality
Impact (of condition on culture and recreation)	• Access to and use of freshwater environments for customary materials and food • Cultural significance of the freshwater environment to Maori • Recreational use of the freshwater environment

2.4.4 Strategy for managing network change

Flood warning and flood management responsibilities through the Civil Defence Emergency Management Act has driven real time data collection through the use of telemetry. The Resource Management Act sets out the driver for monitoring for environmental management and water quality. Operational requirements are therefore the primary driver in terms of network development and management, however there is significant overlap in uses on many sites within the network.

Some councils maintain a relatively high default level of monitoring activity/infrastructure that will cover potential future use and meet national environmental monitoring standards (NEMS), however this is not the case across the board. It's an approach of 'a little more investment up front saves costs in the long term', an example being that by default automated monitoring sites are telemetered leading to reduced loss of data and staff being able to target specific events/conditions. New Zealand is also at the forefront of trying any new technology that looks like it might provide cost and resource savings whilst preserving or improving accuracy. There are generally good relationships with suppliers and some Regional Councils operate a R&D programme to carry out testing (sometimes in parallel with product development). Some footage of recent testing is shown at https://www.youtube.com/watch?v=jqCQIcf93A8 .

As each council operates independently network reviews are carried out in-house and often without any documentation. Network reviews are rare and continual growth in networks and staff resources is the reality within Regional Councils. Having said that, some councils do regularly review the more strategic/long term stations within their networks to ensure justification is still there. A review on a three yearly basis is considered appropriate. These are seldom formally documented or released outside of the council.

Some councils are starting to develop comprehensive asset management plans for their hydrological infrastructure, however comprehensive Asset Management Plans (AMP) for all councils are a number of years away. Wellington Regional Council led the way and have an initial AMP.

Example of Network Review for a Nationally Representative Network

New Zealand Ministry for Environment review of NIWA network representiveness

In 2014, the MfE published a review on the network representiveness of gauges used in the NIWA national state of environment reports. The driver for the report was to ensure that river gauges used in national reports do not under or over represent certain types of river, which could lead to inaccurate estimation of large scale water quality conditions. For example, with too many urban stations, water quality on a national scale may be reported as being worse than reality.

The review used a simplified version of the New Zealand River Environment Classification (REC) scheme to classify all river stretches in the country. The number of gauges per classification was used to determine how representative the existing gauge network is for national reporting. Consideration of statistical robustness is also taken into account to ensure that uncommon river types do not have too few gauges for statistical analysis of data.

It was decided that more gauges are required for some river types. Closing sites on over-represented river types would not be appropriate as these gauges may have specific local requirements. Further, excluding sites from the national analysis was not recommended.

Candidate locations for new sites were identified based on the following criteria for GIS analysis:

- Stream order 3 or higher (so new sites are comparable to existing sites)
- Estimated mean annual flow greater than 100 l/sec (to compare to existing sites)
- Road within 100m of any point on reach (for easy access)
- A natural reach with at least 70% of upstream catchment natural land cover (so new sites are less vulnerable to land use change and urban development)

Stakeholders were involved in the screening of each candidate site in turn to recommend 80 new sites. Many candidate sites were rejected as they were too close to existing sites in the same river type.

Recommendations for new sites to improve representativeness in the New Zealand river environmental monitoring network. MfE (2014)

2.5 Summary statistics

The following tables summarise the hydrometric network in New Zealand. References to hydrometric staff include all staff who undertake a hydrometric role, including management. In many of the Regional Councils hydrometric team members may undertake a number of hydrometric technician roles and other related activities such as data management and other hydrology work.

2.5.1 Density of monitoring stations

Table 2-2 presents some network density statistics for New Zealand as a whole. These give a flavour of the overall degree of provision of hydrometric data in the country. In acknowledgement of the potential multiple uses of flow data, in New Zealand significant emphasis is placed on measuring flows, with comparatively few gauges installed with the intention of measuring level-only. An average of 3.2 river flow gauges per 1000km^2 represents a reasonably sparse network but this is slightly skewed by remote, unpopulated areas remaining ungauged whilst populated coastal regions have better network coverage.

On average each staff member is required to maintain around 10 flow gauging sites and 13 raingauges, but typically these staff are responsible for data management and archiving of recorded data as well as field duties. This represents a reasonably significant workload.

Table 2-2: Network density statistics for New Zealand

Characteristic	Flow	Level-only	Rainfall
Total active gauges (i.e. that currently supply continuous data)	850	130	1100
Percentage telemetered	95%	95%	95%
Active gauges per 1000 km^2 area	3.2	0.48	4.1
Active gauges per million people	200	30	259
Active gauges per FTE hydrometric staff	10	1.5	13
Notes: Figures from New Zealand Authorities. Almost all council staff working in hydrology units also undertake a range of other work such as air quality monitoring, water quality monitoring, groundwater monitoring, operation of Fire Weather stations, bathymetric surveys, as well as many other varied duties. Full Time Equivalent (FTE) staff numbers have been adjusted to reflect this with 85 staff undertaking field based hydrometric work as well as other activities.			

2.5.2 Regional variations in monitoring density

The New Zealand network is operated in a federated way. There are differences between densities of networks operated by different regional councils. Table 2-3 reports a detailed network density breakdown on a council area basis. The totals do not sum to the national figures reported above as only 11 of the 16 Regional or Unitary Councils are included.

Table 2-3: Regional network density statistics in New Zealand- flow gauges

Region	No. flow gauges	AREA (1000 km²)	Population (million)	Gauges per 1000km^2	Gauges per million people
Bay of Plenty	38	12.2	0.27	3.1	142
Taraniki	20	7.3	0.11	2.8	18
Auckland	50	4.8	1.41	10.3	35
Gisbourne	30	8.4	0.04	3.6	687
Horizons	67	22.2	0.22	3.0	301
Northlands	41	12.5	0.15	3.3	273
Otago	50	31.9	0.2	1.6	247
Tasman	41	9.6	0.05	4.3	870
Waikato	78	24.6	0.4	3.2	193
Wellington	59	8.1	0.47	7.3	125
West Coast	12	23.4	0.03	0.5	400
Hawkes Bay	36	14.2	0.15	2.5	240

3 Case study: Wales

3.1 Context

3.1.1 Geography and socio-economics

Wales is bordered by England to its east, the Irish Sea to its north and west and the Bristol Channel to its south. Its total area is 21,700km^2. Wales is part of the United Kingdom, but has had a devolved government since 1998. The population is just over 3 million, Cardiff, Newport and Swansea being the most populated areas.

Having over 2700km of coastline, Wales experiences a temperate maritime climate, with rainfall widely above 1500mm per year in the south and west, but dropping to around 800mm in the north and east. There are strong rainfall gradients with elevation and in the more upland or mountainous areas such as Snowdonia and the Brecon Beacons average annual rainfall is widely above 3000mm. The main river basins include the Severn, Wye, Dee (which all flow from Wales into England), the Usk, Conwy, Teifi and Towy (which all discharge to the Welsh coastline).

Land use is varied but mainly includes urban (10%), forest and woodland (15% by area) and grazing (70%) for livestock. The poor soils mean agriculture is limited with only 1% of land used for agriculture.

3.1.2 Regulatory framework

Natural Resources Wales (NRW) (also known as Cyfoeth Naturiol Cymru) is the agency responsible for environmental monitoring in Wales. NRW is a new body that only became operational in 2013, being formed by a merger of the former Countryside Council for Wales, Environment Agency (Wales) and Forestry Commission Wales. It is sponsored by the Welsh government.

NRW inherited hydrometric monitoring assets, staff and responsibilities from the Environment Agency of England and Wales, which was established in 1996 to replace the earlier National Rivers Authority (established 1989) itself a direct result of the 1989 Water Act which separated the existing regional Water Authorities into privatised water supply companies and regulatory functions governed by DEFRA. Operationally NRW is divided into two directorates, one covering North and Mid Wales and one covering South East and South West Wales.

With Welsh political borders not reflecting river catchment boundaries (e.g. River Severn and Wye catchments cross the Welsh-English border) NRW has arrangements with the Environment Agency in England regarding reciprocal data exchange over monitoring along the border region.

3.2 Current hydrometric network configuration

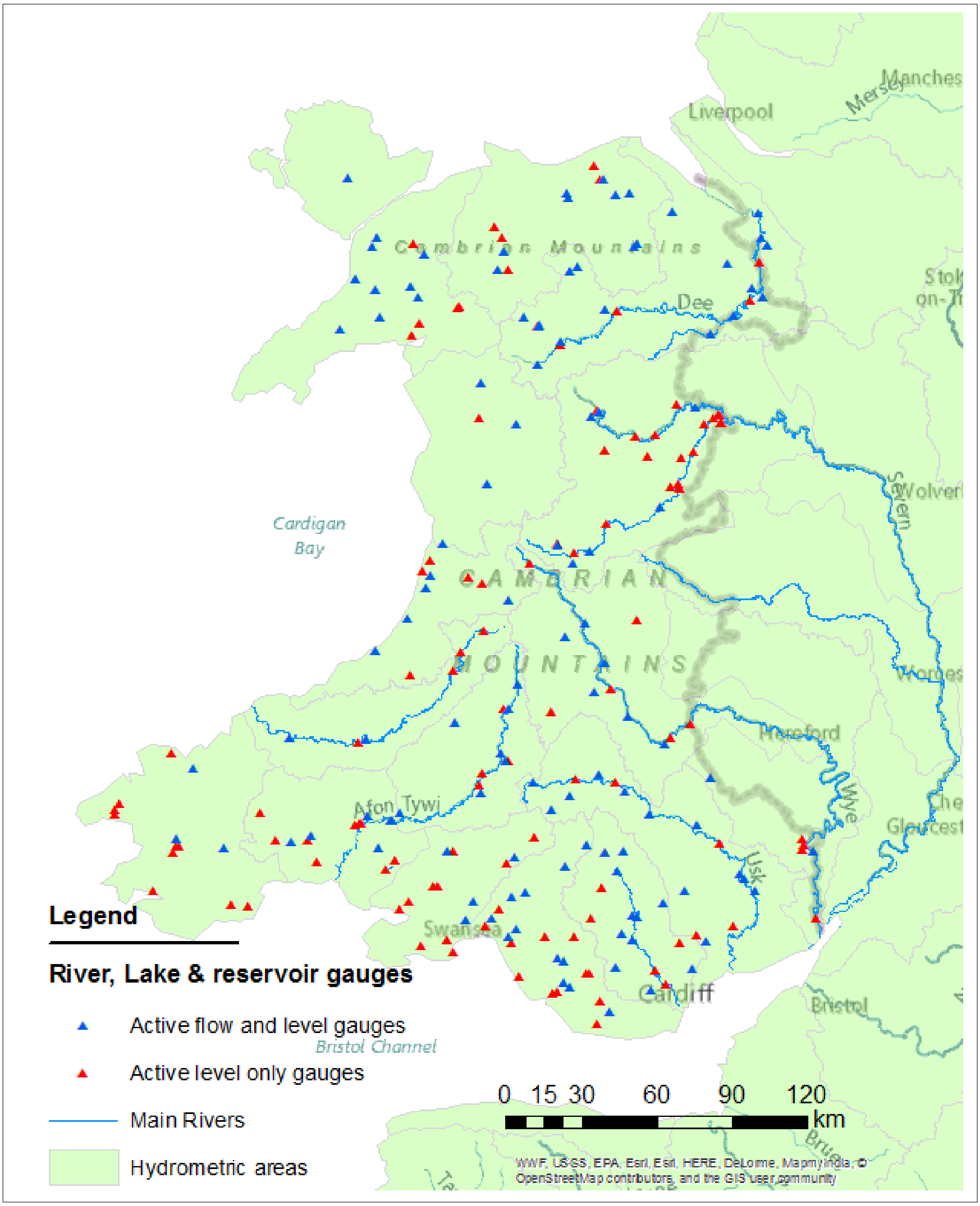
Figure 3-1 illustrates the locations of flow and level gauges within the Welsh network. In total there are 128 river flow gauges and 199 level-only gauges. The figure also shows the gauges with the River Severn catchment within Wales that are not maintained by NRW, and those in the Wye catchment in England that are maintained by NRW.

Surface water monitoring is also undertaken privately by Welsh Water and other water supply companies, universities and research institutes for private or academic purposes. A small number of gauging stations in the Upper Severn catchment are operated by the Centre for Ecology and Hydrology; data is supplied to NRW for inclusion in their databases but not in real time.

There are 211 TBR gauges in the NRW network (some with co-located check gauges) and a further 5 standalone daily storage gauges. The raingauge network is in addition to the Met Office network and has grown to meet flood forecasting and warning requirements.

The Met Office also operates a number of its own rain gauges in Wales. These are used as primary synoptic stations for daily weather forecasting. Rainfall data collected by NRW (previously Environment Agency gauges) is also supplied to the UK Meteorological Office's (Met Office) national rainfall archive, which provides a valuable source of data from across the UK relating to rainfall.

Figure 3-1: Welsh surface water network



3.3 Hydrometric network governance

3.3.1 Operation and maintenance

NRW hydrometric monitoring activities are split over four teams, known as Hydrology and Telemetry (H&T) teams with 20 staff. Three of these are "operational" or "field teams" delivering field activities including field data collection, site management and maintenance, fault response, small site installation and project management. The field teams also provide advice to customers (external and internal data users) on quality of data. Each team has a different spatial coverages as follows

- North and Wales and the Upper Severn team (managed from NRW's North and Mid Wales Directorate).
- South East Wales team, which covering Eastern Valleys, Welsh Wye and the Usk (managed from NRW's Operations South directorate)
- West Wales team, which covering the Western Valleys (managed from NRW's Operations South directorate)

Team activities in each case are managed by the Area Flood & Coastal Risk Manager – this isn't about functional alliance but was a decision made as the H&T teams manage assets there was seen to be a synergy and it balanced structures. This may be reviewed in future.

The fourth team is the National H&T team based in NRW's National Services Directorate. This team has a more strategic role, being responsible for managing the Wales telemetry system, managing hydrometric databases (NRW use a database called WISKI7), data validation, rating analysis, customer data provision, liaison with internal & external customers, determining procedures and policy, setting of standards, implementing new systems, determining & setting strategy, representing the organisation on national & international groups, large scale project management and providing specialist advice.

Much of the current organisation framework is inherited from Environment Agency structures and is likely to change as NRW evolves.

Currently no routine hydrometric monitoring work other than some minor maintenance in North Wales is outsourced. There has been some historic experience with outsourcing and the experience has not been positive, and the management time associated with managing the work and the data has been disproportionate to the benefit of the contract. Field staff are, in the vast majority, trained to carry out all field activities, from basic field work, site maintenance, and through to most telemetry tasks and so can carry out virtually all field tasks to minimise the frequency of site visits – NRW operate a risk based approach to site visit decisions and so try to avoid needless journeys.

Stage is predominantly measured using stilling wells in conjunction with shaft-encoders or pressure transducers, where as a variety of methods are used for flow measurement. These include flow measurement structures, transit time ultrasonics and stage-discharge rating curves, the latter of which is the most widely applied method. Stage-discharge behaviour is informed by spot gauging and NRW use current meters (manual wading/ suspension from cableways) or ADCPs to obtain these. Stage is measured at all flow gauging stations, plus all level-only sites.

The majority of sites are monitored in real time. NRW operate a Schneider Electric telemetry system that transfers the data to a Kister AG WISKI7 archive that went live on 1st April 2007. NRW are still in the implementation phase for the system and still have the backup of the Environment Agency's WISKI6 archive until March 2016.

3.3.2 Funding sources and budget allocation

Funding for hydrometric activities ultimately comes from the NRW functions receiving the core service. This is predominantly from Flood Risk Management Grant in Aid (funded from central UK Government) and Water Resources Charges (levies associated with abstraction and discharge licenses), with a small proportion from Environmental protection and Fisheries Grant in Aid.

Currently hydrometric monitoring within NRW operates on a budget basis whereby there are separate operational budgets and the general rule is that the budgets are on a downward slope (and have been for a number of years) but there is no target cost for operating the network.

However NRW is currently undertaking a review of its monitoring activity and as part of this are looking to better understand baseline costs of the monitoring network costs. This is likely to lead to target operating costs being defined in the future. We have not been provided with a breakdown of the levy and license fee costs and allocations.

3.3.3 Data management and quality assurance

Data are stored on a central archive, based on Kister's WISKI7 hydrometric database software.

NRW have their own internal standards and service levels to which they work, mostly inherited from Environment Agency Wales. These are closely aligned with BS/ EN/ ISO standards. Secondary and tertiary validation is carried out in WISKI with internal data codes used to flag stations having data quality issues or periods of missing data for example.

For those raingauge sites that are registered with the Met Office, NRW provides the data to the Met Office and received back this in an independently validated state.

3.3.4 Dissemination of data

NRW is signed up to the principles of "OpenData", but does not currently have the facility to publish its data in this way. However via a quirk, most of NRW's hydrometric data is currently published via the English Environment Agency's (EA) open data feed on the .gov.uk website.

NRW have three ongoing strategies for future publication of OpenData:

i) A replacement for the EA's River Levels on the Internet service is due to go live in the next six weeks giving the public access to updating river level information for over 200 of NRW's river monitoring sites. The intention is that over the next few years that this will potentially also display other data that NRW obtain on a frequent basis such as river flows, rainfall and soil temperature data.

ii) The flood risk functions within NRW are looking at the development of an API for professional partners to access live river level, flow and potentially rainfall data in an easily accessible format for their use.

iii) Finally, NRW in association with Welsh Government has developed a portal, “Lle”, which will be used as the OpenData portal for a variety of NRW data streams. The intention is for NRW data to be routed through “Lle” in the near future.

NRW supply river flow data for selected sites (about 150 stations) to the Centre for Ecology and Hydrology (CEH) for inclusion in the UK National River Flow Archive (NRFA). Data exchange and associated data quality review is formalised through a Service Level Agreement. Similarly some rainfall data is provided also provide to CEH to facilitate the National Hydrological Monitoring Programme. NRFA data is made publically available through the NRFA website (http://nrfa.ceh.ac.uk/data/search) and passed on to universities and other wider research initiatives.

Formally known as HiFlows-UK, the NRFA Flood Peak database is also made available publically through the NRFA. It is mainly intended to support Flood Estimation Handbook procedures and consists of annual maximum flows and other data from gauging stations deemed to be provide good quality measurements during high flow periods. A number of NRW stations are included in this database.

3.4 Hydrometric network drivers

3.4.1 Past influences

Early network growth in Wales was almost entirely to support Water Resource needs. Since the 1990’s, however the driver has been predominantly flood risk management, with flood warning needs being a particular impetus for network growth. The numbers of new sites increased following the Bye Report and the Pitt Review outputs. Wherever possible existing sites are repurposed and used for multiple purposes so Wales has a very high level of multiple client sites. In the last 15 years there have been an increasing number of sites being put in for flood forecasting purposes. Additionally, NRW have recently installed a number of sites that are used to automatically trigger warnings for communities. Before any site is installed there is a review of the current network and whether existing sites can deliver the required need. Unfortunately, the geography of Wales means that this is often not possible.

There are gauges within the inherited Welsh hydrometric network with important historical legacies. There are many sites that need to be maintained as key members of hydrometric pooling groups for ungauged catchments in Scotland and England.

3.4.2 Current network functions and drivers

The Welsh network has been focussed on delivering functional utility rather than geographical representation. Some sites represent rare site and topographical characteristics, but do not have strong operational drivers, and could be threatened unless there value is recognised. There are a number of areas and catchments that are not currently measured but this is because there has, as yet, been no viable justification for the investment. There are a couple of areas where the rainfall network is considered not to be of adequate density and NRW are considering whether this can be addressed but this is unlikely in the current financial climate.

European reporting, OSPAR etc. takes its information from the existing network. The sampling sites used for European reporting tie in well with NRW's current flow network and so it is possible to reference the data points to existing sites. Further when preparing work for the Water Framework Directive it was determined that NRW's current network was adequate to deliver the data requirements so few adaptations or additions have been required (Figure 3-2). A number of NRW sites contribute to climate change studies and national hydrometric monitoring programmes (Figure 3-3), and additionally NRW manages the ECN and ECBN network sites and so has an additional responsibility in this regard.

As yet, NRW have had few or no requests to remove structures that are considered to be acting as barriers to migration, though extensive discussions have taken place. NRW have however carried out an extensive programme of adaptation installing fish passes, baffles and eel passes at a significant number of their structures.

NRW are currently beginning a network review and it is likely that the network configuration in Wales will change as a result of this but as yet NRW do not have a sense of the likely outcome. The main driver for this review is linked to upcoming changes in funding and the need to drive revenue reductions.

Figure 3-2: Gauges per WFD catchment in Wales

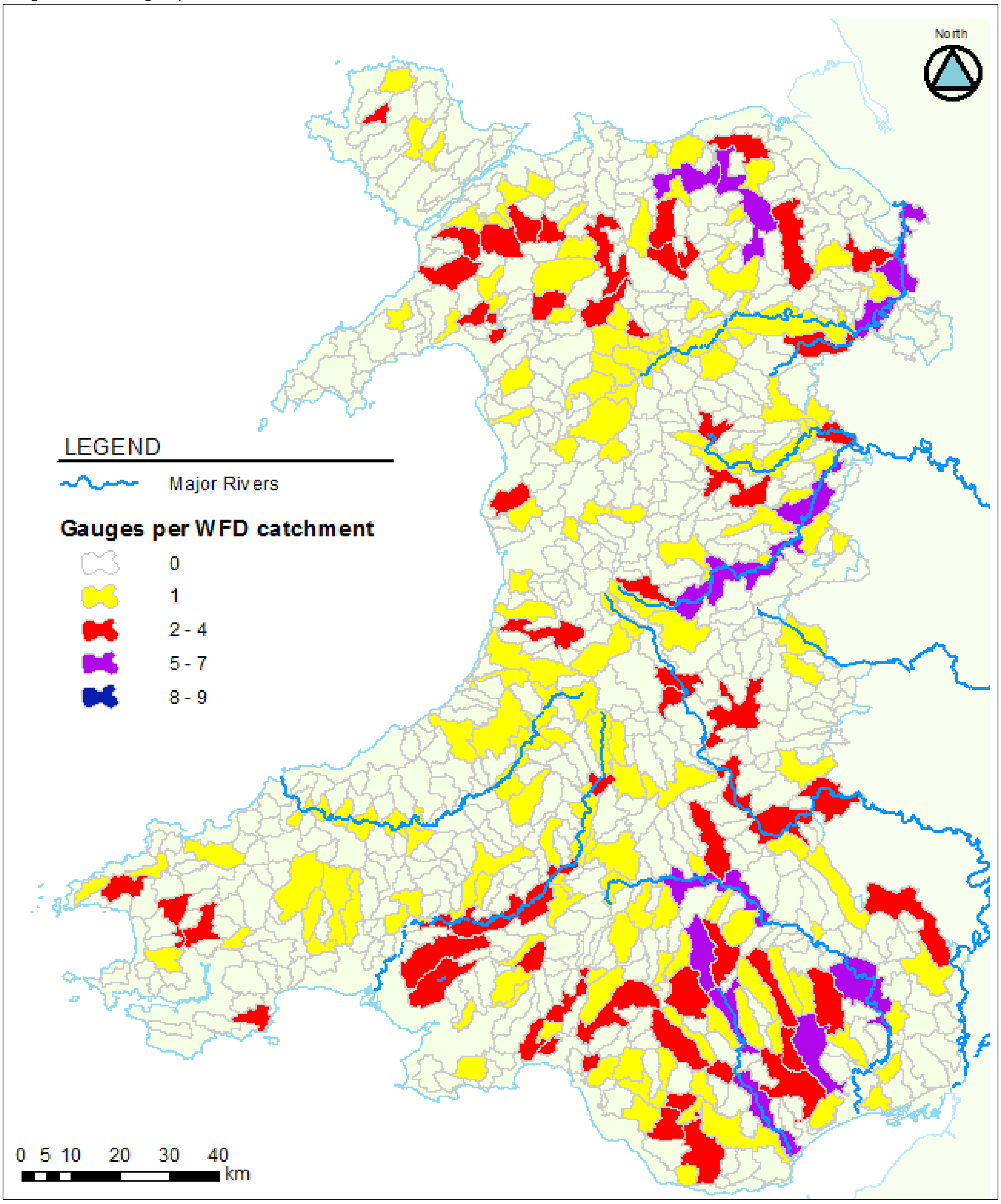
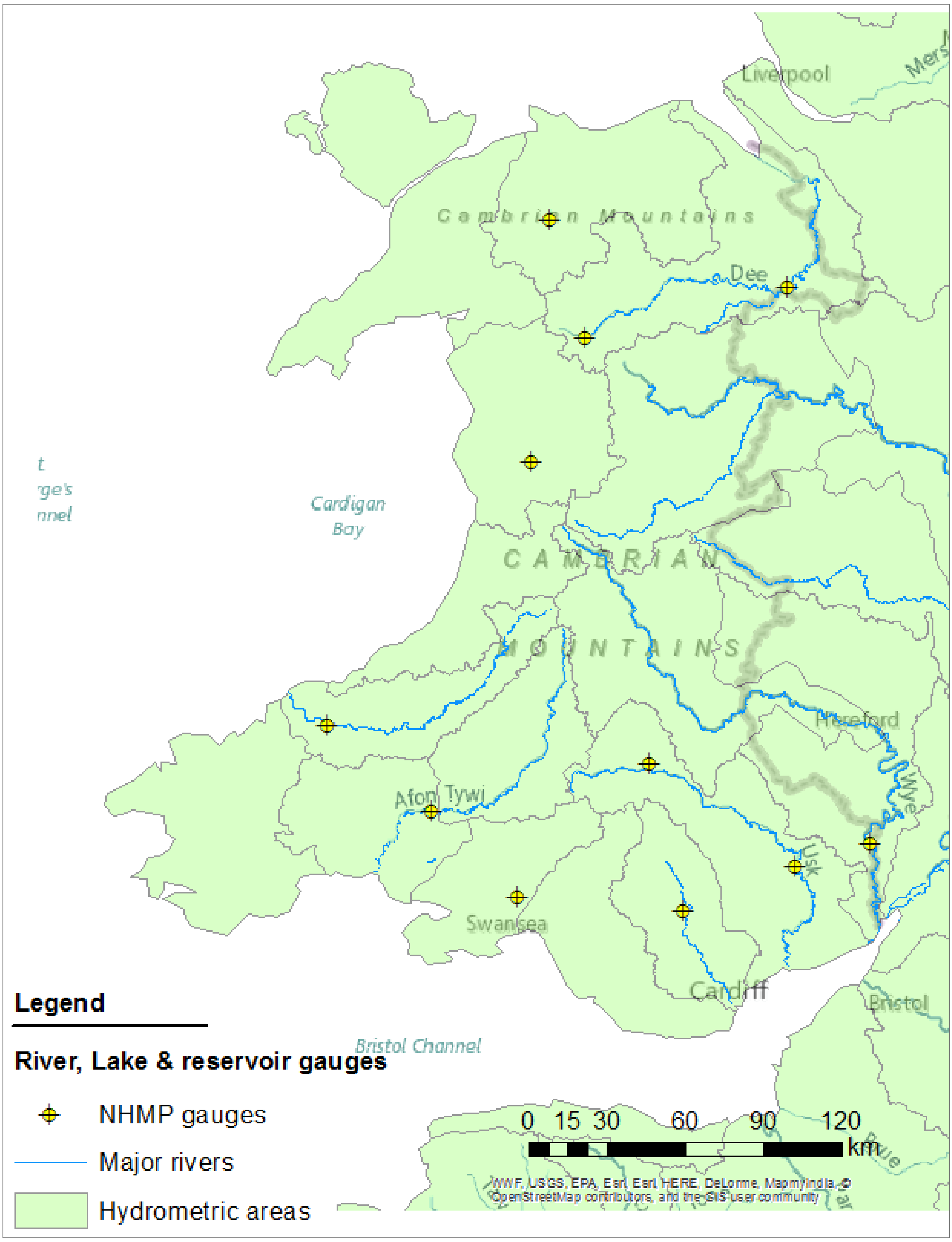


Figure 3-3: Welsh sites within the UK National Hydrological Monitoring Programme



3.4.3 Strategy for managing network change

NRW has just started its first formal review since its inception. This is principally a review of monitoring needs focussing on network utility across the whole water quantity network. However the review is being undertaken specifically as a result of cost pressures rather than network needs.

In general terms, NRW targets are to carry out a review on a three-year cycle. This is to include a review of the network with internal customers discussing both the relevance of open sites and the data quality needs for the sites. Each operational area also has a network user group that meets quarterly to discuss network issues including the current network utility and potential network growth. Any additions to the network are discussed at these meetings so that potential sites (usually for flood risk management purposes) can be explored for their potential multi-functional benefits). The geography of Wales means that in many areas there is still seen to be a need for network growth though this has slowed recently.

The ongoing review is looking at which sites might be potentially closed, either due to a change in drivers or data quality issues. Network growth over recent years has generally involved new level-only monitoring sites (principally for flood warning) and has not attracted any additional supporting revenue for their management – this has had to be delivered via increasingly efficient ways of working.

Example of Management Strategies
Natural Resources Wales Evidence Strategy

The evidence strategy published by NRW sets out how the organisation sources evidence and the future challenges that lie ahead for their evidence base to achieve their corporate strategy and business plan.

The challenges for the evidence base include: ecosystem services, natural capital, state of environment reporting and EU Directives. The strategy sets out how hydrometric data together with sampling, monitoring and modelling is part of the wider evidence base.

The skills and experience related to evidence are considered important and the strategy links to the People Strategy in terms of managing experience, knowledge and succession planning.

NRW, Good Evidence – Our evidence management strategy and delivery plan 2014-2017 (July 2015)

3.5 Summary statistics

3.5.1 Density of river monitoring stations

Table 3-1 summarises the network density seen in Wales. In Wales the level-only network is substantial and denser than the flow gauging network; reflecting recent network expansion in relation to flood warning responsibilities. There is an average of 6 river flow gauges per 1000km^2 compared with 9.2 gauges level only gauges per km^2. The majority of the network is telemetered.

Information regarding the number of gauges each hydrometric staff member maintains has not been supplied. It should be noted that only three quarters of hydrometric staff in Wales are field based. This represents a reasonably significant workload in relation to site maintenance and calibration.

Table 3-1: Network density statistics for Wales

Characteristic	Flow	Level	Rainfall
Total active gauges	127	200	270
Percentage telemetered	90%	90%	80%
Active gauges per unit area (1000 km^2)	6	9.2	12.8
Active gauges per million people	40	63	90
Active gauges per FTE hydrometric staff	6.3	10	13.5
Notes: Gauges per FTE staff is based on 20 hydrometric staff across 4 teams			

3.5.2 Challenges and drivers for hydrometric data for water management

Table 3-2 summarise the main drivers for collection of river flow and level data in Wales. Flow data is used equally for Flood Risk Management and Water Resources activities, however level-only data is primarily used for Flood Risk Management purposes. In addition a number of gauges are used for OSPAR reporting, bathing water quality flag assessments, UK Environmental change network and flood warning alarms.

Table 3-2: Uses of hydrometric data for different operational and strategic drivers

Driver	No of flow gauges	% of flow gauges	No of level only gauges	% of level only gauges
Flood Risk Operations	111	89%	193	100%
Water Resources Operations	119	95%	0	n/a
Environmental Operations	77	62%	0	n/a
Notes:				

4 Case study: Scotland

4.1 Context

4.1.1 Geography and socio-economics

The northern and most mountainous part of Great Britain, Scotland covers an area of 78,000km^2. Scotland's only land border is with England and it has around 10,000km of mainland coastline. The 720 islands of Scotland's Northern and Western Isles make up about 15% of the countries by area, but add a further 6,500km of coastline. Geographical features include the coastal firths including the Solway Firth and Firth of Clyde, major sea lochs such as Loch Fyne, and freshwater lochs including Loch Lomond and Loch Ness. The major river basins include the Tay, Spey, Clyde, Tweed and Dee (Figure 4-1).

Scotland has a temperate maritime climate but temperatures are lower than elsewhere in Great Britain. Annual rainfall totals also vary widely across Scotland, and show a strong west/east gradient; the western highlands of Scotland are one of the wettest places in Europe with average annual rainfall reaching as much as 4500mm, whereas eastern Scotland is significantly drier receiving less than 900mm rainfall annually.

Broadly speaking grazing and unimproved grassland is the predominant land use (70%). Other major land uses include forest and woodland (17%), urban development (8%) and fallow land 7%. Agriculture is very limited accounting for only 2% of the land use by area. The total population of 5.3 million is predominantly concentrated in the Central Belt cities of Glasgow, Edinburgh, Dundee and Perth. Other areas are very sparsely populated.

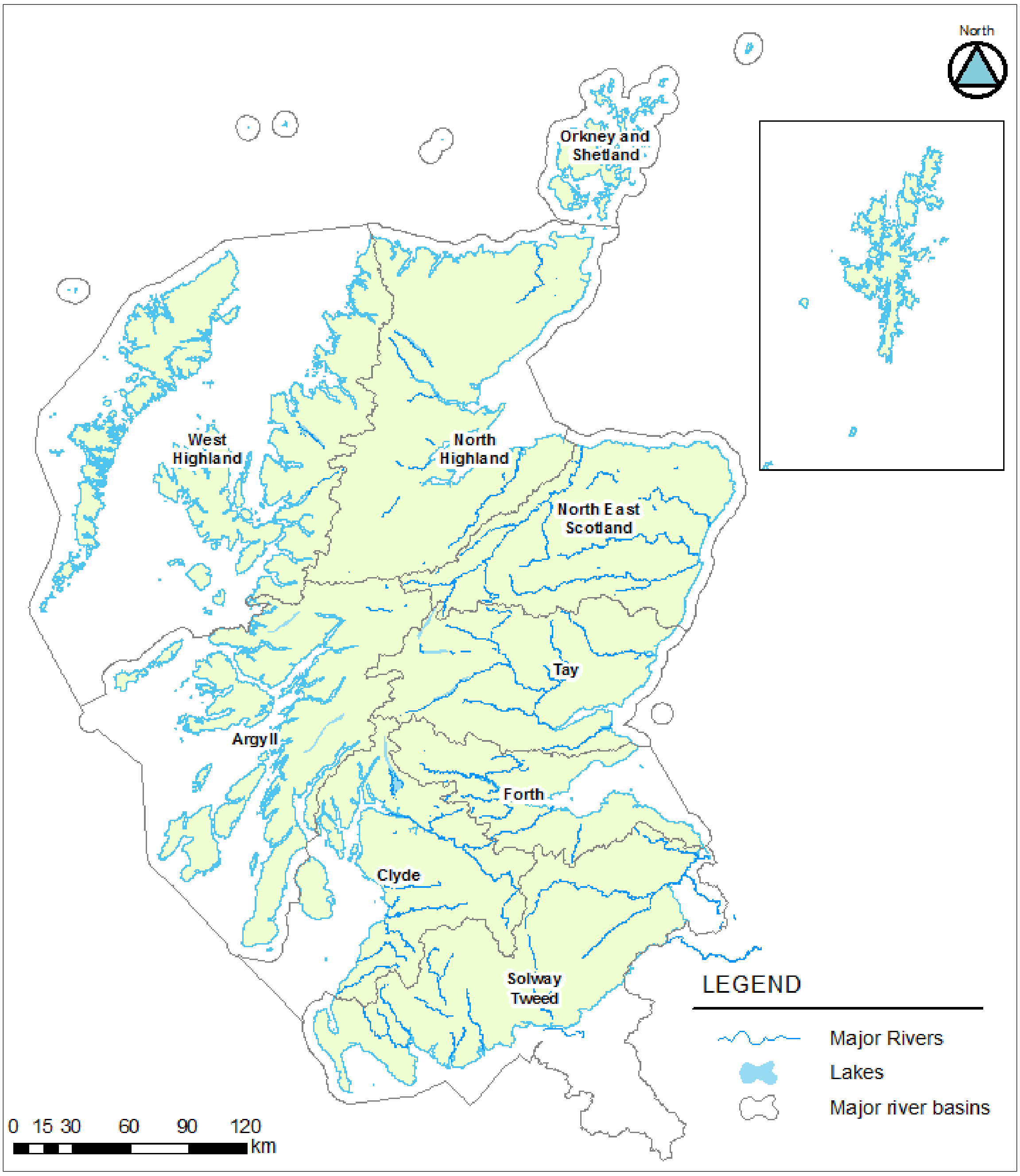
4.1.2 Regulatory framework

Responsibility for the collection and processing of hydrometric data in Scotland rests with the Scottish Environment Protection Agency (SEPA), a non-departmental public body of the Scottish Government which has responsibilities for environmental regulation and protection in Scotland. SEPA was established in 1996 by the Environment Act 1995, and until 2010 was separated into three Regional Boards (North, South-west and South-east).

SEPA inherited the hydrometric networks that were previously maintained by the River Purification Boards prior to UK water industry privatisation (the 1963 Water Resources Act brought about a statutory obligation for the then river authorities to measure rainfall and other hydrometric variables to facilitate water conservation and management). SEPA's current remit includes river flow measurement, river and loch level measurement and rainfall measurement.

The main regulatory obligations that influence SEPA strategies for hydrometric monitoring are summarised in Appendix A2. These include a range of EU Directives as well as more local duties under the Environment Act 1995, the Civil Contingencies Act 2004 (which require arrangements to be in place to prepare for, respond to, and warn the public about various emergencies including flooding and pollution incidents) and the Regulatory Reform Act 2014 (relating to environmental regulation and enforcement).

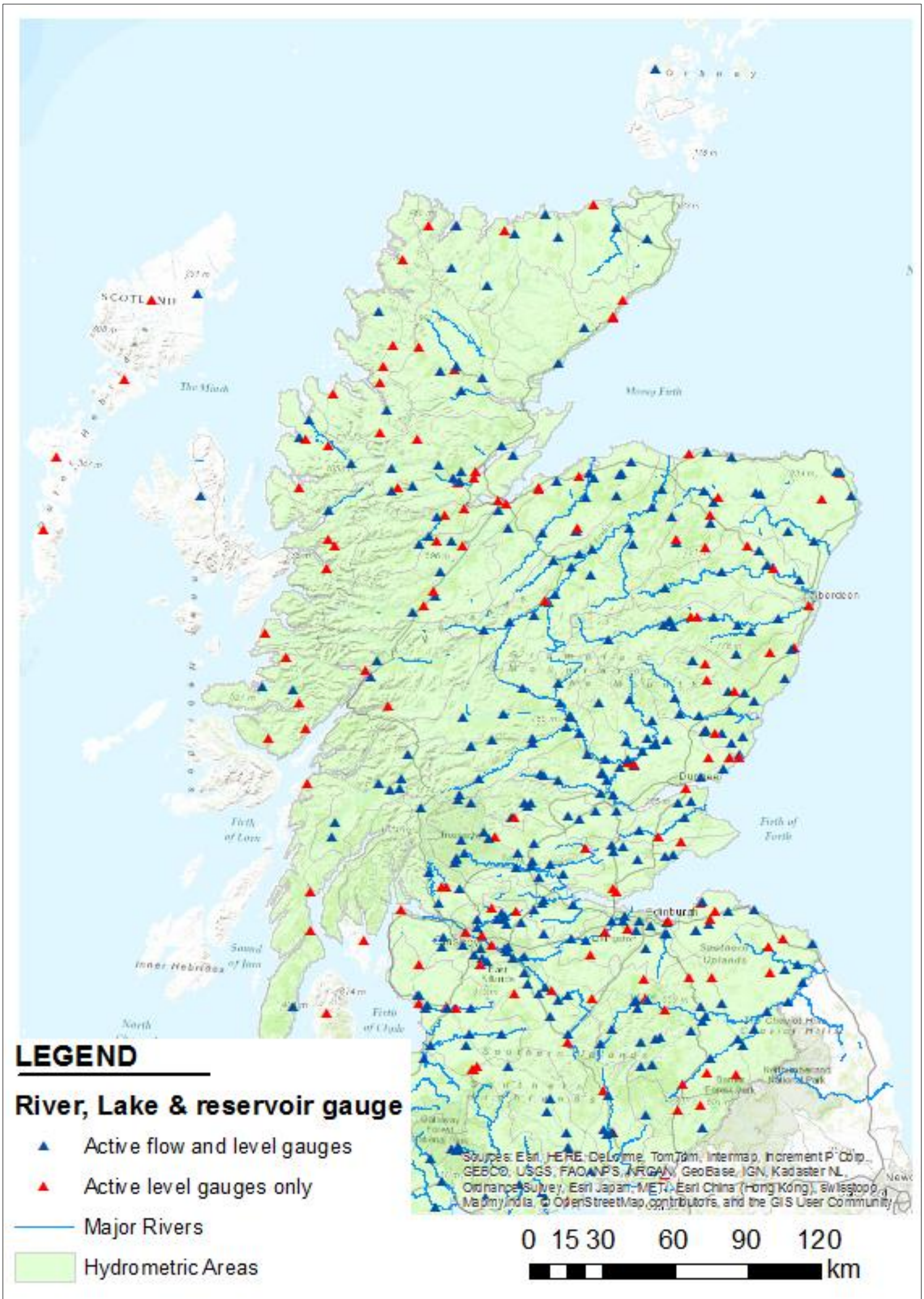
Figure 4-1: Scotland - overview map



4.2 Current hydrometric network configuration

Figure 4-2 shows the spatial distribution of SEPA's river flow and level monitoring sites monitoring network. In all there are over 400 river gauging stations (some of these are level-only stations) and 10 loch level stations. In addition SEPA operates 12 tidal level monitoring sites (not shown).

Figure 4-2: Scottish surface water network with sub-catchment boundaries and major watercourses



SEPA also operates approximately 300 sub-daily rainfall gauges. These are used to measure rainfall in real-time and most are connected to telemetry. Most are tipping bucket raingauges (TBRs), although there are a few other types of instruments. As is normal practice, most TBRs are co-located with either a daily or monthly storage rain gauge. SEPA also operates a further 100 or so independent storage gauges, the majority being daily measurement stations. Rainfall data collected by SEPA is also supplied to the UK Meteorological Office's (Met Office) national rainfall archive, which provides a valuable source of data from across the UK relating to rainfall. The Met Office also operates a number of its own rain gauges in Scotland. These are used as primary synoptic stations for daily weather forecasting and for climate modelling.

Additional flow measurement is carried out by a variety of private bodies (including Scottish Water and Scottish Power and Scottish Hydro), public bodies and research organisations including universities. These stations are not formally incorporated into SEPA's network and some third party data is supplied to SEPA on a reciprocal basis. These sites are not included on the register of gauging stations supplied for this review.

4.3 Hydrometric network governance

4.3.1 Operation and maintenance

Hydrometric monitoring is managed by the Hydrometric Unit of the Science and Strategy Directorate of SEPA. The unit is provisioned with a total of 43 staff and a budget of around £2.4M. The staff are spread over four teams and eight locations. Teams consist of senior and junior staff, and a team leader. Technical specialists sit outside the team structures, providing advice across all teams and sites on relevant specialisms which include instrumentation, network strategy, engineering, telemetry and administration.

Stage is measured via a variety of methods, typically with a digital shaft encoder inside a stilling well, but also using downward looking ultrasonic devices and some radar devices. The majority of SEPA's river flow gauging stations are open channel and based on stage-discharge rating curves. Spot gauging is traditionally via a velocity-area approach using handheld or suspended current meters (especially in difficult settings or where velocities are high). However ADCPs are also widely used where appropriate.

In terms of practical aspects, the terrain in Scotland offers a number of challenges to hydrometric monitoring. SEPA already takes an innovative approach to instrumentation/monitoring methods because of the challenging ground conditions in which some stations need to be located. Vandalism and land access can be problematic in some parts of the network.

SEPA is extremely mindful with regards to technological advances. Direct flow measurement using acoustics or radar, logger technologies, use of "smart" sensors and remote sensing capabilities are all of interest, however SEPA does not consider it as having a responsibility to beta test new devices coming into the market. Whilst looking to capitalise on new technologies these need to be tried and tested, as well as bringing value for money and advantages over current instrumentation.

4.3.2 Funding sources and budget allocation

Funding for the network derives from a variety of sources and there are separate capital and revenue budgets. Grant in Aid schemes provide resourcing for hydrometric data needed to operate flood warning schemes, and abstraction licensing fees also contribute towards the overall budget.

The same funding structure is envisaged to continue into the future. No increase in overall budget is expected.

4.3.3 Data management and quality assurance

All hydrometric monitoring data currently collected by SEPA is stored on a centralised national archive. The database platform used is Kister's WISKI software. This has recently been upgraded to a new version (7.4) and SEPA staff are still within a process of familiarisation. The centralised archive means that the data is accessible to all SEPA staff working within hydrometry and hydrology functions and this is deemed as being of high importance.

SEPA have their own internal standards and service levels to which they work. These are closely aligned with BS/ EN/ ISO standard as far as possible. New data is assessed on a monthly basis as part of quality control / tertiary validation procedures. This involves attributing data records with data quality flags.

Rainfall data provided to the Met Office is quality assured separately by them and returned to SEPA. It should be noted that the WISKI archive holds only the original data and not the data returned following Met Office validation.

Not all historic hydrometric data is stored on the archive; a few older data records have not yet been digitised. An important factor when digitising data is to ensure meta-data and comments are not "lost" if they cannot be easily transferred to the current reporting framework.

4.3.4 Dissemination of data

SEPA are highly customer oriented and whilst public can have access to data under license for a small handling fee, this is presently done on a request by request basis. However, corporate strategy is that SEPA should move towards an Open Data strategy, with all data being freely available via a web platform.

SEPA already make level data from approximately 330 river gauging sites available to the public over the internet (http://apps.sepa.org.uk/waterlevels/default.aspx). The website is updated directly from the data archive once per hour, at which point the most recently polled data is made available. The information on this site is intended to give users a general picture of river levels over the past few days, but it is not intended to provide data in "real-time". Additional information, such as maximum recorded level, is provided to users to help put the current levels into context. The levels on the site are widely utilised by fisheries, for those seeking information on river levels for leisure purposes (such as canoeists) and also by the public, particularly during in periods of high flows/flood. However the data are not intended as a formal flood warning provision.

SEPA supply river flow data for selected sites (about 100 stations) to the Centre for Ecology and Hydrology (CEH) for inclusion in the UK National River Flow Archive (NRFA). Data exchange and associated data quality review is formalised through a Service Level Agreement. Similarly some rainfall data is provided also provide to CEH to facilitate the National Hydrological Monitoring Programme. NRFA data is made publically available through the NRFA website (http://nrfa.ceh.ac.uk/data/search) and passed on to universities and other wider research initiatives. The NRFA Flood Peak database (formally known as HiFlows-UK) is also made available publically through the NRFA. It is mainly intended to support Flood Estimation Handbook procedures and consists of annual maximum flows and other data from gauging stations deemed to be provide good quality measurements during high flow periods. About 100 SEPA stations are included in this database.

SEPA also have a reciprocal data exchange agreement with Scottish and South Hydro Electric and Scottish Water. Some data for border catchments is also supplied to the Environment Agency to assist with flood warning in those areas.

4.4 Hydrometric network drivers

4.4.1 Past influences

The evolution of the hydrometric network in Scotland, prior to SEPA taking over its control, is documented by Black and Cranston (1995). The first river flow measurements were made in 1913 with the aim of establishing available yield relating to the feasibility of hydro-electric power. Subsequent stations followed elsewhere for the same purpose, or to generally assess yield for public water supply. The network became formalised on the formation of River Purification Boards in 1951, and a period of network expansion followed (particularly to provide data to be used for pollution control and prevention). Network emphasis later changed to providing data for flood warning. Since SEPA took over the network in 1996, the largest pressures for new sites have come from needing to meet flood risk management responsibilities as well as from the environmentally-oriented perspective brought about following the introduction of the Water Framework Directive.

4.4.2 Current network functions and drivers

The current drivers and data uses of the Scottish network include the following (after Kennedy, 2010):

Flood management

Hydrometric data is used to support the understanding of flood processes in Scotland, both on a real time basis and in terms of longer climate or catchment-led changes. SEPA is the flood warning authority for Scotland and data from river, rainfall, loch and tidal monitoring sites all play a role in this service. SEPA is also a statutory consultant in the planning system, and carries out duties related to flood risk assessments and mapping, both of which require hydrometric data, either directly for quantification of catchment response or for model calibration. Hydrometric data is used in return period calculation as well as for design flood event estimation. Flood data is also used in the design of flood protection schemes.

Monitoring has also been recently used to evaluate experimental measures in pilot catchments such as natural flood management measures for example. Rainfall and runoff data is also used to assist in the design of SUDS.

Water resources

Much of the early river flow network was put into place to assist with yield assessment, and this remains a key use of data from many sites. Hydrometric data is used to help regulate and manage impoundment activities and compensation flows from reservoirs, as well as abstraction licensing and hydropower assessments.

Environmental monitoring

SEPA is signed up to the OSPAR convention, which means that hydrometric monitoring on river discharges is needed to estimate pollutant load to the marine environment. Figure 4-3 shows the gauges in Scotland used for OSPAR reporting. WFD requirements in relation to surveillance monitoring are actually very similar to those required to meet OSPAR requirements. Hydrometric data is used more generally to assist with diffuse and point source pollution monitoring, both rainfall and river flow data are used for this purpose which includes setting of discharge consents, either directly or indirectly via models, assessing pollution incidents and associated waiver requests.

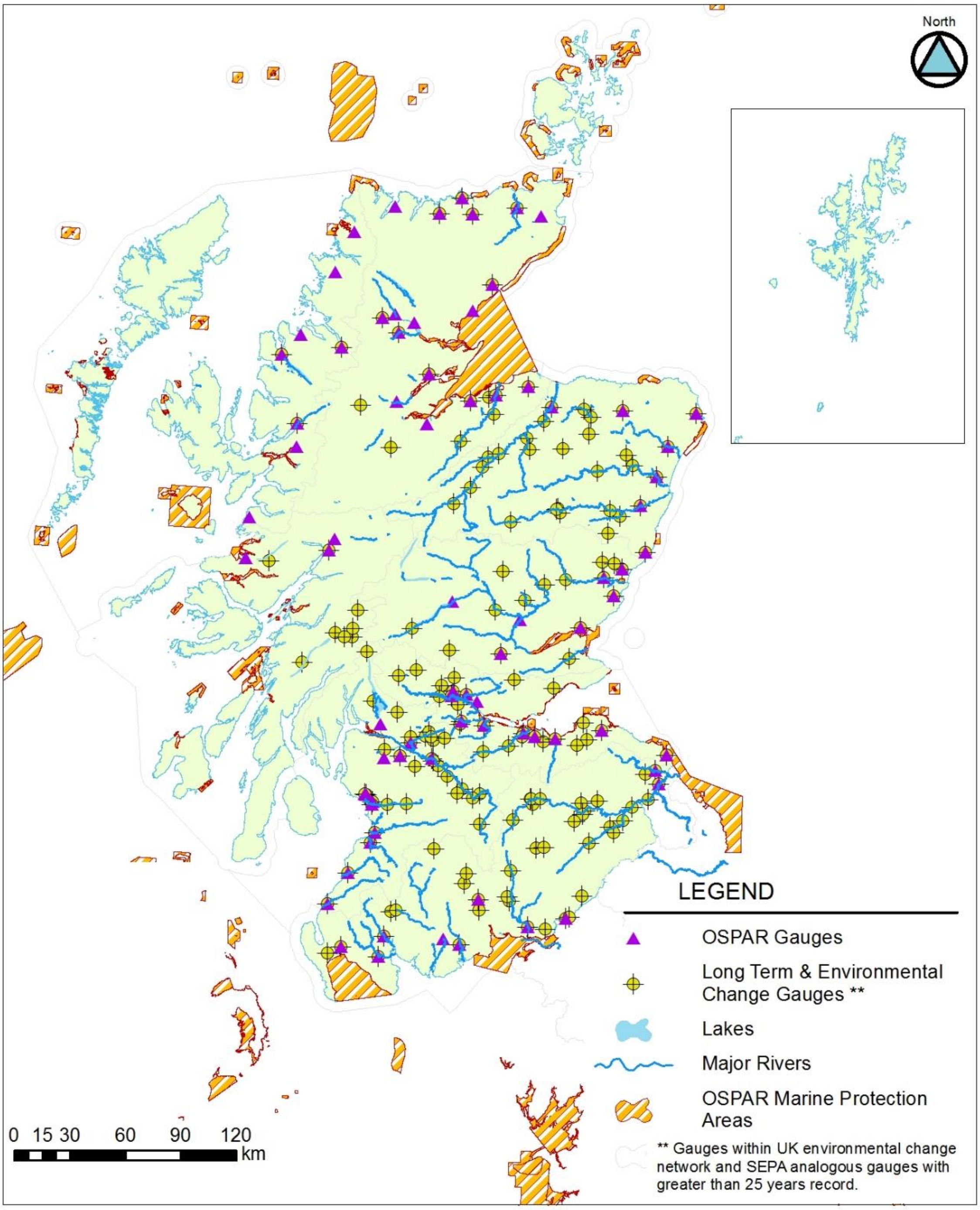
River flows are important within part of the hydro-morphological element describing ecological status of waterbodies under WFD. This requires an understanding of the river flow duration curve in water bodies, and hydrometric data is again used either directly or to furnish estimation models (such as Low Flows for example). River level data is also useful within this context, particularly in relation to assessing impacts of engineered channel changes on ecological status.

Rainfall and river flow is also used in bathing beach assessment, water quality prediction and signage operation, particularly to decide on abnormal weather waiver options in wet weather events.

Climate change monitoring and trend analysis

Monitoring and analysis is a recognised element of SEPA's Climate Change Plan, and hydrometric data has recognised value for trend analysis and predictions. Long river and rainfall records within the network are particularly useful for trend analysis and climate change work. Tidal sites will play an increasingly important role considering projected sea level rises. Figure 4-3 shows the spatial distribution of long term gauges in Scotland.

Figure 4-3: Long term and OSPAR gauges in Scotland



Weather forecasting

As suppliers of rainfall data to the UK Met Office, SEPA network data also contributes to numerical weather prediction activities, including short-range forecasting and longer term climate modelling. The data also assists in the provision of monthly and annual rainfall summaries and bulletins. Within this context, some TBR data is essential for infilling gaps between areas of adequate rainfall radar coverage (particularly in the Solway and Morray Firths) as well as for real-time calibration of radar.

4.4.3 Strategy for managing network change

Operational needs have shaped the network in preference of strategic drivers. The original purpose of some older stations may no longer exist or has become lower priority, and therefore the current purpose and importance of a station may not necessarily be obvious. A less obvious but recognised function of the network is the existence of a long continuous archive of data for more strategic uses. Management strategies need an in-depth understanding of current network purpose as well as future requirements. An individual gauge may service a number of functions in SEPA, including functions which were not originally envisioned when the gauge was installed. Many gauges currently have multiple drivers or users.

SEPA have a limited resource with which to manage the network, and there needs to be very efficient maintenance and management to provide a confident service within these constraints. However hydrometric functions are perceived within SEPA as providing good value for money. There is a preference for monitoring fewer catchments to a higher standard, rather than to operate a greater number of sites but compromise on quality. SEPA look towards the US and Sweden and Norway as examples of well-run networks that are managed centrally.

The network is acknowledged as not being a static. Requirements for new sites are identified on an ad hoc basis, but there is no official strategy for implementing new sites. Recent European directives have dictated an increasing demand for data, which has enforced the need to re-evaluate requirements and refocus resources. With limited operational resources and an expanding demand for data, new requirements may need to be resourced by cuts or closures elsewhere.

SEPA carried out a detailed network review in 2010 and will likely undertake the next review within the next 24 months. There is no formal strategy for frequency or approach for holistic network reviews. Their timing is normally driven by external factors. Following the 2010 review a number of stations and gauges were closed or downgraded to a lower maintenance standard as part of a rationalising exercise for increased efficiency. Over the last few years, however, the network has continued to expand due to the needs of new flood warning projects and to lesser extent, diffuse pollution (flow and raingauge) and bathing waters signage (raingauges). Specific challenges being dealt with at present include the need to facilitate fish passage at gauging structures and applications to use gauging weirs as head generation in hydropower schemes.

Recent network change has primarily been in relation to operational drivers. The need to quantify environmental flows, hydropower assessment and other renewable energy schemes have figured highly. In addition to these SEPA have identified the following potential future drivers on network change:

- Flood risk management. Pressure on the network is expected in relation to improvement of flood warning capability, as well as for flood risk mapping and strategic flood risk assessments.
- Climate change monitoring is considered as an important strategic driver of the network.
- Hydrometric data relating to lochs: There is considered a need to quantify dynamics of loch systems, particularly within the context of WFD.
- Influenced reaches: There is considered a need to collect more hydrometric data in locations heavily impacted by abstraction.
- Bathing water quality
- Diffuse pollution monitoring and modelling

There may also be potential for most growth in the network for strategic reasons. Most gauges are at catchment outlets and as such represent integrated flows from upstream. Hydrometric conditions in small and particularly small upland catchments are not well represented in the network. Overall there needs to be increased instrumentation in areas of higher elevations (both flow and rain). Better coverage of those basins where there are no gauging stations on major rivers draining into the sea is also a priority. Urban flow monitoring is also poorly represented within the current network. Such stations would need to be supported by operational requirements to be justified with a programme of network expansion.

Example of Network Review for WFD Monitoring

SEPA review of network for national scale reporting on quality and dynamics of flow

SEPA believe their river gauge network needs to represent the hydrological characteristics of water bodies within Scotland, and be able to determine how the impacts of human pressures change the quantity and dynamics of flow of natural river systems.

Transposing flow duration curves to ungauged rivers is limited in that it does not consider the ecological flows of either river and does not allow for description of alterations to the natural regime from human activity.

The network review considered whether there are sufficient gauges in the national network to be representative of the rivers within each hydrometric area. Two methods were dismissed as being too time consuming to undertake or ignoring spatial distribution. The chosen method contained three elements. A proximity score based on Euclidean distance from the river reach to the nearest gauge. A pressure score to sum the number of pressures or threats to waterbody status. A typology score based on catchment descriptors (catchment area, mean altitude, dominant geology, annual rainfall) to compare catchment areas of gauged and ungauged rivers in each typology class. The three scores are combined to give a value for each hydrometric area.

Scenario testing can be carried out to determine the most optimal (or minimum to achieve a target level of representivity) number of location extra gauges required.

If a different base to hydrometric area is chosen, the conclusions of the analysis may be different.

A review of SEPA's River Hydrometric Network in Relation to the Monitoring Requirements of the Water Framework Directive (Gosling, et al.)

4.5 Summary statistics

4.5.1 National density of monitoring stations

Table 4-1: Network density statistics for Scotland

Characteristic	Flow	Level-only	Rainfall
Total active gauges	280	126	390
Percentage telemetered	70%	95%	55%
Active gauges per unit area (1000 km^2)	3.5	1.6	5
Active gauges per million people	53	24	74
Active gauges per FTE hydrometric staff	6.5	3	9
Notes: * denotes estimated figures The above figures only account for SEPA operated gauges.			

4.5.2 Regional density of monitoring stations

Table 4-2: Breakdown of operation & hydrometric staff in Scotland

Regional SEPA office	Percentage of network operated from office	No. of Staff
Aberdeen	10%	4
Dingwall	22%	8
Dumfries	9.5%	5
East Kilbride	16%	7
Edinburgh	13.5%	5
Elgin	7%	4
Galashiels	9%	2
Perth	14%	6
Specialists	-	9
Notes: The above figures are those provided by SEPA and may have since changed.		

4.5.3 Challenges and drivers for hydrometric data for water management

Table 4-3: Uses of hydrometric data for different operational and strategic drivers

Driver	No of flow gauges	% of flow gauges	No of level only gauges	% of level only gauges
Flood Risk Operations	254	82%	59	36%
Water Resources Operations	245	80%	19	12%
Environmental Operations	154	50%	16	10%
All three of above	138	44%	4	2.5%
Other (e.g. research)	13	4%	21	13%
Notes				

Table 4-4: Specific uses of hydrometric data for different operational and strategic drivers

Driver	No of flow gauges	% of flow gauges	No of level only gauges	% of level only gauges
Ospar Reporting	73	24%	10	6%
Bathing water quality	9	3%	0	0%
UK Environmental Change Network	171	55%	2	1%
Flood warning alarm	172	55%	38	24%
Notes				

5 Status and requirements of the hydrometric network in Ireland

5.1 Context

5.1.1 Geography and socio-economics

Ireland is similar to the case study countries in terms of the temperate maritime climate, rainfall, land use and variable population density, but with perhaps less variability in altitude, rainfall and temperature. Ireland is considerably flatter than the case study countries with the Shannon basin in the centre, which form historic regional and county boundaries.

5.1.2 Regulatory framework

The different organisations involved in hydrometry in Ireland are governed by separate legislation. The formation, roles and responsibilities of the Environmental Protection Agency are set out in the Environmental Protection Agency Act 1992 (see Table 5-1 for an extract of the section relevant to the hydrometric programme).

Table 5-1: Extract from the Environmental Protection Agency Act 1992

Hydrometric programme.

64.—(1) The Agency shall, after consultation with such persons or bodies (if any) as may be prescribed, prepare a national programme for the collection, analysis and publication of information on the levels, volumes and flows of water in rivers, lakes and groundwaters in the State (in this Act referred to as "hydrometric data"), and a copy of such programme shall, as soon as may be, be sent by the Agency to the Minister.

(2) A programme under this section may, after consultation with the persons or bodies (if any) referred to in *subsection (1)*, be revised from time to time by the Agency and shall be reviewed at least every five years.

(3) It shall be the duty of the Agency to take appropriate steps to ensure that a programme under this section is implemented and for that purpose the Agency may—

(*a*) direct a local authority to provide, operate and maintain such gauges and other equipment as it may specify and to furnish specified information to the Agency in such manner and at such times as it may specify,

(*b*) make arrangements with any public authority, or other person or body to provide, operate and maintain such gauges and other equipment as it may specify and to furnish specified information to the Agency in such manner and at such times as it may specify,

(*c*) provide, operate and maintain gauges and other equipment for recording hydrometric data.

(4) Where the Agency is not satisfied with the response of a local authority to a direction under *subsection (3) (a)*, it shall consult with the local authority concerned, and, if the Agency is still dissatisfied with the response following such consultation, the Agency shall carry out, cause to be carried out, or arrange for, the monitoring concerned and the costs of the monitoring may be recovered by the Agency from the local authority as a simple contract debt in any court of competent jurisdiction.

The Office of Public Works (OPW) are the authority with responsibility for flood management and delivery of the floods directive and flood management schemes. The OPW also has statutory responsibilities for maintenance of arterial drainage scheme channels and embankments. Waterways Ireland has responsibility for management, maintenance, development and restoration of navigable waterways in the Republic of Ireland and Northern Ireland. The Electricity Supply Board (ESB) operates a number of hydrometric stations used for management of five hydro-electric power stations. The Marine Institute was set up under the Marine Institute Act 1991: *"to undertake, to coordinate, to promote and to assist in marine* *research and development and to provide such services related to research and development, that in the opinion of the Institute, will promote economic development and create employment and protect the marine environment."* Met Éireann, the Irish National Meteorological Service, is a line division of the Department of the Environment, Community and Local Government. It is the leading provider of weather information and related services for Ireland.

5.2 Current hydrometric network configuration

5.2.1 Network breakdown

As documented in previous hydrometric reviews in Ireland (Review of EPA Hydrometric Programme (EPA, 2011) and Strategic Review of Options for Flood Forecasting and Flood Warning in Ireland (JBA for OPW, 2011)) and documented in the Irish Hydrometric Register held by the EPA, a number of different organisations own and maintain the stations that informally make up the national network. Each organisation has established a network to serve its own operational and regulatory requirements. Consequently, hydrometric activities are not presently managed in a holistic way or by a single body.However there is agreement and good working cooperation between the various bodies, through the NHWG. A detailed breakdown of the flow and level gauging network is presented in Table 5-2. The combined EPA-Local Authority (EPA-LA) and OPW hydrometric networks consist of a total of 630 active hydrometric stations. The ESB, Waterways Ireland, Marine Institute and Port Companies maintain a number of gauges for operational purposes. The principle purpose of OPW gauges are for flood management and arterial drainage schemes. These OPW gauges represent 62% of the combined EPA-LA and OPW gauge network.

Table 5-2: Hydrometric Network in Ireland with responsible body, no. of gauges, no. with telemetry and data collected

Responsible Body	Active Gauges	With Telemetry	Data Collected		Notes
EPA-LA	230	84	Water level & flow	202	
			Water level only	28	All of these are lake level gauges.
OPW	390	332	Water level & flow	248	Includes 4 tidal, 6 unattributed type. Only 50 of these gauges have satisfactory rating from high to low flows.
			Water level only	142	Includes 30 tidal.
ESB	24	4	Water level & flow	17	Flow ratings of poor quality so in effect level only sites.
			Water level only	6	
Waterways Ireland	122	-	Water level & flow	1	Ratings at some rural sites are subject to review.
			Water level only	121	
Marine Institute	18	6	Water level only	18	17 tidal and 1 river gauge.
Others	4	0	Water level only	4	All tidal. Shannon Foynes Port Company, Iarnrod Eireann Rosslare, Dun Laoghaire Port Comapany and Cork Port Company.

Notes:
Data source - Register of Hydrometric Stations in Ireland 18.08.2015, supplied by the EPA.
The Rivers Agency Northern Ireland operates 156 active gauges. 81 of these have flow ratings and 75 are level only.

5.2.2 Network coverage

The locations of hydrometric gauges operated by both the EPA-LA and OPW are shown in Figure 5-1. From a visual interpretation (excluding Waterways Ireland gauges, which are sited mainly on canals, used only for navigation) there is a reasonably even coverage along main rivers, with no strong bias towards greater station density in populated areas (Figure 5-2). Headwater catchments are poorly gauged in comparison, and there are also a number of smaller coastal catchments that are ungauged (Figure 5-3).

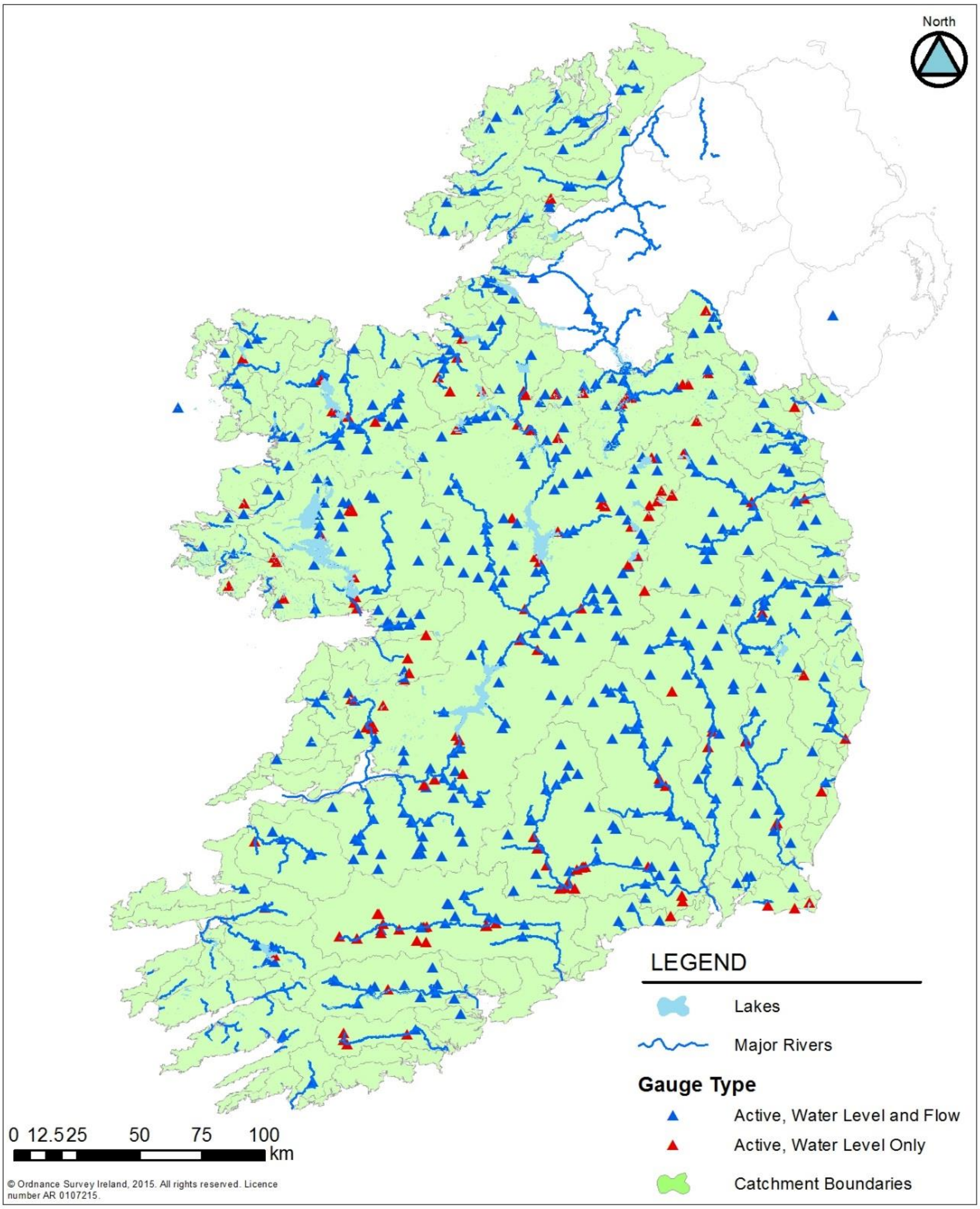
Hydrological estimation models, which in Ireland include the HydroTool for low flow estimation and the Flood Studies Update (FSU) for flood estimation, rely on capturing data from a wide variety of catchment types. Therefore from a strategic perspective, the network needs to be representative of all catchment types, including common catchment types as well as some of the more unusual catchments to provide data to calibrate such models. At the same time catchments for which such models don't work need to be well provisioned with gauged data (because model outputs are less reliable in such cases).

Figure 5-4 highlights the gauge network in relation to catchments with karst or lake influences, where hydrological models are more uncertain.

The gauges which form the Irish Reference Network (IRN) for HydroDetect and those used in OSPAR reporting are shown in Figure 5-5. The IRN is a subset of the national gauge network for the purpose of long term climate change detection and monitoring. Gauges were selected for inclusion in the IRN based on their record length, minimal artificial influence in terms of regulation, drainage and urban development and representative of Irish hydrological conditions. Two of the IRN gauges in the EPA/LA network are currently suspended due to lack of resources to maintain them in safe working orderand two others are under threat of suspension.

In Ireland raingauges are operated by OPW in the Suir and Blackwater catchments, where rainfall data streams contribute mainly to flood forecasting and warning activities, and by Met Éireann elsewhere, but in the latter case this network is sparse and focussed on weather forecasting needs (Figure 5-6). A recent review of flood forecasting and warning in Ireland carried out jointly by JBA and the Met Office for the Office of Public Works (JBA 2011), highlighted the advantages of expanding the raingauge network in order to enhance forecasting capabilities, but cautioned that new equipment needs to be standardised in order to reduce long term calibration and maintenance costs.

Figure 5-1: Irish surface water network



Note: Marine Institute gauges have been omitted for clarity on all maps.

Figure 5-2: Ireland - population density and gauge locations

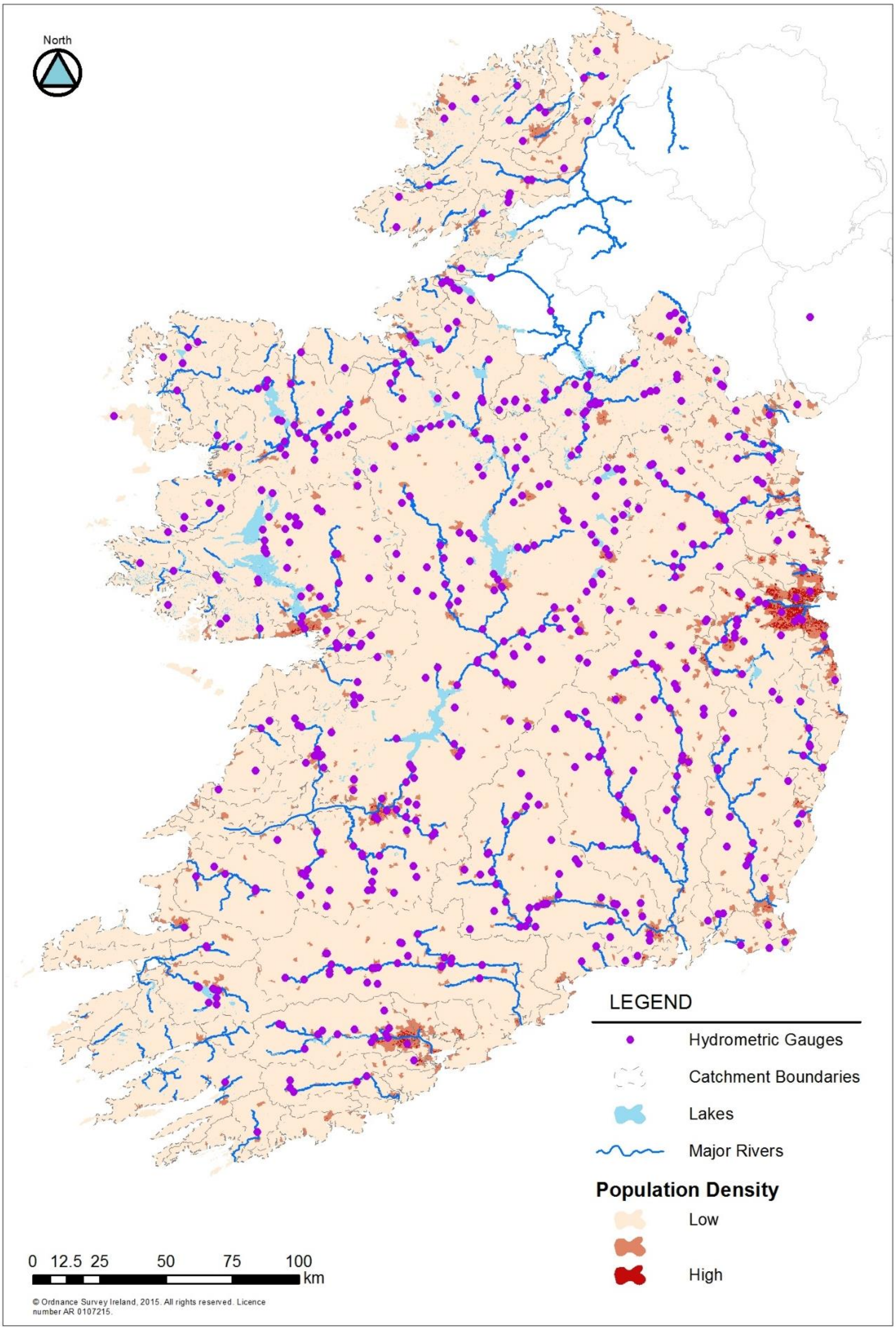
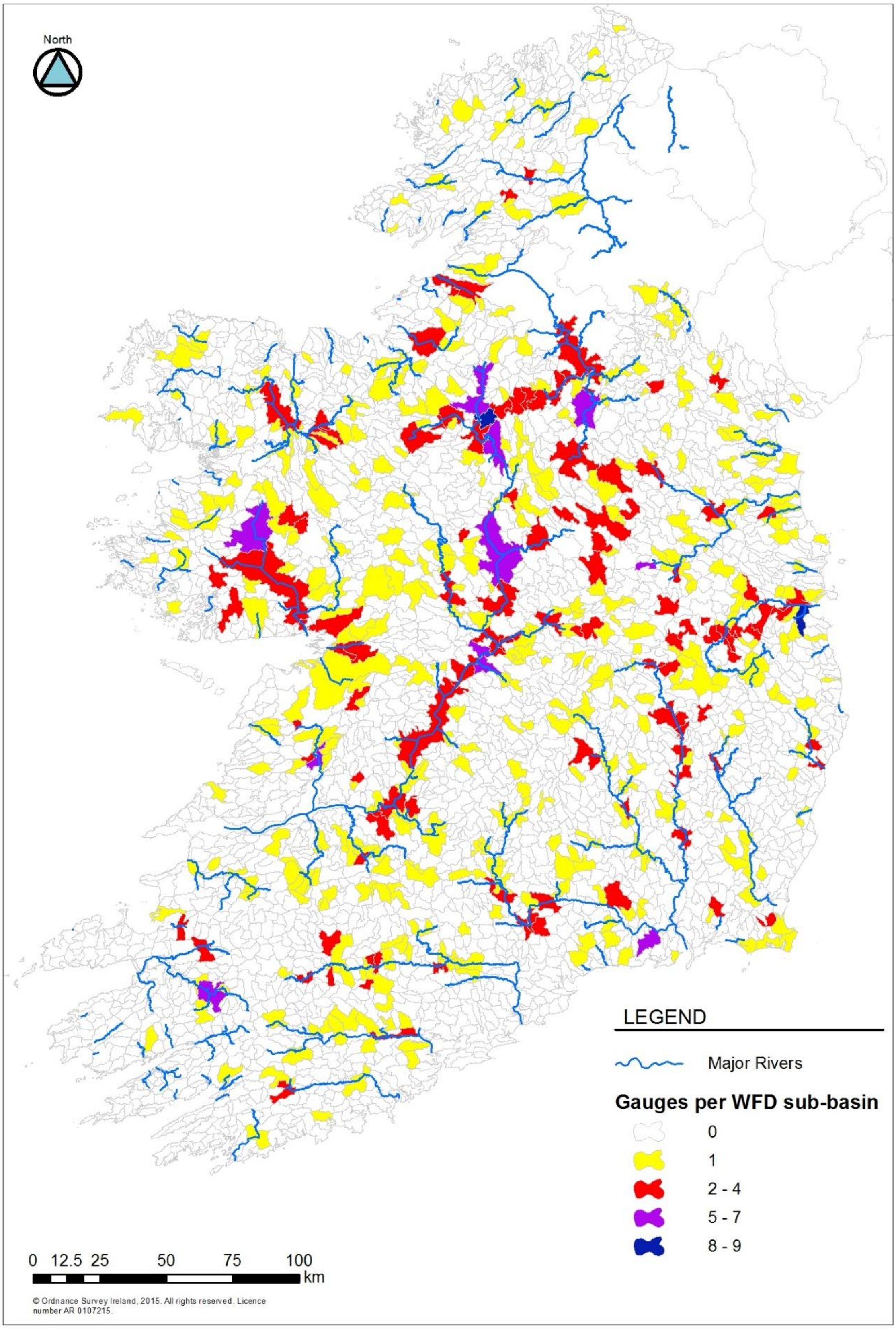


Figure 5-3: Ireland - gauges per WFD sub-basin



Note: Includes level and flow gauges to show potential coverage from existing gauges.

Figure 5-4: Irish hydrometric network with lakes and karst groundwater bodies

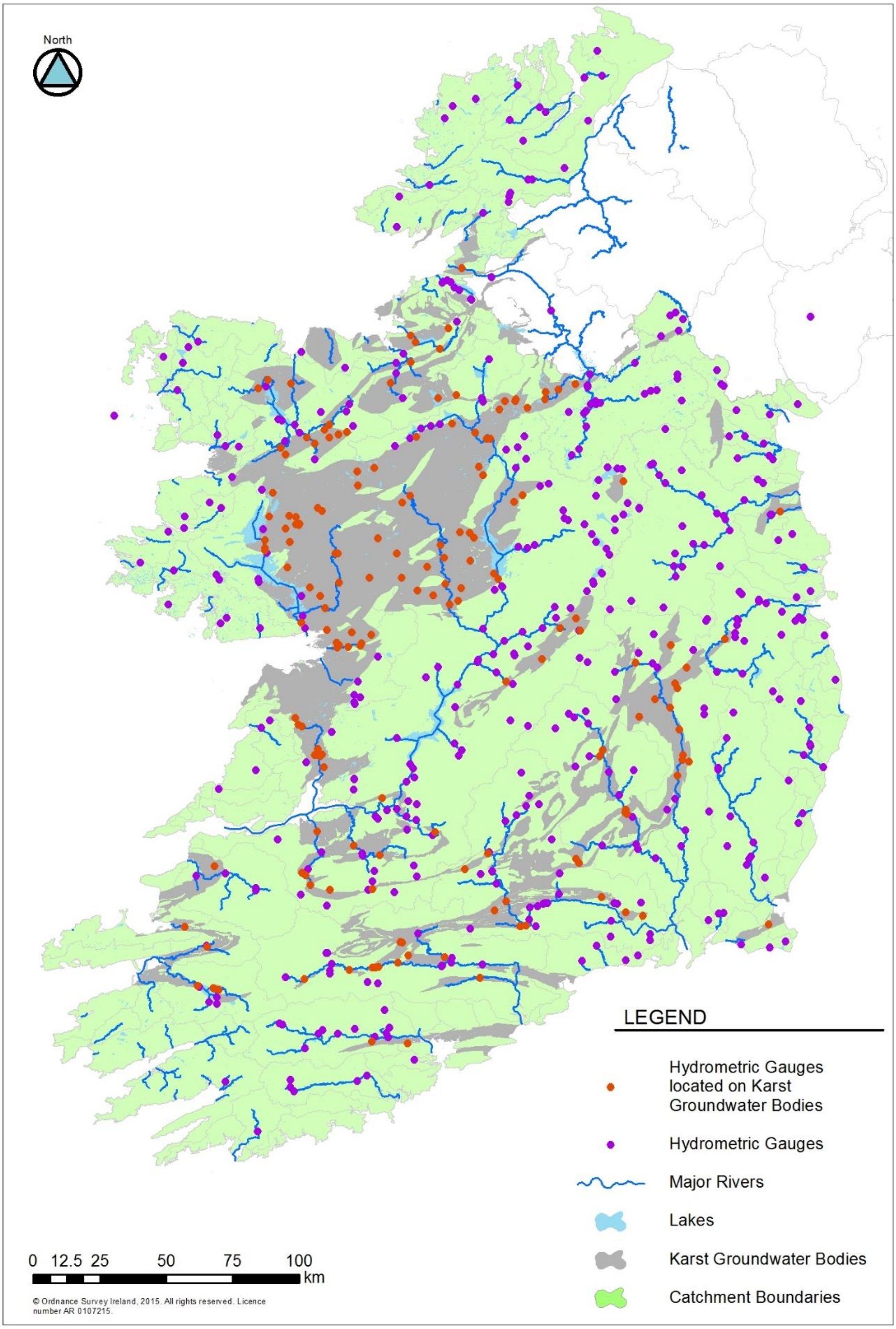


Figure 5-5: Irish hydrometric network for long term climate change monitoring and OSPAR Reporting

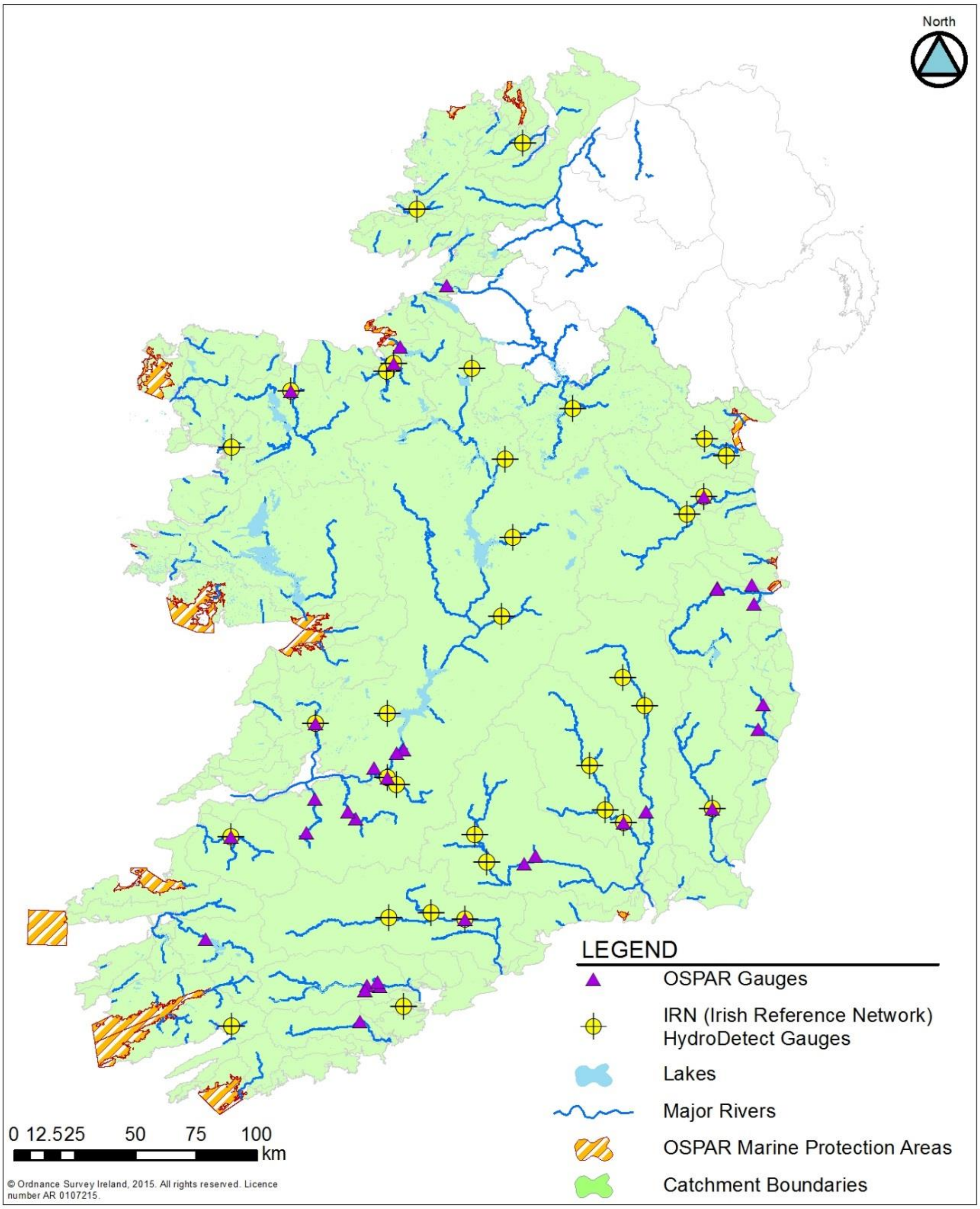
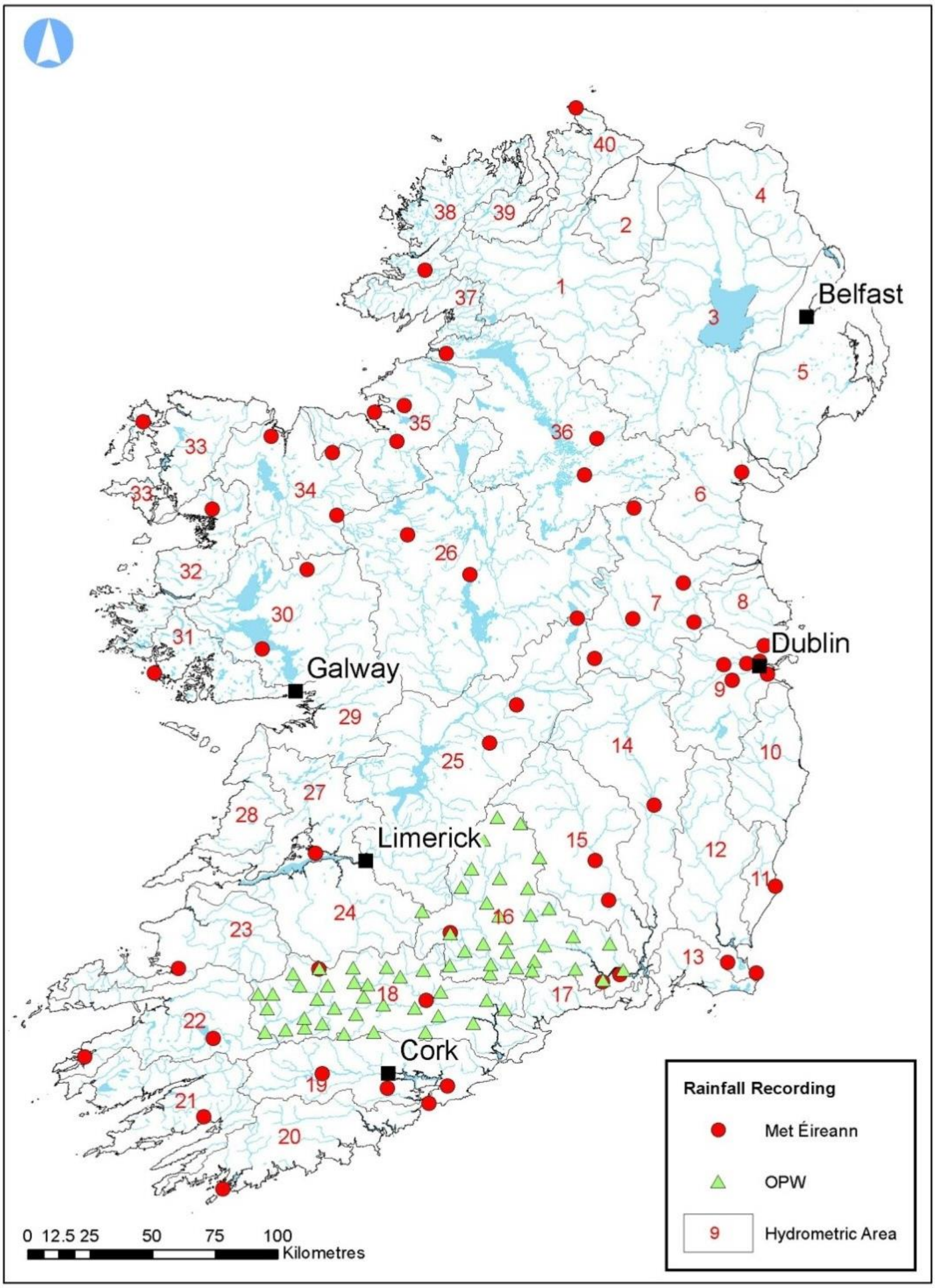


Figure 5-6: Automatic raingauges in Ireland[6]



[6] Figure taken from JBA Consulting. 2008. Strategic Review of the Hydro-metrological Monitoring programme, Final Report by JBA Consulting for Office of Public Works.

5.3 Hydrometric network governance

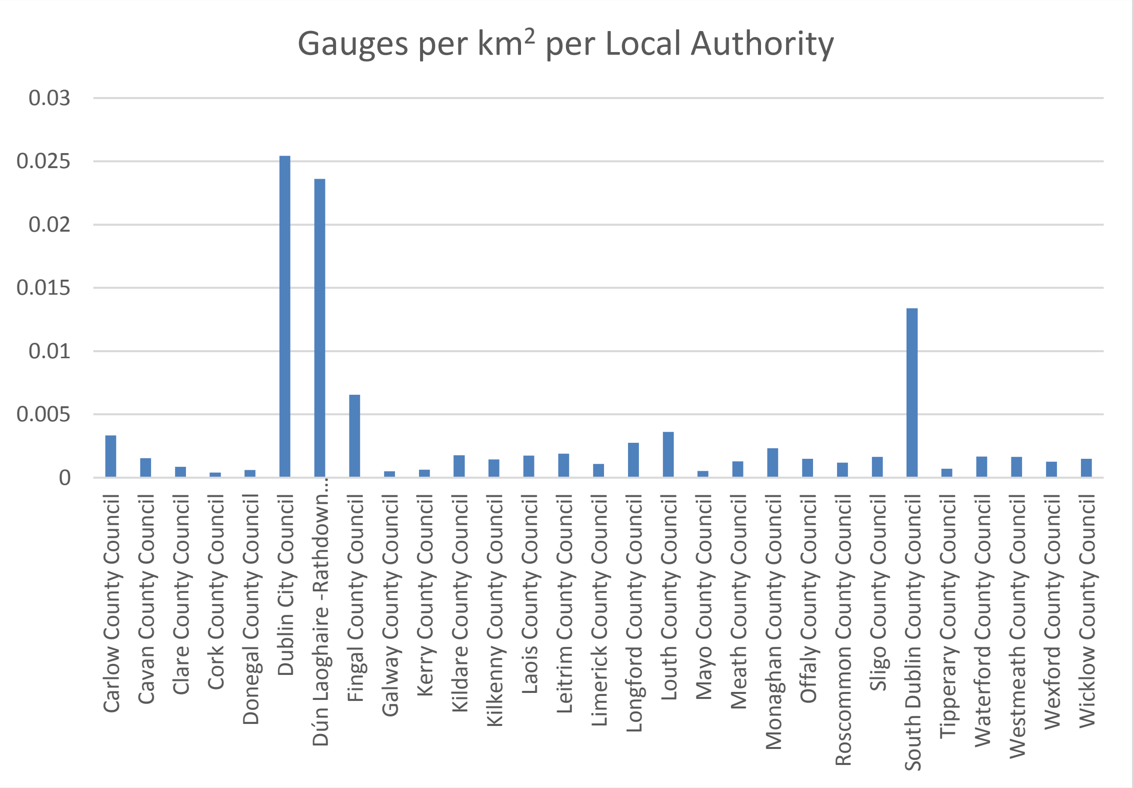
5.3.1 Ownership model

The current situation in Ireland with respect to governance of the gauge network is complex. There is no unified ownership and maintenance model, the EPA-LA and OPW networks being governed and operated quite separately.

The Local Authorities own the gauging stations in the EPA-LA network, funding their construction and physical maintenance. Under the Environmental Protection Act (1992) the EPA have powers to direct Local Authorities to construct gauges and maintain existing gauges, but this power has not been implemented to date. The EPA has responsibility for operating stations including data collection, development and update of stage-discharge relationships and quality assurance of collected data.

The distribution of gauges by local authority is uneven (Table 5-2 and Figure 5-7) - for example County Mayo owns 29 stations whilst Dublin City Council owns just 4 stations, yet Dublin City, South Dublin, Fingal and Dún Laoghaire-Rathdown have significantly more gauges per km^2 than the national average. County Mayo is significantly larger in area and has a lower population than Dublin, but is likely to have similar or smaller staff resources and funding available to maintain each gauge.

Figure 5-7: Gauges per km^2 by Local Authority[7]



The OPW has the ability to design, construct, open and operate the hydrometric gauges to fulfil its statutory responsibility. The national hydrometric working group was set up as recommended in the Review of the EPA Hydrometric Programme (EPA, 2011). A memorandum of understanding between the two organisations has been agreed. Closer co-operation with Local Authorities is also recommended in the 2011 review (EPA, 2011).

There are no procedures or standards to ensure abstraction and discharge license holders (such as Irish Water) install reliable gauges as part of the license conditions or that abstraction/discharge plant works or fisheries improvement works do not interfere with the functioning of existing hydrometric stations. It is important that the Hydrometric and

[7] One gauge in the EPA/LA network on the Hydrometric Register is owned by Bord na Mona.

Groundwater Section of the EPA are consulted in advance of all such works to ensure appropriate locations and equipment are selected.

There is no mechanism by which data from third parties (such as the OPW) can be accessed by the EPA. An example could be level or rainfall gauges installed by the OPW for flood forecasting and warning or Local Authority owned raingauges. Data from these gauges could be used to enhance many EPA activities such as to identify where failures in bathing water quality standards might be attributable to heavy rainfall. There is no strategy for bringing gauges that are permanently or temporarily installed for a specific operational use, into the "network", so that they might be allowed to mature into established reliable hydrometric gauges that offer strategic as well as operational value.

5.3.2 High priority and strategic gauges

There is no formal status for the Irish Reference Network (IRN) gauges used to monitor and detect climate change. Two IRN gauges are currently suspended and two further gauges are at threat of suspension due to a lack of available resources from Local Authorities concerned. There are no formal agreements to manage the potential conflict between removal of barriers for fish migration or environmental river enhancement projects and the impact on gauge ratings at operational or strategic hydrometric gauges. There are cases of local fishermen and landowners removing hydrometric gauges without consultation. There is no formal view on the role of hydrometric gauges and Natura 2000 designated sites on whether the gauges are impinging on the condition of the site or critical to understanding the pressures to the site to inform protection measures.

5.3.3 Staff resources

All hydrometric monitoring work on the OPW and EPA gauges is undertaken by in-house staff. There is no formal succession planning policy for technical hydrometric staff or operational non-field staff, including data management and IT.

There are 30.5 hydrometric field based staff working for the EPA and OPW in Ireland. This includes the 10 support staff (van drivers to ensure two person teams for managing health and safety risks) to the OPW hydrometric technicians. Table 5-3 shows the breakdown of these staff by EPA hydrometric area. Figure 5-8 shows the gauges each EPA hydrometric team is responsible for and indicates the area the teams cover. The average number of field staff per active gauge is similar for the EPA and OPW staffing levels. Table 5-4 shows the breakdown of operational staff (non-field based and include management, administrative support, data management, analysis and IT support). The EPA and OPW have similar numbers of technical field staff. These figures do not account for consultants involved in analysis or Local Authority input.

As part of this review the EPA is currently reviewing its role in the national hydrometric programme, with a view to providing a basis for succession planning. There is currently no formal succession planning in the EPA for hydrometric technicians, data management or resource management staff. The OPW have specific concerns regarding to retention of specialist knowledge within the public sector structure. Their main constraint being the inability to recruit in advance of a planned retirement or transfer. The hydrometric working group facilitates knowledge transfer between the EPA and OPW, through events such as shared training.

5.3.4 Budget allocations and funding

Funding for the EPA hydrometric network comes from national government funds for EPA activities and the Local Authorities fund construction and maintenance from their budgets. There is no charging of abstraction and discharge license holders (as happens in all case study countries). Met Éireann charge for data supply, including raingauge data, in Ireland.

In Ireland there is no existing mechanism to transfer funding for hydrometric work between organisations, including between Local Authorities and the EPA. The relative level of funding is unequal between Local Authorities either on a cost per gauge or cost per required gauge quality basis, with some Local Authorities allocating no funding.

5.3.5 Data management and quality assurance

The EPA and OPW both use WISKI 7 for hydrometric data management. Each organisation holds a separate archive and web visualisation and hosting platform. A single website exists which contains links to the various data visualisation platforms on organisation websites. There is currently no way of viewing all gauges through a single online GIS based viewer.

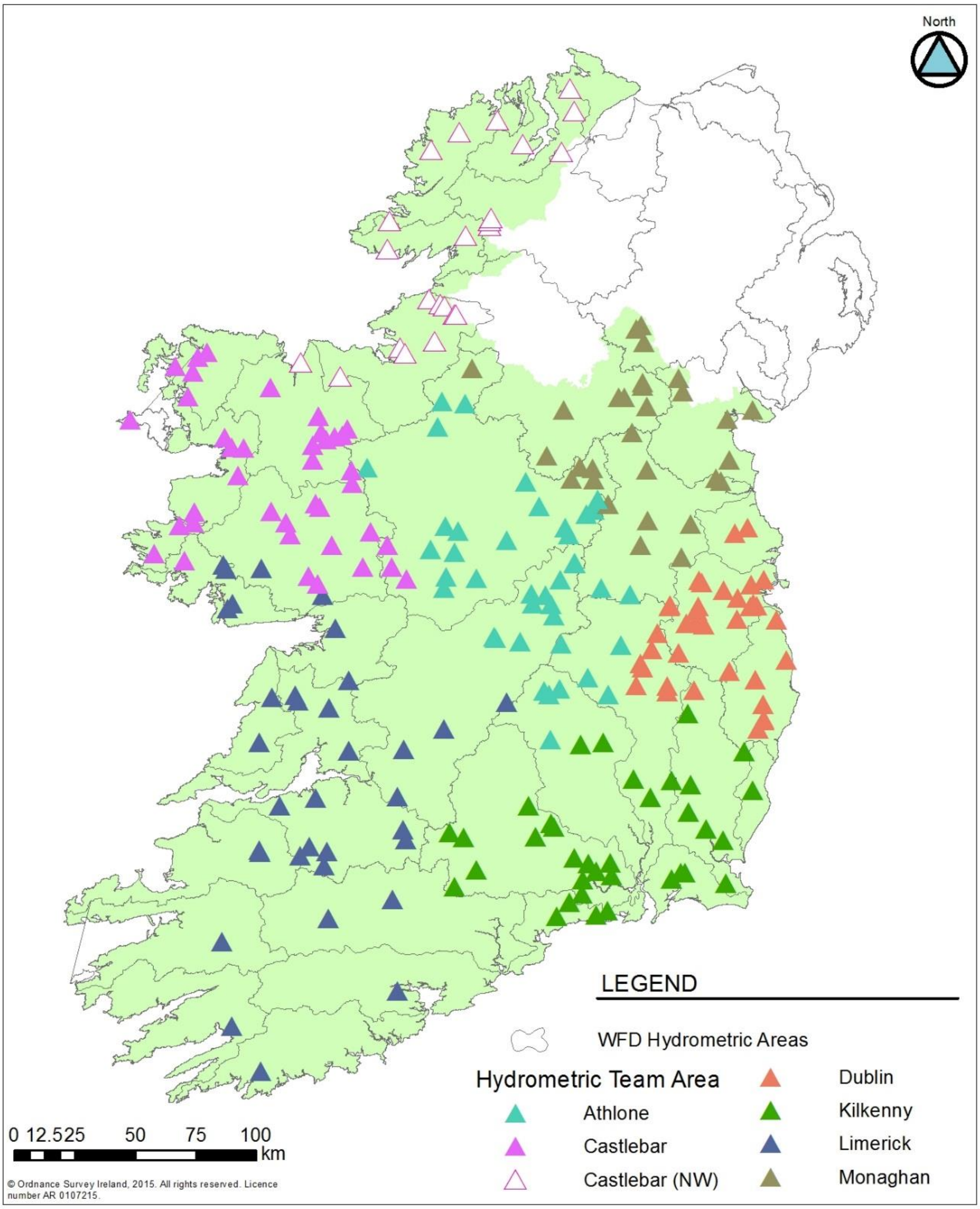
Table 5-3: Breakdown of hydrometric staff in Ireland

Responsible Body	Hydrometric Team Area	No. of Active Gauges	No. of Hydrometric Staff	Gauges per staff	Notes
EPA	*Total*	*230*	*10.8*	*21.2*	
	Athlone	41	2	20.5	
	Castlebar (& North Western)	63	2.8	22.5	Includes 80% of a technician based in Castlebar office
	Dublin	36	1	36	
	Kilkenny	35	2	17.5	
	Limerick	35	2	17.5	
	Monaghan	30	1	30	
OPW	*Average*	*390*	*20*	*19.5*	Includes the drivers/support staff to hydrometric technicians. Also responsible for 63 rainfall stations. Each hydrometric team consist of one hydrometric technician and an industrial support officer. 10 teams in total.

Table 5-4: Breakdown of office based (inc. administrative) staff in Ireland

Responsible Body	No. of Active Gauges	No. of Office Based Staff	Gauges per Office Based Staff	Number of Office Based Staff per Hydrometric Technician
EPA	240	3.2	57.1	0.4
OPW	390	9	43.3	0.45

Figure 5-8: EPA hydrometric gauges by hydrometric team and hydrometric areas



5.4 Drivers for hydrometric data collection

Current and likely future drivers for hydrometric data collection in Ireland are set out in the tables below. Table 5-4 summarises the main regulatory drivers that have direct relevance to EPA activities, which include environmental reporting, WFD assessments and licensing responsibilities.

Table 5-6 outlines other main drivers, including OPW's flood risk management obligations. These drivers are not exclusive to Ireland; all EU countries face similar obligations under EU Directives, as exemplified in the case study examples for Wales and Scotland. The need for hydrometric data to support water resource, flood risk management and environmental management is a challenge faced across all developed countries.

Overall no major expansion of the hydrometric network in Ireland is anticipated in order to meet these challenges. Through the current review process, the EPA have identified specific gaps in the network. The JBA review in 2011 of flood forecasting and flood warning for the OPW and the OPW Flood Studies Policy Review 2004 highlighted the need for new temporary and permanent gauges to develop, calibrate and operate forecasting and warning systems. Some of these gauges might be temporary (e.g. to improve flood model calibration or to design flood management schemes), whilst others would be permanent telemetered sites for flood forecasting and warning purposes (especially rainfall gauges). Many of these gauges are likely to be level only gauges.

The EPA Hydrometric and Groundwater Team have indicated that the recent formation of Irish Water has not changed the responsibilities, ownership and roles of the various bodies that undertake hydrometric work in Ireland. The EPA's duties remain those under Section 64 of the 1992 Act, despite some Local Authorities having assumed that their obligations regarding the collection of hydrometric data are now the responsibility of Irish Water. Irish Water does represent a new stakeholder which will utilise hydrometric data for modelling, design and licensing purposes.

Table 5-5: Hydrometric data requirements with direct relevance to EPA activities

Driver	Type	Examples	Data requirement	Responsibility
EPA use of hydrometric data				
Environmental Reporting	European Statutory	Irelands Environment 2012	**Representative** and **statistically robust** data at national scale.	EPA and other bodies
Climate Change Detection	Research and Operational	HydroDetect and Irish Reference Network (IRN)	**Representative** and **statistically robust** data at national scale with long interrupted record series with minimal anthropogenic influence	EPA and other bodies with gauges in the IRN. Currently only the EPA and OPW.
WFD ecological flows	European Statutory		**Representative** and **statistically robust** data at national and European scale including the ability to calibrate and operate HydroTool.	EPA as part of the WFD cycle 2
Discharge and abstraction licensing	Statutory.WFD operational.	Estimation of upstream flows. Setting of license limits based on flow regime. Monitoring in real time. Use in legal proceedings.	**Robust** and **reliable evidence** for specific locations. For estimates of flow regime including the ability to calibrate and operate HydroTool.	EPA and other operators with reliable flow gauges. Potentially Irish Water and/or other license holders for monitoring.
Diffuse pollution monitoring and modelling	Operational	Data for model calibration.	**Robust** and **reliable evidence** for catchments and specific locations.	EPA and other operators with reliable flow gauges.
WFD characterisation,	WFD Statutory	For setting standards	**Robust** and **reliable evidence**	EPA and other operators with

Driver	Type	Examples	Data requirement	Responsibility
risk and objectives		and objectives.	for catchments and specific river reaches including the ability to calibrate and operate HydroTool.	reliable flow gauges.
OSPAR and bathing waters	EU Statutory	Potential in future to link rainfall gauges to predictive forecasts.	**Specific reporting** on national scale	EPA and other operators with reliable flow gauges.
Public information			**Specific reporting** on national scale.	All bodies (inc. EPA) with reliable gauges.
WFD monitoring of waterbodies at risk of not achieving objectives	EU Statutory		**Specific reporting** on national scale	EPA and other operators with reliable flow gauges.

Table 5-6: Summary table of challenges and pressures for non-EPA use of hydrometric data in Ireland

Driver	Type	Examples	Data requirement	Responsibility
Non-EPA use of hydrometric data				
Research	Research and Operational	Flood Studies Update, Climate Change studies. Some studies are EPA funded.	**Representative** and **statistically robust** data at various spatial and temporal scales	All bodies (inc. EPA) who collect, process, analyse and archive hydrometric data
Ecosystem services and natural capital valuation			**Representative** and **statistically robust** data at national and European scale	
Flood estimation, management and modelling	OPW duty / Operational	Gauge data for pooling groups and donor/pivotal sites for data transfer. Calibration of flood models for risk mapping or scheme development. Strategic and Site Flood Risk Assessment.Use in legal proceedings.	**Representative** and **statistically robust** data for site in question with as long as possible temporal record. Metadata on changes in gauge conditions and rating development is important.	Operators (inc. EPA) of FSU rated A1 and A2 gauges. Operators of gauges in areas of high flood risk or development pressure. Operators of new gauges which could become key pooling group or data transfer sites.
Flood forecasting and warning	Operational	Data for model calibration. Real-time data for warnings and model runs.	**Robust and reliable evidence** for catchments and specific locations. Combination of rainfall, flow and level gauges.	OPW, some EPA/LA gauges are currently used.
Flow regulation for navigation and hydropower	Operational and Statutory	General Public and recreational water users	**Robust and reliable evidence** for specific locations.	3rd party bodies to EPA

Low flow and drought management	Operational	Data for model calibration. Real time monitoring	**Robust and reliable evidence** for catchments, sensitive rivers, abstractions and discharges.	No set body has responsibility for drought management.
River management and maintenance	Operational	For model calibration and design of river management measures	**Robust and reliable evidence** for catchments and specific river reaches.	OPW, private landowners and Local Authorities.
Natura 2000 site management	Operational and Statutory	For determining flow regime. Monitoring of condition.	**Robust and reliable evidence** for catchments and specific river reaches.	All bodies (inc. EPA) with reliable gauges.
Planning and Development Control	Operational and Statutory	National, regional, local and site planning	**Robust and reliable evidence**	National, regional and local planning authorities. Developers and applicants.

5.5 Summary statistics

5.5.1 National density of monitoring stations

Table 5-7: Network density statistics for Ireland

Characteristic	Flow	Level-only
Total gauges (including inactive sites)	1710	579
Total active gauges	479 (300 of which have high quality flow ratings)	298 (176 excluding Waterways Ireland and Marine Institute)
Percentage telemetered	64% (will be close to 100% by Q1 2016)	80% (60%)
Gauges per unit area (1000 km^2)	6.8	4.3 (2.5)
Gauges per million people	104	65 (38)
Gauges per FTE hydrometric staff	11	7 (4) (OPW staff only)
Notes: High number of closed (inactive) flow sites are staff gauges only and remain on the national hydrometric register.		

5.5.2 Regional density of monitoring stations

The regional distribution of river and rain gauges within Ireland is not consistent across WFD cycle 1 river basin districts or hydrometric areas. WFD cycle 2 will contain one national and two international river basin districts. This dissparity is due to the different types of catchments, pressures and population.

Table 5-8: WFD Hydrometric Area breakdown of hydrometric network in Ireland with gauge type

Hydrometric Area	River Network		
	Total active river gauges	Flow	Level only
1 - Foyle	7	6	1
2 - Lough Foyne	-	-	-
3 - Lough Neagh & Lower Bann	14	3	11
4 - Bush & NE Coast	-	-	-
5 - Belfast Lough & East Down	-	-	-
6 - Newry, Fane, Glyde and Dee	13	11	2
7 - Boyne	39	21	18
8 - Nanny-Delvin	10	6	4
9 - Liffey and Dublin	45	22	23
10 - Ovoca-Vartry	10	7	3
11 - Owenavorragh	2	1	1
12 - Slaney & Wexford	19	11	8
13 - Ballyteigue-Bannow	6	3	3
14 - Barrow	45	28	17
15 - Nore	20	18	2
16 - Suir	48	30	18
17 - Colligan-Mahon	5	3	2
18 - Blackwater (Munster)	32	13	19
19 - Lee, Cork Harbour and Youghal Bay	18	17	1
20 - Bandon-Ilen	7	3	4
21 - Dunmanus-Bantry-Kenmare	2	2	0
22 - Laune-Maine-Dingle Bay	11	8	3
23 - Tralee Bay-Feale	8	5	3
24 - Shannon Estuary South	25	22	3
25 - Lower Shannon	75	44	31
26 - Upper Shannon	97	50	47
27 - Shannon Estuary North	19	8	11
28 - Mal Bay	4	4	0

29 - Galway Bay South East	16	11	5
30 - Corrib	29	21	8
31 - Galway Bay North	7	3	4
32 - Eriff-Clew Bay	11	10	1
33 - Blacksod-Broadhaven	6	5	1
34 - Moy & Killala Bay	24	19	5
35 - Sligo Bay & Drowse	20	15	5
36 - Erne	47	22	25
37 - Donegal Bay North	3	3	0
38 - Gweebarra-Sheephaven	5	5	0
39 - Lough Swilly	7	6	1
40 - Donagh-Moville	2	1	1
Notes: Republic of Ireland gauges only.			

6 Comparison with case study countries

6.1 Network governance styles

6.1.1 Overall management strategy

The review has indicated that a range of governance styles are employed in hydrometric network management. As shown in Table 6-1, in Scotland and Wales the national regulatory agency is responsible for administration, strategic management and maintenance of the hydrometric network, whilst in New Zealand local authorities take on this role on a regional basis, with the regulatory authority being one of many end-users of hydrometric data. Network governance in Ireland sits in between these two extremes, although the EPA as regulatory authority actually has very little influence over network governance.

Table 6-1: Comparison of network governance styles in Ireland and case study countries

Governance issues	New Zealand	Wales	Scotland	Republic of Ireland
Overall approach	Federated system with local government leading monitoring	Regulatory Agency (NRW) responsible for all hydrometric monitoring	Regulatory Agency (SEPA) responsible for all hydrometric monitoring	Multiple regulatory authorities operating in same geographic coverage for different uses of hydrometric data.
Scope of hydrometric network	Flow, level, rainfall and groundwater	Flow, level, rainfall and groundwater	Flow, level, rainfall and groundwater	EPA: River, spring, lake and groundwater gauges OPW: flow, level and rainfall
Other considerations	Water quality monitoring undertaken at same station locations	NRW also responsible for environmental monitoring		EPA also responsible for groundwater level and quality monitoring and assist with lake level and water quality monitoring.
Funding sources	Local taxes, discharge and abstraction licence fees.	National government grant, discharge and abstraction licence fees.	National government grant, discharge and abstraction licence fees.	From national funding. Local government funds station maintenance.
Team structures	125 staff over 16 teams	Four teams, three local teams and one overarching national team	43 staff over four teams	44 staff over 16 field and office teams. OPW and EPA covering the same geographical areas.
Frequency of network review and current status of governance	Well established governance, ownership and responsibilities.	Inherited from the Environment Agency and a review by NRW is impending.	Well established hydrometric function.	Ownership and governance established through the EPA Act 1992. OPW operate gauges to achieve their objectives. Formation of Irish Water has changed dynamic between network and data managers.

6.1.2 Funding streams

There are some key differences in terms of the funding strategies for the networks. In New Zealand a large majority of stations are funded by, and often owned by, other council functions; there is very little central funding for gauges. Ultimately, therefore, in New Zealand funding for the hydrometric network is drawn from local authority taxation. Wales and Scotland operate under a different funding model, which see monies drawn from a range of sources amalgamated into a single pot. All the case study countries set discharge and abstraction license fees, part of which goes towards funding hydrometric data collection. Funding in Ireland is through central national budgets for the EPA and OPW and local government budgets for EPA/LA network site maintenance. In Ireland all funding comes from national pots and there are no taxes or charges levied on data users and licence holders to fund hydrometric networks and data provision. Potential sources of funding are not necessarily being fully exploited.

6.1.3 Staff resources

There are also differences in the extent of responsibilities and staff resources, as highlighted in Table 6-2. New Zealand, Wales and Scotland have more staff than are employed in Ireland, but these staff have wider responsibilities. For example SEPA, NRW and the Regional Councils in New Zealand are responsible for maintaining sub-daily rainfall monitoring networks which neither the EPA nor OPW in Ireland have responsibility for, with the exception of the OPW Suir and Blackwater flood forecasting systems. Further in New Zealand hydrometric team members may undertake a number of hydrometric technician roles and other related activities such as data management and other hydrology work. The total number of teams shows that there are more teams in Ireland and each team is comprised of fewer team members. If not carefully managed thus may be a less sustainable model than the larger teams where relationships can be built to share expertise, resources and cover gaps.

Table 6-2: Comparison of team structures and responsibilities

Characteristic	New Zealand	Wales	Scotland	Republic of Ireland
Total no. of staff across all teams	125	20	43	44 EPA:10.8 field 4.2 non-field, OPW 20 field, 9 non-field
Total no. of teams	16	4	8	19 EPA:7, OPW 11
No. of field teams	Mixed teams, including operation and processing staff	3	TBC	18 EPA: 6, OPW: 10
No. of non-field teams		1	TBC	2 EPA: 1, OPW 1
Av. no. staff per team (including non-field teams)	7.8	TBC	5.3	2.3 EPA: 1.8, OPW: 2.6
No. of field visits per site	Variable – depends on access to site	Risk based approach adopted	Risk based approach adopted	Targeted approach based on rating curve gaps
Percentage of work outsourced	15%	<1%	<1%	<1% (for OPW and EPA)

Notes:
These figures are correct at the time provided.
Outsourcing in NZ relates to specialist spot gauging in difficult conditions.
In New Zealand, Wales and Scotland some staff also undertake other activities.
Precise breakdown not readily available or comparable.
Total staff includes field and non-field based staff and those who undertake other activities as well as

hydrometry. In Ireland the staff numbers include the time for lake sampling and groundwater level monitoring and some air quality monitoring. Previously the EPA also undertook some estuarine surveys.

6.1.4 Experience with outsourcing

Outsourcing is not common in the case study countries, being mainly employed only where specialist services are required (such as flow gauging in challenging conditions). In New Zealand there is occasional outsourcing to other regional council teams rather than to private contractors. Wales has experimented with outsourcing work in the past, but found that this did not generally have satisfactory outcomes and the vast majority of work is now undertaken in house. The ESB in Ireland outsource work to maintain and collect flow, level and rainfall data. The gauges are maintained on an annual basis and the data is used to manage the operation of dams and hydropower schemes. Waterways Ireland outsource all of their hydrometric work.

6.1.5 New site and site closure processes

Experience from the case study countries suggests that it is important to have controlled site opening and site closure processes. This especially the case for site closures, where it is possible to underestimate the extent to which the station data is utilised by third parties or could be valuable in the future. For example, SEPA closed a number of stations following a network review in 2010, only for unanticipated users of the data to subsequently come forward.

6.1.6 National hydrometric standards

Gauging methods in the case study countries are aligned with ISO standards for hydrometric measurements. There are local procedures and operational instructions for equipment and telemetry, calibration and data quality assurance.

6.1.7 Natura 2000

None of the case study countries have a strategy for decision making with regards to the need for flow gauges to inform the management of Natura 2000 sites and the removal of barriers such as to weirs to meet site conservation objectives. In Ireland the National Parks and Wildlife Service (NPWS) have responsibilities for the management of the Natura 2000 network, but are currently understaffed to determine an appropriate way forward for hydrometric gauges in and around the Natura 2000 network sites.

6.2 Network density

Table 6-3 reports a comparison of river flow measurement density across the three case study countries and Ireland. This indicates that Ireland is at least as densely gauged as the other countries, both in terms of number of flow gauges per unit area and per head of population.

Table 6-3: Statistics in relation to the flow measurement network

Characteristic	New Zealand	Wales	Scotland	Republic of Ireland
Total active flow gauges	850	127	280	479
Percentage telemetered	95%	90%	70%	64%
Gauges per 1000 km^2 area	3.2	6	3.5	6.8
Gauges per million people	200	40	53	104
Gauges per hydrometric staff (field and office based)	10	~6.5	6.5	11
Notes: **Direct comparisons are not possible due to differences in the categorisation of gauges and description of hydrometric teams.** No distinction is made between high quality flow gauges and those with unreliable ratings. **In**				

Ireland around 300 flow gauges have high quality ratings and 100% of these will have telemetry by 2016. Of these high quality gauges there are around 4.2 gauges per 1,000km2 and around 65 gauges per million people.
In New Zealand Almost all council staff working in hydrology units also undertake a range of other work such as air quality monitoring, water quality monitoring, groundwater monitoring, operation of Fire Weather stations, bathymetric surveys, as well as many other varied duties.
Figure for Ireland represents total across EPA-LA network, ESB, OPW, Waterways Ireland and Marine Institute.

It is important to note that this does not imply that the Irish network has greater fitness for purpose than the other case study networks. Gauge density statistics do not take into account of whether the gauges are well-sited or are good quality "full range" sites. Whilst there is some necessary 'duplication' in most hydrometric networks (i.e. due to hydraulic conditions it is possible that low flow and high flow conditions have to be measured at separate stations), in the Irish case this has been exaggerated by separate bodies being responsible for low flow and high flow monitoring, leading to few stations being full range. In some places it may be possible for the EPA and OPW to consolidate two existing nearby gauges into a single full range station. This will bring many benefits in terms of network efficiency, but will result in a decrease in gauge densities.

Also, compared to other countries the percentage of gauges that are currently telemetered is low. This is something that is being addressed with all high quality gauges on the EPA/LA network to be telemetered by 2016.

The comparison does highlight that, for its size, there are comparatively few staff resources allocated to the Irish network than for the other countries. On average each FTE staff member in Ireland has to maintain 11 flow gauging stations, whereas in the other countries this figure is much lower around 6 or 7 gauges per staff member (although they also may have other duties). This seems to imply that more staff resource is needed in Ireland or the number of sites should be reduced to enable delivery of fewer quality sites rather than many poor quality sites.

Table 6-4 illustrates the same statistics in relation to the level-only networks in Ireland and the three case study countries. In Scotland and New Zealand level-only sites are seen as supplementing the flow network (i.e. used where it may not be necessary or affordable to install a full flow gauging station) and as such are generally used for flood warning and forecasting applications. Wales has more level-only stations that flow stations, but the majority of these were installed in the last 10 years in response to high profile political drivers to improve flood warning services in England Wales (e.g. following the 2007 floods and other events). These stations are mostly concentrated in urban areas, so density figures for Wales are strongly skewed.

Ireland has a very large number of level-only gauges used for lake level monitoring and flood management, which is at least as dense as that in Wales (when considered in terms of gauges per unit population). Considered in conjunction with the flow gauging network, this implies a satisfactory surface water network in Ireland, when compared against what has been achieved in countries with similar challenges and drivers.

Table 6-4: Network density statistics in relation to level-only stations

Characteristic	New Zealand	Wales	Scotland	Republic of Ireland
Total open level-only gauges	130	200	126	**298** (176 excluding Waterways Ireland and Marine Institute)
Percentage telemetered	95%	90%	95%	**80%** (60%)
Gauges per 1000 km^2 area	0.48	9.2	1.5	**4.3** (2.5)

Gauges per million people	30	63	24	**65** (38)
Gauges per hydrometric staff	1.5	TBC	3	**14** (9) (OPW staff only)
Notes: Figure for Ireland represents total across EPA-LA network, ESB, OPW, Waterways Ireland and Marine Institute. We do not hold resource statistics for the 121 water level gauges operated by Waterways Ireland Figures for case study countries do not include electricity or navigation resources or gauges.				

The above tables indicated that the river gauging networks in Ireland are at least as dense as in contemporary countries. One factor for this may be the greater use of rainfall data for flood warning and forecasting purposes in the other countries. For example, SEPA and NRW both maintain their own networks of automatic raingauges (mainly tipping bucket gauges) for flood risk management purposes and do not rely on the UK Met Office for provision of such data streams. One major difference between the situation in Ireland and the other case study countries considered is the more complete integration of rainfall gauges into the hydrometric network. In Ireland the EPA do not currently use rainfall data as part of the national environmental evidence base. The OPW operate rainfall gauges where flood forecasting systems are in operation. Local Authorities have not installed many rainfall gauges for local operational needs such as the management of wastewater treatment plants, however many of these are not maintained but still used to inform flood management schemes in the absence of other data.

Table 6-5: Network density statistics in relation to rainfall stations

Characteristic	New Zealand	Wales	Scotland	Republic of Ireland
Total open rainfall gauges	690	270	390	630
Total TBR gauge	>600	211	274	118
Percentage of TBR gauges telemetered	85%	80%	55%	100%
Gauges per 1000 km^2 area	3.9	12.8	5	1.7
Gauges per million people	200	90	74	25
Gauges per hydrometric staff	10	TBC	9	3 (OPW staff only)
Notes:				

6.2.1 Flow gauges for OSPAR convention

Scotland and Ireland both identify gauges which are used in monitoring and reporting for the OSPAR convention. The majority of Marine Protection Areas (MPA) around mainland Scotland's coastline have associated flow gauges on rivers that drain into estuaries within or within a zone of influence of the MPA (Figure 4-3). Many of the MPAs around the Scottish Islands do not have flow gauges for the smaller catchments that drain nearby. In Ireland there are some notable catchments which flow into MPAs which do not have any flow gauges specifically marked as for use in OSPAR monitoring and reporting (Figure 5-5). There are also a number of OPSAR gauges which do not drain directly or near to MPAs. In Wales OSPAR reporting is based upon a range of hydrometric data which includes rainfall monitoring.

6.3 Uses of hydrometric data

Overall flood risk management and water resources operations draw approximately equal benefit from the flow gauging networks in New Zealand, Wales and Scotland. Roughly 80-90% of the network provides data that feeds in to flood risk management applications, whilst similarly 80-90% of sites provide data that are used for water resources management purposes. This implies that data from a large proportion of flow gauging stations has multiple-end uses. As shown in Table 6-6 a large proportion of flow gauges in New Zealand are also used for environmental operations. This probably reflects the significant emphasis placed on environmental monitoring in New Zealand and the formalisation of this through the LAWA initiative. In Wales and Scotland less use is made of flow data for environment reporting, however overall it is evident that most data sets have multiple end-users.

Table 6-6: Operational uses or drivers of river flow monitoring data (figures show % of sites used for purpose)

Driver	New Zealand	Wales	Scotland	Republic of Ireland
Flood Risk Operations	80%	89%	82%	69%
Water Resources Operations	80%	95%	80%	46%
Environmental Operations	90%	62%	50%	46%
Notes: It has not proved possible populate this table based on information provided by New Zealand Regional Councils and Unitary Authorities. The majority of sites have multiple current uses, including flood risk management, water resources and environmental reporting. The figures in the table are therefore JBA assumptions based on anecdotal information provided by the New Zealand Regional Councils.				

In Ireland there is a slight bias towards flood risk management applications with 70% of flow gauges appearing to be used for flood risk purpose, whereas less than half the stations have a water resources or environmental use. The percentage of gauges used for different purposes is lower, or at least perceived in Ireland than all the case study countries for all uses. I.e. most gauges either have a flood risk management purpose or a water resources/environmental purpose. This suggests that the EPA and OPW gauges networks have evolved for their own purposes with little coordination.

Overall, it appears that there is a much clearer understanding of uses of hydrometric data in New Zealand, Scotland and Wales than is potentially the case for Ireland. In these countries provision of the data to multiple end-users is much more widely acknowledged and recognised, even where stations were originally installed for (and funded for) a single purpose.

Table 6-7 provides a similar comparison for the level-only networks. This suggest that the majority of level-gauges are used for flood risk operations and just a small number are used for other purposes (including monitoring lake levels and river levels at intakes etc.). For example the 130 level-only gauges in New Zealand are mainly used for flood warning purposes or for the control of gates associated with flood control structures. In Wales and Scotland some level-only gauges are also used to monitor stream levels immediately upstream of culvert screens to monitor potential impact of water levels due to blockage or debris.

Table 6-7: Operational uses or drivers of level-only monitoring data (figures show % of sites used for purpose)

Driver	New Zealand	Wales	SScotlandc otland	Republic of Ireland
Flood Risk Operations	100%	100%	36%	90%
Water Resources Operations	0%	0%	12%	5%
Environmental Operations	0%	0%	10%	5%
Notes:				

6.4 Data management and dissemination strategies

There are two main elements to be discussed here; i) internal data management and quality assurance, and ii) means of disseminating data.

There are many overlaps in terms of how the case study countries manage, quality control and disseminate data, the greatest similarities being between Wales and Scotland. Both use the WISKI database platform to store and manipulate hydrometric data and follow ISO standards for data collection and quality assurance. Both have a reciprocal arrangement with the UK Met Office for validation of rainfall data and a MOU with NERC to provide data from key stations to the National River Flow Archive, which carries its own independent review of hydrological data series and makes selected data series and statistics available to the public. NRW and SEPA also have similar approaches with respect to the split of staff resources between field and office (processing duties) with key staff having a national overview of hydrometric data collection. SEPA and Wales are signed up to the concept of OpenData, currently make river level data for selected gauging sites publically available via websites, and have plans to make other data including river flows available in the same way (data is freely available via request, with a handling charge).

There is no overarching data management system in New Zealand. Each regional council has its own individual approach to data storage and dissemination with a variety of different website styles and types in use. Most customers for NZ data are probably from within the local council area (i.e. internal customers) so this does not appear to be problematic from a practical viewpoint. Data is forwarded on to the LAWA initiative for use in national environmental reporting, where it is available in a consistent form.

Within Ireland each hydrometric body has a separate archive and web mapping system. At present the only consistent link is the data.gov summary page containing links to each of the systems and data holders (http://www.gov.ie/services/access-hydrometric-data/). This is similar to the situation in New Zealand, but without the LAWA initiative to bring the data together.

7 Conclusions and Recommendations

7.1 Conclusions

There are a number of drivers that necessitate changes to the hydrometric network in Ireland. All of these drivers are present in the three case study countries (New Zealand legislation requires similar levels of hydrometric data to EU legislation). None of the case study countries have a perfect situation, but lessons can be learned to inform recommendations. From our comparison we can conclude that the broad themes driving network change are:

- The need to do more with less requires efficient management of hydrometric networks.
- New and recent legislation places new demands on hydrometric data, on top of established legislation such as OSPAR and WFD reporting.
- Conflicting priorities for high quality reliable gauging stations such as the removal of barriers to migration and requirements to meet Natura 2000 site objectives.
- The data requirements of new and expanding activities such as flood forecasting and warning systems and the Water Framework Directive.
- The data sharing requirements to achieve the Government's Open Data policies.
- The recent establishment of Irish Water and evolving management of water supply and treatment.

7.2 Considerations for short term activities

Based on an assessment of hydrometric network governance and management in the three case study countries, there are a number of recommendations that can be applied to Ireland.

To address the drivers for hydrometric network change JBA have identified a number of recommendations for hydrometric networks in Ireland. These recommendations are outlined below and grouped into those which are achievable in the short term and those which would require significant organisational, legislative of financial change. The achievable short term recommendations are based upon the likely assumption that the remit of each organisation involved in hydrometric gauges and data will not change for the foreseeable future. The long term considerations should be assessed in line with Government vision and priorities for the use of all hydrometric data in the future.

The short term c outlined in more detail below are:

Recommendation 1: The EPA individually and also with the OPW and other hydrometric bodies to set out a future vision for hydrometric networks in Ireland.

Recommendation 2: A strong Hydrometric Working Group to facilitate governance of the hydrometric network.

Recommendation 3: The EPA to complete the ongoing review of the classification of hydrometric gauges into strategic, operational and project gauges.

Recommendation 4: The EPA to collate details of all hydrometric gauges on the hydrometric register and expand the metadata the register holds.

Recommendation 5: The EPA to lead the development of acceptable quality standards for the different gauge categories in conjunction with the NHWG.

Recommendation 6: No change in station ownership from the current model.

Recommendation 7: The EPA to review funding opportunities and consider better coordination of budgets.

Recommendation 8: The EPA to develop a national approach to succession and resource planning.

Recommendation 9: The EPA to consider whether the ESB approach to outsourcing could be applied to lower priority gauges and for Local Authority operational and project gauges with no EPA data requirements.

Recommendation 10: The EPA to develop and implement through the Hydrometric Working Group a new site and site closure process.

Recommendation 11: The EPA to set the framework for collecting hydrometric data to ISO standards.

Recommendation 12: Once the classification of stations is complete, the EPA to continue the ongoing consideration of a strategic network review in the density of gauging stations.

Recommendation 13: Once the classification of stations and setting of acceptable quality standards is complete, the EPA to reconsider site visit frequency.

Recommendation 14: Once the classification of stations and setting of acceptable quality standards is complete, the EPA should consider alternative flow gauging methods for existing sites to deliver the required data quality.

Recommendation 15: Continue development of, publish and continue to update the GIS based webmap viewer with all gauges to work towards Open Data policies.

Recommendation 16: Develop a national strategy for environmental evidence to value the contribution and benefits of the hydrometric network.

Recommendation 17: As part of an evidence strategy consider integration of the hydrometric network with catchment modelling and monitoring.

7.2.1 Recommendation 1: The EPA individually and also with the OPW and other hydrometric bodies to set out a future vision for hydrometric networks in Ireland.

None of the case study countries have set out a future vision for their hydrometric network or governance in 2020, 2030 and so on. All of the case study countries are continuing with the current hydrometric network and governance that has evolved over time, rather than a full and objective strategic review of needs. Natural Resources Wales are due to commence a fuller strategic review of hydrometric data and this may consider their vision and needs for the future.

Perhaps the most critical element of a future vision, which has not been considered is to determine the acceptable levels of uncertainty in hydrometric data in the future. Such an assessment may conclude that no gauge needs to provide perfect quality data.

For example a vision could set out the quality, coverage and respresentivity for each classification of gauge (e.g. acceptable quality standards for gauges could be set with uncertainty along the lines of low to moderate uncertainty for strategic gauges, moderate uncertainty for operational gauges and high uncertainty for project gauges). The costs and benefits of achieving different levels of uncertainty should be understood to justify the vision and level of investment and resources to achieve the vision.

7.2.2 Recommendation 2: A strong Hydrometric Working Group to facilitate governance of the hydrometric network.

For the foreseeable future the EPA will continue to be the responsible agency for environmental protection in Ireland, whilst the OPW will continue to be the lead agency in flood risk management and flood relief. Whilst both bodies have need of hydrometric data there is limited overlap in their day to day activities, corporate aims and objectives. In the legislative setting therefore makes it very difficult to envisage a single body would be responsible for all hydrometric stations in Ireland.

That is not to say that a coordinated hydrometric network cannot exist, rather that split ownership of the physical components of the network is inevitable. The case study example for New Zealand has shown that it is possible for hydrometric data from disparate sources/owners to be collated together in a single consistent archive, thereby maximising its wider value and benefit. This is not an achievable goal in the short term. Given the powers, responsibilities and the remit attributed to the EPA through the 1992 Act and the OPW under the EU Floods Directive, it would seem appropriate that the EPA and OPW leads this group, working in close collaboration with all bodies involved in hydrometric data collection (i.e. including the Marine Institute, ESB and Waterways Ireland). As is also evident from the New Zealand example, strong leadership of this group is essential to developing a strong hydrometric network that is fit for purpose.

The terms of reference for the Hydrometric Working Group should be reviewed to determine which of the following activities to standardise aspects of hydrometric network governance and management between the organisations can be included:

- Managing and enhancing the National Hydrometric Register
  - Establishing and maintaining the Hydrometric Register as the definitive inventory of all stations, including meta-data such as site classification (strategic, operational, project as set out in the Review of the EPA Hydrometric Programme 2011) site type, ownership, gauging type, period of record
  - To agree strategic gauges for the next 5 years, that require high levels of service.
  - To identify operational sites to be maintained by the site owners.
  - To identify and understand project sites, which may be closed after a short lifetime or have the potential to become operational or strategic.
  - Establishing and maintaining a log to understand the uses and end-users of data from individual gauges, including revision of gauges for OSPAR monitoring and reporting.
  - Establishing and maintaining an understanding of data quality achieved (including measurement uncertainty and artificial influences on measured flows)
  - Important gauges with less than ideal flow ratings should also be identified to identify where data from poor quality gauges is better than a lack of gauged data.
  - Establishing and maintaining an understanding of wider environmental impact of gauging structures, especially in relation to fish passage and sediment control at weirs
- Data quality maintenance and archiving
  - Standards for maintaining gauge ratings for all hydrometric sites and identifying which gauges could be used to deliver both low and high flow ratings for use by other organisations.
  - Logging calibration and validation checks on gauged data as part of the Hydrometric Register metadata
  - Consideration of single web portal to visualise the location of all gauges on the hydrometric data register.
  - Primary data quality assurance through shared technical expertise
- Establishing best practice and operational instructions for:
  - Stage-discharge ratings (this could involve spot gauging, gauging via ADCP, or rating extensions using models
  - Design standards for new and existing gauges
  - Exploitation of new technologies
  - Standards for site visits and maintenance regimes
  - Establish responsibilities for maintenance of individual stations[8]
- Control of network change
  - Undertaking of coordinated strategic and operational network reviews so that consistent conclusions can be reached which benefit both the EPA and OPW.
  - Set-up and operation of panels to review proposals for potential new sites, including detailed station specification (location, station type, construction

[8] The standards and license agreements should also set out who is responsible for gauge maintenance. These standards are especially required for Irish Water and other abstraction or discharge license holder, where monitoring of the abstraction, discharge or river flows is part of the license conditions

proposals, cost model. Ideally powers to ensure proposals satisfy best practice and legislative requirements.
    - Set-up and operation of panels to review stations that are flagged for closure (i.e. review strategic value and approval of closure if strategic value not considered sufficient)
- Strategic development of a pool of technical hydrometric skills in Ireland.
    - Training programmes for hydrometric staff
    - Strategies for exchange of skills and know how
    - Dissemination of best practice and standards of service
    - Gauging reviews and spot gauging
    - Maintenance of telemetry equipment
    - Data management and processing
    - Resource management and work planning
    - IT services, hosting, archiving and contract management
    - Contract management for any other outsourced work
    - Training

Based upon the above set of considerations for the hydrometric working group terms of reference, there are a number of short term actions that should be undertaken regardless.

7.2.3 Recommendation 3: The EPA to complete the ongoing review of the classification of hydrometric gauges into strategic, operational and project gauges.

The EPA should recommend gauge classifications and consult with gauge owners and operators allowing them to upgrade the classification where specific extra data requirements outside the EPA remit are present, but not downgrade. The EPA should continue to use the classification set out in the Review of the EPA Hydrometric Programme (EPA, 2011).

7.2.4 Recommendation 4: The EPA to collate details of all hydrometric gauges on the hydrometric register and expand the metadata the register holds.

Gauges with unknown or poor data quality or missing data should be noted as such rather than omitted from the register.

Whilst the EPA maintain a register of hydrometric sites, this contains limited metadata and information about users and uses of station network. It is recommended that the EPA develop a more formal catalogue of the network, and attempt to include within this some indication of uses of data as well as known data quality issues. This information needs to be documented consistently and updated frequently so that it can be drawn upon in site closure appraisals. The case study examples have illustrated that station data is often much more widely used than appreciated by measuring authorities. Naturally over time a station will come to have many users and uses as it is used opportunistically for purposes other than the station was originally conceived and installed. Understanding these uses can lead to more equitable resourcing of network costs over the long term.

7.2.5 Recommendation 5: The EPA to lead the development of acceptable quality standards for the different gauge categories.

These should be based upon the level of uncertainty that is acceptable to meet the data requirements with consideration of what is achievable given technological, budget, health & safety constraints.

7.2.6 Recommendation 6: No change in station ownership from the current model.

Multiple station owners across the network should not be seen as a barrier to the effective operation of a single network. The multiple ownership model works well in New Zealand, but there are other international examples such as the USA, where the USGS operates the network, but this in on behalf of many partners

Local Authorities are not currently in a position to fund, coordinate or undertake the technical hydrometric work undertaken by the EPA or OPW and so transfer of responsibilities following the New Zealand model would not be effective in the short to medium term. Further the geography of Ireland would present challenges as most river catchments cross numerous local authority boundaries.

7.2.7 Recommendation 7: The EPA to review funding opportunities and consider better coordination of budgets.

Funding for hydrometric networks currently comes from EPA, Local Authority, OPW and other public bodies. There should be consideration of the following funding streams used in the case study countries:

- Consolidation of Local Authority funding to a single Local Authority WFD office as opposed to 32 separate contacts and/or central government funding. The National Hydrometric Working Group should be in a position to inform the levels of service necessary for gauges of different categories to determine evidence based funding levels.
- Investigate potential for contributions from Irish Water.
- Abstraction and discharge license fees to include a contribution to hydrometric networks. Fees could also be levied onto other licenses related to water and river use, such as navigation and fisheries.
- Data processing fee, as charged in England for Freedom of Information requests to cover the administrative costs of supplying data. However this may be contradictory to the Open Data agreement the EPA has signed up to.

Unlike the New Zealand NIWA, the EPA is unable to conduct commercial work and equally funding through local taxation of levies on properties protected from flooding is not likely to be a politically desirable option. None of the case study countries have provided budget figures to allow a comparison of the costs of hydrometric services.

7.2.8 Recommendation 8: The EPA to develop a national approach to succession and resource planning

The structure of hydrometric teams (two-man teams) within the EPA, leads to significant vulnerability and issues in relation to resilience. Many experienced staff are due to retire, or have recently retired with no structured transition of skills or experience being in place. This has been accentuated in recent years with the restrictions on public sector recruitment. There needs to be a strategic national approach to succession planning to ensure retention of knowledge and continuation of experience. A strategic national approach to succession and resource planning could consider hydrometric technicians, resource management, data management, hydrology and IT services. The strategy should be developed and shared with the OPW hydrometric services.

It is clear that, compared to other countries, the numbers of FTE staff per team are low in Ireland. Moving towards slightly larger teams would help with workloads and resilience. Any expansion of staff numbers should be coupled with a review of staff roles and an updated strategy to site visits. This would help staff time to be focussed on the most vital tasks within the network.

7.2.9 Recommendation 9: The EPA to consider whether the ESB approach to outsourcing could be applied to lower priority gauges and for Local Authority operational and project gauges with no EPA data requirements.

Based on experiences in the case study countries, in the short-term outsourcing of maintenance and operation of hydrometric sites is unlikely to provide satisfactory outcomes. The experience from the ESB suggests that outsourcing is possible, but the EPA would need to be satisfied the appropriate level of service can be delivered. A blanket approach to outsourcing may not be appropriate, but an approach based upon gauge priority or status could be considered. The financial costs of the ESB model to outsourcing should be compared with EPA costs to maintain gauges in consideration of the different level of service that can be provided.

7.2.10 Recommendation 10: The EPA to develop and implement through the Hydrometric

Working Group a new site and site closure process.

Processes for opening and closing sites needs to be formalised. This is particularly important in Ireland as an operator may no longer see a direct operational need for a gauge, but the data provided by the gauge has a (or potential for) strategic value, either to the EPA or more widely (e.g. climate change monitoring or feeds into regional hydrological models). Historic data from temporary gauges may retain value for other users in the future and so archiving of temporary and closed stations is important. Greater control should be exerted over the network in the future to prevent the installation of stations with little or singular benefit, or that cannot be established or maintained in future according to necessary standards.

The Hydrometric Working Group should set out the process for new sites and site closure, which should be administered by a single section of either the EPA or OPW. The EPA Hydrometry and Groundwater section or WFD office are ideally placed to allow a national overview, however must be open to prioritising their needs together with those of the OPW and other hydrometric bodies.

It would be beneficial if more detailed best practice and operational instructions could be developed in relation to design standards for new stations, which should include guidance on choice of gauging method and specification requirements. It is also recommended that the set-up of expert panels to review proposals for potential new sites is considered. These panels would ensure strategic and practical considerations had been fully explored before any sites were installed.

Similar expert panels could be set-up to review stations that are flagged for closure. These panels would review operational value, from the current uses/users of the data but also anticipated possible future drivers, as well as strategic value including the length of record, quality of data and naturalness of the catchment. Consultation with other members of the hydrometric working group should be carried out before any station is decommissioned. The cost of fully decommissioning a station also needs to be evaluated, as in some cases this may be prohibitive. This must be balanced against the cost of continuing to collect data for no benefit.

In Wales and Scotland there is an effort to ensure that priority sites are ring-fenced against closure or other changes that might influence data collection/data quality although benchmark sites certainly have not legal status and some have been decommissioned in the recent past.

7.2.11 Recommendation 11: The EPA to set the framework for collecting hydrometric data to ISO standards.

All hydrometric data collection in Ireland should be aligned to the relevant ISO standards, including ISO 772:2011, ISO 9825:2005, ISO/DTR 21044-1/2. The methods of evaluating measurement uncertainty outlined in ISO 25377:2007 (Hydrometric Uncertainty Guide) should also be adopted. These generic standards need to be worked up in the operational instructions and work plans that are appropriate from the Irish perspective, relevant to the types of instrumentation used within the Irish network and aligned with the overall governance strategy.

7.2.12 Recommendation 12: Once the classification of stations is complete, the EPA to continue the ongoing consideration of a strategic network review in the density of gauging stations.

It is unlikely that there are many measuring authorities whose budget is sufficient to maintain its network to an ideal standard in terms of gauge density and data quality. This means effort and expenditure has to be focussed on where it gives the most value, and this is typically on sites that provide data for key operational uses. In the case study examples presented earlier in this review, the network densities achieved reflect practical and financial restraints, and not the ideal or target situation. On this basis, the average station density being achieved in Ireland (of almost 7 flow gauges per 1000km^2), is at least as good as that seen elsewhere.

Such figures may hide regional variations and other influences, such as more stations in highly populated catchments, or the fact that not all stations will be classed as full range sites (i.e. providing poorer data quality or not good at both high and low flows). The network might be dense, but with stations poorly sited. A more detailed review would be needed to investigate such issues for the Irish case.

A range of network optimisation techniques have been trialled in other countries, but it is very difficult for such exercises to provide practical outcomes in countries with an existing established network driven by operational requirements. A number of measuring authorities are exploring the concept of a tiered monitoring network. This is already being implemented in Ireland with the classification of strategic, operational and project gauges. The EPA should consider the potential for operational, project or lower priority strategic gauges with lower data standards to provide supplementary data (e.g. to fill gaps in the other tiers) but use "cheaper" measurement approaches, such as remote sensing, or water surface velocity measurement via radar.

7.2.13 Recommendation 13: Once the classification of stations and setting of acceptable quality standards is complete, the EPA to reconsider site visit frequency.

Site visits are essential to ensuring network performance and data quality and no technology currently exists that can significantly reduce the requirement for site visits at hydrometric stations. In addition to equipment maintenance, site visits are required for calibration (e.g. collection of check gaugings) and also to monitor changes in sites that could impact on data accuracy, such as gravel build up at a weir, or overhanging trees causing a back-water effect. Site visits are however costly and time consuming. Optimising site visit frequency can be considered as an essential part of network management.

One possible option is a reactive approach to site visits, i.e. visiting site only in response to a perceived or anticipated problem. This requires making more use of telemetered data feeds to detect problems in real time. For example sudden jumps in level can be suggestive of blockage or drowning issues. Comparison of event hydrographs with the usual flow response at a gauge and real time data at other gauges is already being carried out to identify potential problems. The problem with this approach is that more problems generally build up when sites aren't visited often enough. There is a strong link between the risk of deterioration in data quality and site visit frequency.

An alternative approach is to match the number of site visits to the importance of the station. Some other countries, such as England and Wales for example, are taking a risk-based approach to site visit frequency and the standard to which stations need to be maintained or calibrated. In such a system those gauges that are deemed as most important or critical are prioritised in terms of maintenance strategies, site visit frequency, quality assurance standards. This requires the network to be appraised in a holistic manner, taking account of, and potentially consulting more widely on, all data uses and users.

7.2.14 Recommendation 14: Once the classification of stations and setting of acceptable quality standards is complete, the EPA should consider alternative flow gauging methods for existing sites to deliver the required data quality.

The vast majority of gauging stations in Ireland operate under the velocity-area principle. That is, an assessment of the mean velocity within the measurement section is achieved through flow gauging and this is multiplied by an estimate of the wetted area to determine the overall flow rate. This method is made applicable for continuous flow measurement by use of an empirical relationship between the river level (stage) and gauged flow, which is built up by repeated flow gauging, and more widely known as a rating curve. This means that providing stage is measured in continuous time, flow can determined continuously also. For a stable rating to be achieved there must be an appropriate hydraulic control such that there is a unique flow for a given stage. Typical controls include rock steps and weirs; basically there must be a non-changing channel that ideally includes a constriction. Extending a rating so that it is valid during flood conditions is very challenging; there are practical issues with undertaking a flow gauging in such conditions to inform on rating curve shape, but furthermore the stage-discharge relationship can become distorted in flood conditions.

There needs to be more open acknowledgement of the uncertainties in flow measurement during high flow conditions, and the development of strategies to combat these. One option is to consider the use of hydraulic models of the river system to investigate and estimate changes in stage-discharge behaviour during high flow conditions. Modelled rating curves can be blended with existing curves so as to capitalise on existing spot gauging records. A second option is to consider the adoption of alternative methods for flow gauging that are based on new technologies. A range of different methods are available but most focus on measuring velocity in continuous time. Examples include radar and laser devices, time of flight ultrasonics, and

Dopper ultrasonics. All have their advantages and disadvantages and most require some kind of calibration through check gaugings, however uncertainties are not as well understood and whilst equipment costs are not generally prohibitive, there can be a trade-off in terms of reliability. It is recommended that the EPA investigate, through a research project or field trials, which options might work well in an Irish setting.

In the case study countries, there is evidence of pressure to avoid the use of weirs at gauging stations. This includes weirs that form a control for a stage discharge relationship or where they are ISO compliant measuring structures in their own right. The principal issue is impact on ecological status under WFD due to impediment to fish passage and natural sediment regime of river catchments. Fish passes can be retrofitted to weirs, but the cost of installing fish passes can exceed the cost of removing structures. Where multiple WFD failures at structures occur, such as through a combination of fish passage / ecological or geomorphological reasons, removal of the structure will be almost inevitable. Benefits of retaining weirs include their attractiveness for run of river hydropower schemes, white-water canoeists and better control of mobile bed problems. These are issues that the EPA may have to address in the near future, and for which it would be advantageous to have strategic plans in place. These should tie in to design standards for new gauges.

7.2.15 Recommendation 15: Continue development of, publish and continue to update the GIS based webmap viewer with all gauges to work towards Open Data policies.

An Open Data policy is being widely adopted in the case study countries, including Ireland. There is an expectation by users of hydrometric data for that data to be provided freely and in real time. A range of initiatives are in place to communicate this information to potential users include websites and API feeds for reporting data in real time. Historic data is not as widely available. Generally a data processing fee is charged for freedom of information requests. This fee covers the cost of extracting and supplying data to customers, and there is no charge for the data itself.

A webmap with all hydrometric gauges located is in development and should be published when complete. The map should be updated as changes to the hydrometric register are made. Each site should have a link to either the data or the hydrometric body's website.

7.2.16 Recommendation 16: Develop a national strategy for environmental evidence to value the contribution and benefits of the hydrometric network.

As discussed previously a good hydrometric network is essential for effective catchment management and needs to be considered together with monitoring, sampling and modelling. A national level strategy should be developed to determine the most optimal use of available resources to form the environmental evidence base. Such a strategy would also help to value the contribution and benefits gained from the hydrometric network. This could be used to justify and provide evidence for budgets, funding and resource plans.

Such a strategy should consider a process for requests for new or temporary gauges and also closure of existing gauges. The aim of this process will be to ensure the maximum use of new gauges and that key strategic gauges are not closed without appropriate consideration of the implications. This will also manage the evolution of temporary gauges installed for specific operational reasons, which then over time become more strategic (e.g. long term record series, pooling groups).

A separate review of the monitoring network for the Water Framework Directive is being carried out by the EPA as part of the WFD cycle 2 assessments. However there is no overarching environmental evidence strategy for the EPA, OPW or at Government Department level.

A good hydrometric network is essential not only for quantifying flows, but also for quantifying fluxes of pollutants and sediments associated with a range of catchment processes. It is important to understand these at the catchment scale to help us understand and manage the risks associated with flooding and diffuse pollution, whilst working with the ecosystem services that a catchment naturally provides. Therefore it is useful to combine water quality and sediment monitoring locations at sites where flows are well defined.

7.2.17 Recommendation 17: As part of an evidence strategy consider integration of the

hydrometric network with catchment modelling and monitoring.

Catchment flow regime models

This is already underway through the Hydrotool update programme and work of the EPA catchments team.

The network also have a more strategic role to play in furnishing data that can be used to support catchment environmental and flood flow estimation models. This is not a purely academic use of the data, as standard methodologies for flood and low flow estimation at ungauged locations are essential to regulatory and operational activities within Ireland (e.g. Low Flows and FSU).

To maximise this potential, the network needs to sample the hydrological variability in Ireland on a spatial and temporal basis. Gauging stations therefore need to be distributed across catchments that are wide ranging in climate, topography and size, yet provide representative coverage of the more commonly occurring catchment types and include both natural and urban settings. The network also needs to adequately sample extreme flows (high and low flows), monitor a sufficient number of uninfluenced catchments and provide as many long and uninterrupted data series as possible. Specifically for HydroTool, the network needs to be maintained to give national coverage, with supplemental effort needed for regions not covered by the tool (karst, lakes, small catchments) and validation of data for ungauged catchments.

It is recommended that EPA seek to establish which gauging stations are most well suited for this purpose, according to the following criteria:

- the flow regime of an unusual type of catchment is sampled by the station (e.g. catchments in the wettest or driest parts of the country or having rare geology and soils)
- the station samples a catchment type that is relatively common, but under represented in the network (e.g. small catchments or heavily urbanised catchments)
- there is a very long continuous record at the station.
- the quality of data in either of, or both of, the extremes is good.
- there is minimum impact of artificial influences and the data is considered as "natural".

Water quality monitoring and models

There are many advantages to better integration of water quality and water quantity networks, such as: improved decision making, to inform licence conditions and for overall catchment management, as exemplified in the case study example for New Zealand. Recent studies have considered the use of modelling for catchment management and the optimal monitoring regime for reliable models. Supporting limited investment in hydrometric stations with alternative predictive modelling techniques is finding traction.

There is an increasing need to quantify the impacts of diffuse pollution on freshwater, to plan and model potential reductions of agricultural diffuse pollution. Diffuse pollution is often episodic, requiring expensive, simultaneous high frequency flow and water quality monitoring data to understand distributed nutrient fluxes at the catchment scale. This has led to a tension between funding extensive monitoring data to provide evidence of significant responses to diffuse pollution measures, and funding the build and calibration of a defensible water quality model on the basis of just enough data. Research studies[9] have assessed the performance of four catchment models (SIMCAT, HYPE, INCA-N, INCA-P) to predict nitrate and phosphorus concentrations against four hypothetical monitoring regimes with different spatial and temporal sampling frequencies were assessed.

A key conclusion was that targeted sampling of headwater watercourses upstream of point discharges is essential for calibrating diffuse loads, and can exert a strong influence on the whole-catchment model performance. Further downstream, if the point discharges and loads are accurately represented, then the improvement in the catchment scale model performance is relatively small as more calibration points are added in space or time. For phosphorus,

[9] Modelling for Monitoring *Hankin (et al.) (In Press) Catchment-scale sensitivity and uncertainty of multiple diffuse pollution models assuming different monitoring regimes*

SIMCAT model performance is strongly influenced by travel time and the lumped loss rate parameter, and efforts to represent these accurately can directly reduce model uncertainty at the catchment scale. Using higher order, dynamic models INCA N & INCA P which incorporate sediment and biotic interaction, resulted in improved whole-catchment performance, although there are still large uncertainties around runoff generation and the emissions of pollutants from the land.

Assuming point sources are accurately represented, the sampling of all WFD sites within the catchment only marginally improved model calibration beyond use of only headwater sites upstream of point sources. Monitoring only at the four reliable flow sites does not result in a more reliable model. The most optimal use of resources for modelling of diffuse phosphorous and nitrates is to focus on frequent sampling of headwater sites.

For the more complex water quality model, INCA-P, which represents continuous hydrology and has more complete handling of nutrients, it is more possible to model the dynamics of the episodic pollution events that are important to phosphorus transport. However, it was found that the more complex models were highly sensitive to catchment hydrology, which is perhaps not surprising given the non-linear interactions of sediment adsorption and release.

To model diffuse pollution better, we need to quantify diffuse flows and quality better, and the best way to do this is to monitor in headwater locations on watercourses least affected by point source discharges. In this way models can be used to characterise the fluxes of nutrients, relate these to land management practices and transfer the knowledge to other un-gauged catchments.

7.3 Long term considerations

The following long term considerations should be considered as part of the future vision for the hydrometric network however all require legislative or regulatory change that is unlikely in the short term.

7.3.1 Governance

There needs to be some consideration of whether a single umbrella body for hydrometric gauges could function in the future. Such assessment would consider the transfer of ownership of stations, funding streams and budgets. Such a body should also aim to be completely holistic, i.e. should its remit also include Northern Ireland?

7.3.2 Funding

The most efficient budget management would be to have a single co-ordinating body with responsibility for obtaining funds and allocating budgets to gauge owners and bodies which undertake maintenance, gauging and data management on its behalf.

A funding strategy for the new body would need to be established. Depending upon the corporate setup and governance a single hydrometric body could potentially undertake commercial work to raise funding (such as customer specific analysis or installation of gauges and sensors or research work) or gain through handling fees for hydrometric data.

7.3.3 Resources, shared services and outsourcing

There is notable overlap of technical hydrometric technicians for the EPA and OPW operating in the same region. Single combined specialist teams of hydrometric technicians could service OPW, EPA and other gauges.

The dissemination of hydrometric data in Ireland should ultimately be through a single portal, however this is unlikely given the different approach to data quality standards used by the OPW and EPA. Consideration should also be given towards shared archive and data management systems. All hydrometric data collectors should contribute towards the funding of a single system rather than duplicating effort and expenditure on their own systems. Existing systems should be appraised for their suitability to act as a single portal before developing new systems.

There is also some overlap and duplication in the coverage of the EPA and OPW hydrometric teams. Opportunities for shared services and field work within existing organisational frameworks should be identified. Coordination of hydrometric resources could avoid duplication of field work, equipment, materials and office work.

The hydrometric working group could have the power to prioritise activities, allocate budgets and plan resources. The National Biodiversity Data Centre operates as a fully outsourced service for specific technical work under 5 year contract agreements with standards of service (see Appendix D.1).

7.3.4 Data management and dissemination

A consistent strategy to Open Data needs to be established in Ireland. This is all the more important due to the various different owners of hydrometric stations/hydrometric data and the opportunities for inconsistently processed or archived data being released. The EPA and OPW operate with inconsistent data quality and licensing criteria, which have evolved for their own purposes. Albeit fit for their own purpose, the inconsistency does not allow for a single archive and data dissemination portal.

Appendix D contains case studies which present examples of sensor and information technology, organisational frameworks and the interaction of gauge data, monitoring and modelling. The Digital Ocean platform shows how data from a range of organisations can be brought together on a single platform for users with different requirements.

New technology presents opportunities for more efficient network communications. The Oxford Flood Net is an example of community lead innovation responding to the reduced costs of sensors and opportunities to use existing communication networks. The quality offered needs to be considered in light of the acceptable data quality standards for different gauge classifications.

7.3.5 As part of an evidence strategy consider the potential for the wider use of rainfall data.

Rainfall has wider application for hydrological and environmental modelling and assessment than is currently made use of in Ireland. For example in Wales rainfall data is used for determining whether wet weather waivers are appropriate for pollution incidents related to storm overflows at sewage treatment works. It is recommended that the EPA collaborate with Local Authorities, the OPW and Met Éireann to determine how wider or more imaginative use can be made of the raingauge network, and to evaluate how rainfall and river flow/level datasets can be used to complement each other whilst minimising duplication. Rainfall data, simple hydrological models, may be of use in supplementing the gauges identified for monitoring and reporting for the OSPAR convention.

7.4 Concluding remarks

The hydrometric network (river flow and level) network in Ireland appears to be at least as dense as in comparable countries (in terms of size, population and environment) without considering the quality of hydrometric data provided. There are fewer resources to service and maintain the network and a lack of succession planning to ensure local knowledge and know-how is distributed between team members. Understanding of the uses and users of hydrometric network data needs to be better understood, and there needs to be increased cooperation between the EPA and the OPW to ensure the network is managed in a holistic and coherent way, despite differences in station ownership and usage.

The drivers for hydrometric data collection are changing and the distribution and type of gauge is likely to change. To respond to this change the current governance and funding of the existing network is not flexible or sufficiently strategically grounded to change from the status quo at the pace that is required.

There are a number of recommendations in this report which would seek to improve the efficiency in managing the hydrometric network and resources. Long term considerations have also been identified.

References

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http://watermaps.wfdireland.ie/HydroTool/Authentication/Login.aspx?ReturnUrl=%2fhydrotool%2fDefault.aspx

http://digitalocean.ie/

http://oxfloodnet.co.uk/

http://www.biodiversityireland.ie/

A Appendix A - Regulatory obligations

A.1 List of relevant legislation in New Zealand

Legislation	Details
Resource Management Act 1991	New Zealand's main piece of legislation that sets out how we should manage our environment. It outlines how to get involved in RMA processes such as resource consent, council plans and designations, proposals of national significance, what legislative tools are issued under the RMA, and RMA reforms. It also explains how local authorities are monitored under the RMA. http://www.mfe.govt.nz/rma/
Environmental Reporting Bill 2014	The purpose of this Bill is to create a national-level environmental reporting system to ensure that reporting on our environment occurs on a regular basis and can be trusted by the public as independent, fair, and accurate. http://legislation.govt.nz/bill/government/2014/0189/9.0/whole.html
New Zealand National Environmental Monitoring Standards	These documents prescribe technical standards, methods and other requirements associated with the continuous monitoring of a number of environmental parameters. The agencies that developed these standards are responsible for the majority of hydrological and continuous environmental related measurements within New Zealand. http://www.lawa.org.nz/learn/factsheets/(nems)-national-environmental-monitoring-standards/

A.2 List of relevant legislation in Scotland

Legislation	Details
Water (Scotland) Act 1980	Provides ministers with the duty to promote the conservation of water resources and Scottish Water's provision of adequate water supplies. The Act also gave water suppliers the duty to provide a supply of wholesome water for domestic purposes (drinking, washing, cooking, central heating and sanitary purposes) and to provide water on reasonable terms and conditions to non-domestic customers when requested.
Environment Act 1995	Established SEPA, with duties which include the promotion of the cleanliness of rivers, other inland waters and ground waters in Scotland.
Water Industry (Scotland) Act 2002	Established Scottish Water, replacing the three previous water authorities in Scotland
Water Environment and Water Services (Scotland) Act 2003	Provides for Directive 2000/60/EC of the European Parliament to be implemented, establishing a framework for water policy. The main points of the Directive were to prevent deterioration of surface and ground water, to achieve good surface and ground water status by 2015, to prevent or limit ground water pollutants, to comply with measures against hazardous substances and to achieve compliance with relevant standards for protected areas. Member states were required to put in place systems for managing their water environments. The Directive repealed and replaced older EC Directives and incorporated the Bathing Water, Nitrates and Urban Waste Water Treatment Directives (see below). Defined the water environment and set out the duties of Scottish ministers and SEPA for protecting it. River basin areas were established and SEPA were required to produce management plans for each one by the end of 2004. Clarified Scottish Water's role in new connections to the water and sewerage infrastructure.
Water Services etc (Scotland) Act 2005	Allowed the creation of the Water Industry Commission for Scotland, which is responsible for determining Scottish Water's charges.
Control of Pollution Act 1974	Established controls over discharges of poisonous, noxious or polluting substances to controlled waters in Scotland. Discharges can only be made after authorisation

	from SEPA specifying the quality and quantity of effluent permitted.
Water (Scotland) Act 1980	Requires Scottish Water to supply wholesome water to any premises for domestic or food production purposes
Bathing Water Quality Directive (76/160/EEC)	To protect the environment and public health by reducing the pollution of bathing water and to protect such water against further deterioration.
Fresh Water Fisheries Directive (78/659/EEC)	Makes provisions for protecting and improving the quality of fresh water in order to support fish life.
Shellfish Water Directive (79/923/EEC)	To protect the quality of coastal and brackish waters which are designated for protection or improvement to support particular shellfish populations.
Drinking Water Quality Directives (80/778/EEC and 98/83/EEC)	Sets standards and sampling requirements for drinking water quality.
Urban Wastewater Treatment Directive (91/271/EEC)	To ensure that pollution levels in urban wastewater are kept below certain thresholds for discharges into controlled waters. Discharge consents issued by SEPA under the Control of Pollution Act must satisfy the requirements of the Directive.
Nitrates Directive (91/676/EEC)	To reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution.

A.3 List of relevant legislation in Wales

Legislation	Details
Bathing Water Quality Directive (76/160/EEC)	To protect the environment and public health by reducing the pollution of bathing water and to protect such water against further deterioration.
Fresh Water Fisheries Directive (78/659/EEC)	Makes provisions for protecting and improving the quality of fresh water in order to support fish life.
Shellfish Water Directive (79/923/EEC)	To protect the quality of coastal and brackish waters which are designated for protection or improvement to support particular shellfish populations.
Drinking Water Quality Directives (80/778/EEC and 98/83/EEC)	Sets standards and sampling requirements for drinking water quality.
Urban Wastewater Treatment Directive (91/271/EEC)	To ensure that pollution levels in urban wastewater are kept below certain thresholds for discharges into controlled waters. Discharge consents issued by SEPA under the Control of Pollution Act must satisfy the requirements of the Directive.
Nitrates Directive (91/676/EEC)	To reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution.

B Appendix B - Breakdown on network details

Table 7-1: Rain gauge network statistics for other countries

Country	Source of information	Total number of gauges (if known)	Approximate average area per gauge (km2)
England & Wales	Network review analysis (see Chapter 5)	2773 unique locations	56
Israel	Kutiel & Kay, 1996	Not known	60
Northern Ireland	Met Office's Rainmaster database	167	85
Germany	Conference proceedingsa	Not known	88
Cataloniab	Conference journal paper	Not known	90
Switzerland	Meteoswissc	Not known	95
Scotland	Met Office's Rainmaster database	770	100
Eire	JBA Review	TBC	TBC
France	Meteo France websited	4690	116
Netherlands	Robinson (2005)	Not known	130
Finland	Kutiel & Kay, 1996e	Not known	330
USA	Robinson (2005)	Not known	1040
India	Robinson (2005)	Not known	790

Source;
http://ams.confex.com/ams/pdfpapers/94897.pdf
http://www.cosis.net/abstracts/EGU2007/10281/EGU2007-J-10281.pdf
http://www.meteoswiss.admin.ch
http://www.meteo.fr/meteonet_en/index.htm
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C Appendix C - Comparison of Case Study Countries

Country	Area (km2)	Altitude	Climatic Setting	Rainfall	Land Use
New Zealand	268,216 [10]	New Zealand is made up of two narrow, mountainous islands. The Southern Island contains the Southern Alps, which extends the length of the Southern Island and includes the highest mountain in NZ, Aoraki/Mt Cook (3754m). Within the Southern Alps approximately 19 mountains rise above 3,000m. On the Northern Island, most mountains are volcanic in nature and some remain active. On the southwest of the island, Mount Taranaki rises to 2,518m. In the central	New Zealand experiences a temperate maritime climate, however, the day-to-day weather climate is defined by wind and pressure patterns across the country.[12] In the South Islands the climate is cool and temperate and in the North Islands it is warm subtropical. The various mountain ranges extend the length of New Zealand, which provide a barrier for the prevailing westerly winds, which split the country into significantly different climatic regions. In addition, phenomenon such as El Nino and La Nina, directly affect the weather type and influence the variability of	Rainfall is variable in New Zealand, however, the average annual rainfall ranges from 600-1600 mm. According to the National Institute of Water and Atmospheric Research (NIWA) the mean annual rainfall for 1981-2010 was 1366.4 mm[13].	The landscape in New Zealand is variable due human and natural pressures, such as land-use changes and geological and ecosystem processes. The largest urban cities in New Zealand are Auckland (the largest urban area with a population of more than 30,000 people), followed by Wellington, Christchurch, Hamilton, and Dunedin, respectively. The Land Cover Databases (LCDB) have been mapped using satellite imagery of NZ since 1997. Based on the LCBD 2, New Zealand's land cover consists of: • 50% native forests, native vegetation, and other native cover. • 39% pasture (high-producing and low-producing grassland land cover classes) • 9% exotic forest and exotic shrub land • 1.6 % horticulture (horticulture, viticulture and cropping land-cover

[10] http://www.mfe.govt.nz/more/environmental-reporting/land/land-cover-indicator/land-cover
[12] Woods and Henderson. (2003). Surface Water Components of New Zealand's National Water Accounts 1995-2001. *Statistics New Zealand Ministry for the Environment.*
[13] http://www.niwa.co.nz/education-and-training/schools/resources/climate/meanrain

		region, the highest mountain is an active volcano called Mount Ruapehu (2797m), followed by Mount Ngauruhoe (2,291), and Mount Tongariro (1,968m)[11].	the climate.		classes) • 0.8% artificial surfaces such as urban and built up areas, landfills and transport infrastructure.
Scotland	78,810 [14]	Scotland contains many mountainous and upland regions and there are many islands off the West Coast. The Northern Highlands rise steeply from the glens and fjord-like sea lochs. The region has extensive areas of high ground and includes the highest point in the UK - Ben Nevis (1344 metres), near Fort William. Much of the landscape of Western Scotland consists of high ground more than 200 metres above sea level, especially in the north, where there are many peaks that exceed 1000 metres. Fjord-like sea	The warm air of the North Atlantic Drift results in milder climate in Western Scotland. There is a significant difference in temperature and rainfall between the east and west coast, as well as, the coast and mountain top. Scotland is a great example of how oceanic and continental influences, elevation, and latitude, all affect climate.	Annual Average Rainfall is extremely variable in Scotland. Less than 700 mm falls in parts of Eastern Scotland, with between 1000 and 1700 mm for most of Northern and Western Scotland. In the Western Scotland. In the highlands rainfall increases to over 3500 mm in the highlands and 4000 mm northwest of Fort William.	There are very few large towns in the Highlands, North or West of Scotland. The larger cities (Edinburgh, Aberdeen and Dundee) and towns are generally located on the East Coast, with the exception of Glasgow and surrounding towns further west. The Rivers Tweed, Forth, Tay and Dee flow eastwards. The River Clyde flows through Glasgow to the west. Traditional land uses (agriculture, forestry, and game management) still strongly impact the land management practices of Scotland, where 95% of the land is rural where18% of the Scottish population resides.[15]

[11] http://www.worldatlas.com/webimage/countrys/oceania/newzealand/nzland.htm
[14] http://www.ons.gov.uk/ons/rel/environmental/uk-natural-capital/land-cover-in-the-uk/index.html
[15] http://www.snh.gov.uk/publications-data-and-research/research/current/rural-land-use/

		lochs and the islands of the Hebrides characterise Western Scotland. Many of the islands also contain substantial peaks; the highest point on any of the islands is Ben More on Mull at 967 metres.			
Wales	20,780 [16]	Wales is a mainly mountainous country with much of the land being over 150 metres. In the north, Snowdon is the highest mountain in England and Wales, at 1085 metres, and in the south the Brecon Beacons rise to 885 metres. The rivers drain radially from the upland areas, the Severn being the longest river in England and Wales. There are a number of hydro-electric schemes and reservoirs that supply water to major towns. The mountainous nature of the landscape means that large	The climate in Wales is maritime, which consists of cloudy, wet, and windy weather. Due to the shape of the coastline and the high ground from Snowdonia to Brecon Beacons forms localised differences in climate. The upland areas tend to experience harsher weather than the coast.	Rainfall in Wales varies widely, with the highest average annual totals being recorded in the central upland spine from Snowdonia to the Brecon Beacons. Snowdonia is the wettest area with average annual totals exceeding 3000 mm, comparable to those in the English Lake District or the western Highlands of Scotland. In contrast, places along the coast and, particularly, close to the border with England, are drier, receiving less than 1000 mm a year. Throughout Wales, the months from October to January are significantly wetter than those between February and September.[18]	The cities of Cardiff and Swansea with the surrounding towns and industrial areas are heavily concentrated on the South Coast and the valleys. Other towns are generally located along the coast. 81% of the land surface in Wales is devoted to agriculture. • 16,000 km2 Agricultural Land • 10,000 km2 Permanent Pasture • 3,000 km2 Sole Rights • 2,000 km2 Grassland under 5 years • 1,000 km2 Crops and horticulture • 1,000 km2 Farm Woodland and other

[16] http://www.ons.gov.uk/ons/rel/environmental/uk-natural-capital/land-cover-in-the-uk/index.html
18http://www.metoffice.gov.uk/climate/uk/regional-climates/wl

		areas are only sparsely populated, with most of the settlements on or near the coast and in the southernmost counties, where almost half the population lives.[17]			
Ireland	70,284	Ireland has numerous mountain ranges around the coast, with a generally flat internal topography. The mountains are not significant with highest peak just over 1,000m above sea level. The Dublin region is the most populated, with other main population centres of Cork, Galway and Limerick also located on the coast.	The climate in Ireland is heavily influenced by the Atlantic Ocean. The south-westerly winds from the Atlantic influence rainfall especially in the northwest, west, and southwest parts of the country. Winter brings the highest rainfall, while early summer has the lowest rainfall figures. The average mean temperature is 9°C.	Most of the eastern half of the country gets between 750 and 1000 (mm) of rainfall in the year. Rainfall in the west generally averages between 1000 and 1400 mm. In many mountainous districts rainfall exceeds 2000mm per year. The wettest months, in almost all areas are December and January. April is the driest month generally across the country. However, in many southern parts, June is the driest. Hail and snow contribute relatively little to the precipitation measured.[19]	Population is heavily concentrated in the Dublin area and other coastal towns with more sparse population in rural areas. Land use[20] • Pasture 55.1%, • Arable Land & permanent crops 7.2%, • Forest 8.4%, • Semi-natural vegetation 2.0%, • Artificial areas 1.8%, • Wetlands 15.8%, • Water 9.1 %.

17 http://www.metoffice.gov.uk/climate/uk/regional-climates/wl

19 http://www.met.ie/climate-ireland/rainfall.asp

20 http://www.epa.ie/pubs/reports/indicators/irlenv/43366%20EPA%20report%20chap%20111.pdf

D Appendix D - Other relevant examples of governance, technology and data management

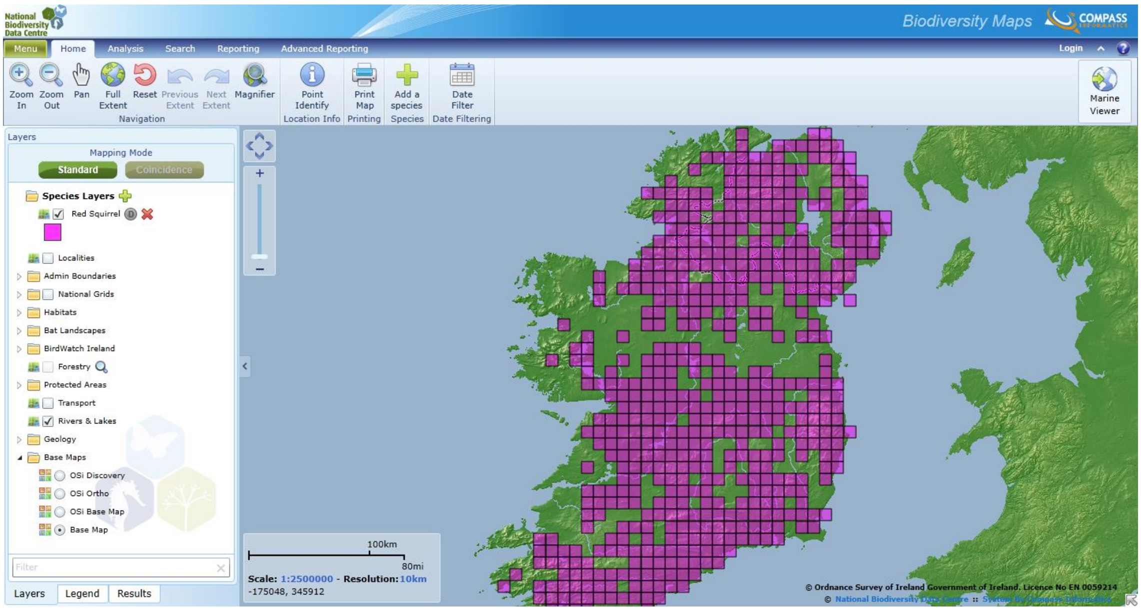
D.1 National Biodiversity Data Centre

http://www.biodiversityireland.ie/

The centre was established by the Heritage Council and funded by the Heritage Council and the Department of Arts, heritage and the Gaeltacht. The centre is responsible for collating, managing, analysing and disseminating data on biodiversity in Ireland. It is operated on a five yearly contract to outsource running of the centre and technical work to a private organisation. The contract sets out service level agreements for deliverables, services and standards that the contractor must provide. Some of these services include statutory international, European and national biodiversity reports.

The centre has developed and hosts standards for biodiversity surveys, sampling and data management.

The centre also hosts biodiversity maps for Ireland as a web mapping service to disseminate data records.



D.2 Oxford Flood Net

http://oxfloodnet.co.uk/

The Oxford Flood Network is a citizen lead flood detection network in Oxford, England as an alternative and to supplement the Environment Agency level gauge network. The network takes advantage of the reductions in cost and availability of sensor and wireless network technology. A number of water level ultrasonic sensors have been installed in accessible locations in and around Oxford to monitor changes in water level in real-time. The sensors are connected to local wifi networks and TV whitespace frequencies. The sensors can be built from materials lists which include Raspberry Pi hardware and software code shared freely via GitHub. Interested parties can build their own sensors and connect these to the network. Data quality is reliant upon all contributors to the network and maintenance of their sensors.

The community that the network creates can be used to drive innovation, cost savings and alternatives to government funded systems at the same time as raising community awareness through engagement.

Water level sensor mounted on utility pipe under bridge.

D.3 Digital Ocean

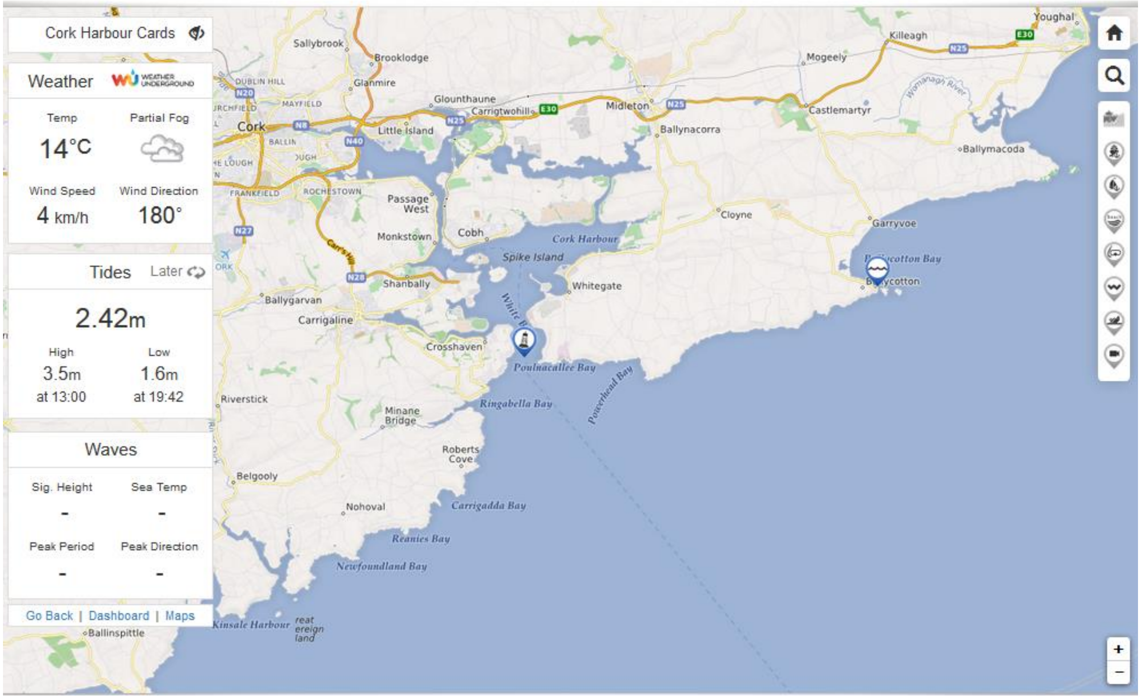
http://digitalocean.ie/

Digital Ocean is a Marine Institute hosted platform which combines data, web mapping and decision support tools into a single website platform with maps and dashboards for main harbours in Ireland. It is an example of how data and information from different bodies can be brought together and made accessible to users with different interests. The maps and data are grouped into three themes (observations, leisure, explore) directed towards different potential users. The dashboards and map popups show recent, historic and forecast information.

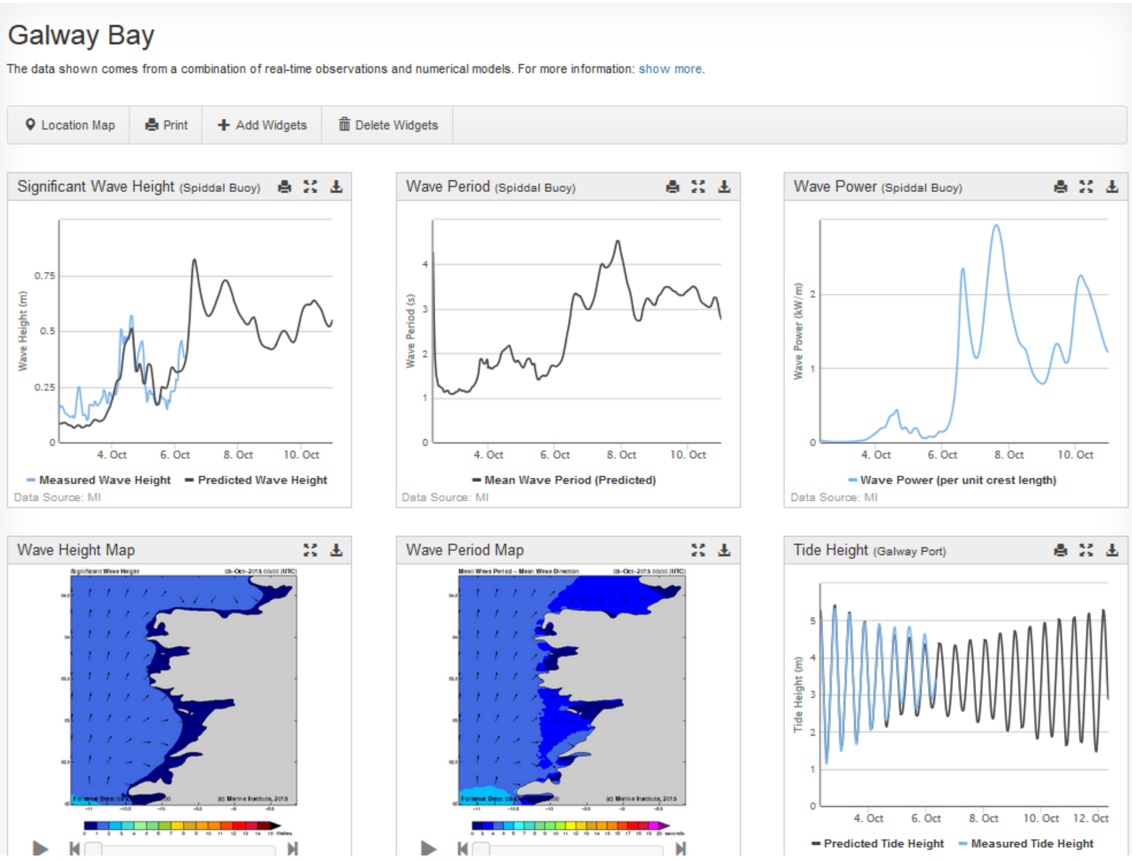
Currently, the data providers include the Environmental Protection Agency (EPA), Geological Survey of Ireland (GSI), Infomar, SmartBay, Sustainable Energy Authority Ireland (SEAI), NOAA and data is accessed via a number of existing data platforms such as the Irish Spatial Data Exchange (ISDE), GSI web data and Marine Data Online. Existing mapping applications such as EPA maps, Biodiversity maps INFOMAR viewer and Ireland's Marine Atlas are incorporated and decision support tools are included for aquaculture and viewing particle transmission forecasts.

The platform does not currently include the storm surge forecasts issued by the OPW.

Example Map



Example dashboard.



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