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Digital Smart Flood Warning Systems: User Research Report

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1. Overview of Project Governance and User Research Methodology

The Digital Smart Flood Warning Systems (DSFWS) project was funded by the Local Digital Fund as a Discovery project, running over a 12-week duration between 4th September and 14th December 2023 (Table 2.1). Its purpose was to investigate current surface water flood mitigation and response in Leeds, Kirklees and Wakefield Local Authority areas, and determine opportunities, needs and risks associated with establishment of a LoRaWAN for flood warning and response. Table 1.1 shows members of the project team, their role and organisation.

Table 1.1: Project team members

Team	Member	Organisation	Role
Flood	Paul Maddison	Wakefield Council	**DSFWS Project lead/Flood team lead** Flood Risk Manager
Flood	Jonathan Moxon	Leeds City Council	Executive Manager of Flood Risk & Climate Resilience, Programme Manager of the West Yorkshire Flood Innovation Programme
Flood	Martin Stephenson	Kirklees Council	Principal Flood Risk Officer
Flood	Nicole Taylor	Leeds City Council	Engineer Technical Systems in Flood Risk Management
Flood	Zoe Pattinson	Environment Agency	Flood and Coastal Risk Management
Facilitation	Henry Hargreaves	Wakefield Council	Land Drainage & Flood Risk Management
Facilitation	Steph Bond	iCASP	**DSFWS Facilitation lead** Impact Translation Fellow
Facilitation	Sam Ramsden	iCASP	Impact Translation Fellow
Digital	Simon Cowen	Leeds City Council	Senior Responsible Officer - Leeds Full Fibre Programme
Digital	Carl Tinson	Kirklees Council	**DSFWS Team Lead** Digital Programme Team Leader – Kirklees Digital Programme

Prior to beginning to Digital Discovery research, the project was presented externally at the West Yorkshire Flood Innovation Programme (WYFLIP) Annual General Meeting (AGM) in May 2023 in a 45-minute workshop. The workshop presented the project outline as submitted in the successful original bid to the Local Digital Fund (LDF), and gathered initial thoughts from attendees regarding opportunities, needs and risks to setting up a LoRaWAN for flood warning and response. Attendees were from a wide range of disciplines including academics, local authorities, Yorkshire Water, Environment Agency, catchment managers, and the third sector. Key topics to investigate included options for data shareability; sensor power, monitoring, and maintenance needs; audience requirements; and key locations for a pilot scheme.

Following feedback at the WYFLIP AGM, the project team established project governance and created a roadmap (*see Appendix A*) in July 2023 to ensure clear project purpose and progression prior to beginning the research period. The roadmap ascertained 17 digital-based questions, 7 flood-based questions and 5 digital-flood crossover questions we wished in investigate. To maintain communication between the project team, fortnightly update meetings were held during the research period (September – December

2023), and Trello, a communications platform, was used to share progress and feedback; project facilitation was managed by iCASP. Table 2 summarises the key stages of data acquisition.

Table 1.2: Summary of data acquired and methods to collect that data

Name	Information Acquired (discovery phase)	Format	Date of last communication
Partner Council Flood Risk Managers (project team)	Key flooding issues, existing solutions, hotspots, flood response, data required and digital cross-over.	Interviews	October 2023
Partner Council Digital Team Leads (project team)	LoRaWan requirements, specific area requirements, management of the network, data processing methods and platform	Interviews	October 2023
Environment Agency (project team)	Key flooding issues, existing solutions, current EA data, validation, responsibilities – warnings, flood advisory service, how might fluvial warning sit with pluvial and suggestions for the product.	Interviews	12th Oct 2023
Flood Wardens	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire	Workshop	12th October 2023
Service Providers	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire	Workshop	25th Sept 2023
Norfolk County Council	Understand the pros and cons of an existing LoRaWan network	Consultation Meeting	29th Sept 2023
West Yorkshire Fire and Rescue	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire – emergency services perspective	Consultation meeting	23rd November 2023
Alliot, Probado and Andel – LoRaWAN businesses	Existing technology and investment/procurement opportunities for a future LoRaWAN system	Consultation meeting	23rd November 2023
West Yorkshire Resilience Forum	Key challenges and opportunities for implementation of a LoRaWAN in West Yorkshire – emergency services perspective	Consultation meeting	4th December 2023

To establish current practice and internally recognised needs, opportunities and risks relating to surface water flooding or LoRaWAN, project team members were interviewed by iCASP (*Appendices B-H*).

Two workshops were held to gain external steer towards answering the questions set out in the roadmap. Collated workshop notes are included in *Appendices J and K*. The first workshop was attended by Service Providers, including persons from the Environment Agency; Leeds, Bradford, Kirklees and Wakefield Local Authorities; Yorkshire Water; and JBA consulting. The second workshop was attended by EA Flood Wardens and community flood groups.

In addition to the two workshops held, information was collated through consultation meetings with Norfolk County Council (NCC; *Appendix L*), LoRaWAN companies Alliot, Andel and Probado (*Appendix M*),

West Yorkshire Fire and Rescue (*Appendix N*) and the West Yorkshire Resilience Forum Severe weather group (*Appendix O*).

Within the DSFWS flood team, current incident data was reviewed and hotspot maps were produced showing key areas of focus for surface water flooding in Leeds, Kirklees and Wakefield (*Appendix P*).

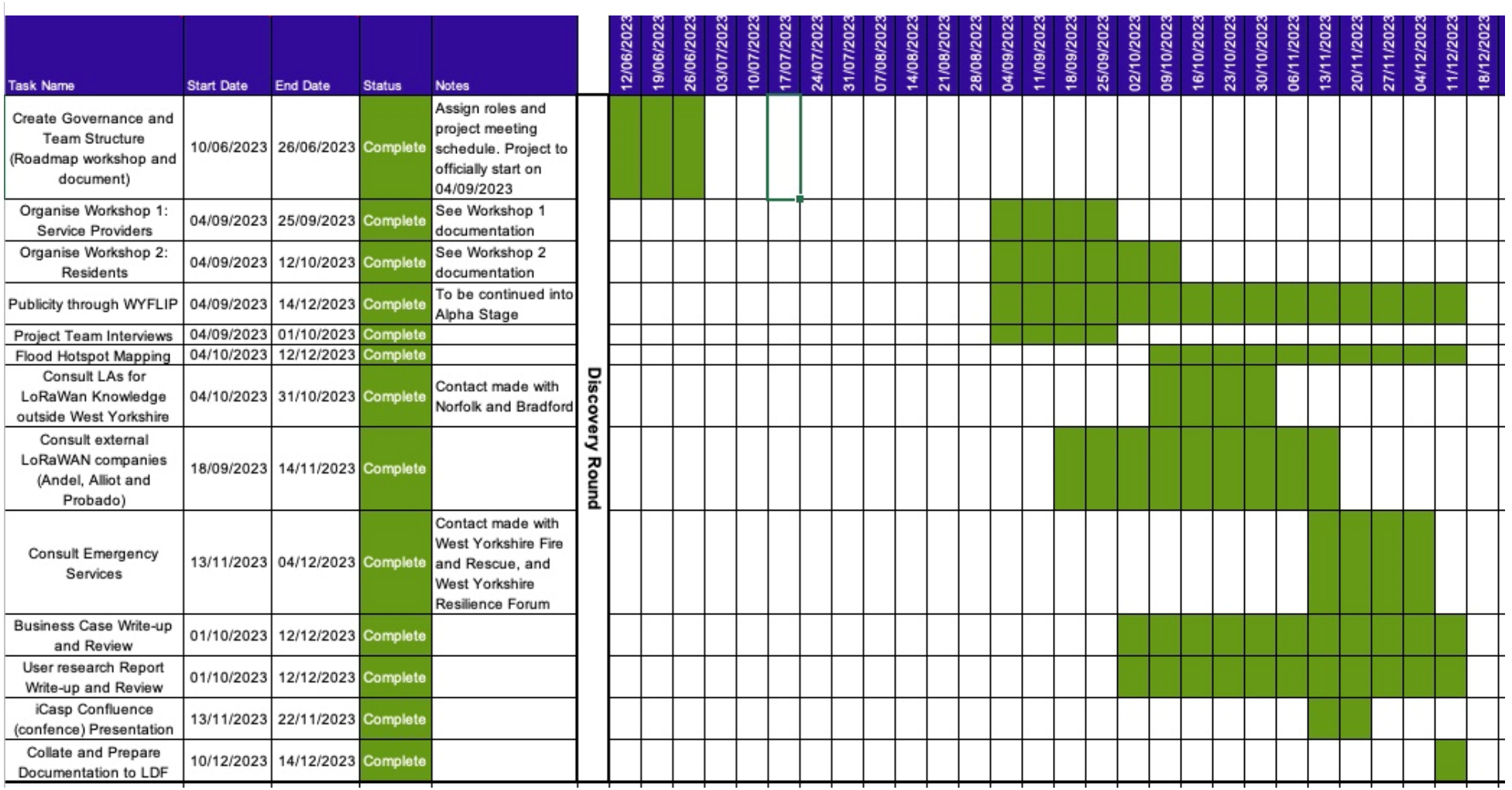
Finally, recommendations were collated based on the information gathered, and a business case for an alpha-stage pilot study was created and reviewed by all members of the project team and surface water experts at the University of Leeds.

The following section presents the approach and key findings from each user group, including how user knowledge contributed to filling recognised knowledge gaps. In S*ection 4*, a summary is given of project findings and recommendations for next steps.

2. Gantt Chart of Achievements

Table 2.1: Project Gantt Chart

Task Name	Start Date	End Date	Status	Notes
Create Governance and Team Structure (Roadmap workshop and document)	10/06/2023	26/06/2023	Complete	Assign roles and project meeting schedule. Project to officially start on 04/09/2023
Organise Workshop 1: Service Providers	04/09/2023	25/09/2023	Complete	See Workshop 1 documentation
Organise Workshop 2: Residents	04/09/2023	12/10/2023	Complete	See Workshop 2 documentation
Publicity through WYFLIP	04/09/2023	14/12/2023	Complete	To be continued into Alpha Stage
Project Team Interviews	04/09/2023	01/10/2023	Complete	
Flood Hotspot Mapping	04/10/2023	12/12/2023	Complete	
Consult LAs for LoRaWan Knowledge outside West Yorkshire	04/10/2023	31/10/2023	Complete	Contact made with Norfolk and Bradford
Consult external LoRaWAN companies (Andel, Alliot and Probado)	18/09/2023	14/11/2023	Complete	
Consult Emergency Services	13/11/2023	04/12/2023	Complete	Contact made with West Yorkshire Fire and Rescue, and West Yorkshire Resilience Forum
Business Case Write-up and Review	01/10/2023	12/12/2023	Complete	
User research Report Write-up and Review	01/10/2023	12/12/2023	Complete	
iCasp Confluence (confence) Presentation	13/11/2023	22/11/2023	Complete	
Collate and Prepare Documentation to LDF	10/12/2023	14/12/2023	Complete	



3. Stakeholder approach and key outcomes

This discovery phase project centred on scoping information about LoRaWAN and its use as an early flood warning system in Leeds, Kirklees and Wakefield. Key to this project was knowledge exchange between local authorities, Environment Agency, service providers, flood wardens, community groups and academics. Below, we have outlined our approach to each stakeholder group and adaptations made to the business case in response to stakeholder viewpoints.

3.1 Project team interviews

Interviews were conducted with members of the project team only. The project team (Table 1.1) comprised specialists in flood management and response, and in local authority-based digital technology, including an established LoRaWAN for air quality and footfall monitoring in Leeds. Interview questions were generated in a Roadmap workshop by the project team, also in consultation with representatives from the Local Digital Fund who approved the Roadmap. Roadmap questions represented the key aspects of creating and establishing a LoRaWAN in West Yorkshire as understood by the project team themselves and through the WYFLIP AGM workshop. It was expected that these questions would be added to as the project progressed and external stakeholders were consulted.

Interviews were conducted within the first four project weeks by iCASP, and responses were summarised in a document which was reviewed and approved by the interviewee, with any non-publishable, sensitive information removed. The interview process enabled us to establish the scope of knowledge within the team at the beginning of the project, and exchange knowledge between the organisations involved to ensure all members were at the same level of understanding. Gaps in project team understanding were established and external organisations were contacted to participate in workshops or consultation meetings to improve our knowledge scope. Table 3.1 identifies the key learnings and knowledge gaps identified during project team interviews. Full summaries of the project team interviews can be found in *Appendices B-H*.

Table 3.1: Key learnings and knowledge gaps identified in project team interviews.

Key learnings/topics well-represented:	
• Recognition that watercourse (fluvial) flooding is well-monitored compared to surface water flooding with established rainfall and river warnings/alerts; surface water flooding is difficult to predict. Some hotspots for recurrent flooding are known.	
• Current practice for local authority and EA for flood monitoring and response 1) in advance of storm events, 2) during storms, and 3) post-flood incident. Current response is primarily reactive, not proactive.	
• Current practice for maintenance of flood infrastructure	
• Current uses of the LoRaWAN in West Yorkshire and extent of system establishment	
• Preference for self-ownership of the system (i.e., not managed by a third party)	
• Recognition that permissions will be required to share data and install gateways/sensors.	
Key knowledge gaps identified:	**Addressing knowledge gaps**
How to share data between organisations effectively (data ownership/GDPR concerns/management and cost to run a shared system in the long-term/cybersecurity)	See *section 3.4* & *Appendix B*
Incident report data to identify hotspots for surface water flood varied significantly between organisations	See *section 3.5*. Established mapping protocol by Leeds City Council was applied to Wakefield and Kirklees data where available. Recommendations were made on

	what kind of data would be required to map hotspots in the future.
Specifics regarding cost for a complete LoRaWAN	Broad costs were investigated, estimated by Leeds City Council who have previously set up a LoRaWAN. A pilot is required to fully answer costs of full sensor rollout.
Is LoRaWAN the best option or would sensor systems such as NBIOT, Sim Cards or CCTV be more suitable?	See *Section 3.4*
Recognition of need to speak with other groups who may wish to receive sensors data (what are their needs? Should the data be publicly available in real-time and/or post validation?)	See *Section 3.2 & 3.3*
In Kirklees and Wakefield: Recognition of training required to set-up and run a LoRaWAN network if councils opt for a DIY approach	Leeds City Council have offered to provide training on set up of a LoRaWAN, including sensors, gateways and dashboard.
Viability (cost/expertise) of setting up a LoRaWAN using a DIY, council-owned approach	See *Section 3.4*

3.2 Service Providers Workshop

A service providers workshop was necessary to further understand current practice for flood mitigation and response in West Yorkshire, and to learn about what kind of system would be required to improve these practices. i.e., What is the current situation and how would that be changed to improve the service provided by the organisations in attendance? Nineteen people attended the event, with representatives from Kirklees, Leeds, Bradford and Wakefield councils, Yorkshire Water, JBA Consulting and EA, including one EA representative from the national surface water management team.

The workshop was held at the University of Leeds as a neutral party, over 3-hours to enable networking over lunch, presentation of the DSFWS project with time for questions, and discussion of opportunities, needs and risks. Attendees were split into two groups, with even representation from each organisation in each. On each table, one member of the DSFWS team facilitated discussions with aid from a facilitation guide created by iCASP; another member of the DSFWS facilitation team took notes from the table discussion. The key questions included in the facilitation guide as discussion guidance were as follows, with questions 1-3 marked as priority:

1. How do you currently respond to flooding? What works/doesn't work?
2. What specific information does your services need in order to respond to flooding? Are services dependant on other factors before they can act?
3. If the LoRaWAN was operational in West Yorkshire, what data would be most useful to you?
    a. In what format? – Alerts only? Real-time dashboard for monitoring? Simple location only or more specifics? To one key contact?
4. What challenges do you foresee? How might these be overcome?
5. Have you experienced working with a LoRaWAN or early warning flood system before? If yes, what was good & what needed improving? Lessons learnt.
6. Are there 'hotspot' locations which are prone to flooding, in which a sensor would be useful?

Despite the above questions to guide conversation, a broad range of topics was discussed and varied between tables. Table 3.2 summarises the key learnings and knowledge gaps identified at the service providers workshop.

Table 3.2: Key learnings and knowledge gaps identified in the service provider's workshop.

(New) Key learnings/topics well-represented:
• Highly localised nature of surface water flooding
• Sensors would provide data. Data enables a proactive response to flooding and provides a basis for future modelling of flood forecasting
• A hotspots approach is the best way forward for a pilot project
• If LoRaWAN is implemented, it should be open to multiple uses, not just for flooding

(New) Key knowledge gaps identified:	Addressing knowledge gaps
What data already exists for known hotspot locations?	Established mapping protocol by Leeds City Council was applied to Wakefield and Kirklees data where available. Recommendations were made on what kind of data would be required to map hotspots in the future.
Agreement that data should be open-source as much as possible (GDPR approved), however concerns were raised over alert/warning messaging, false alarms, and members of the public receiving data which they might not understand.	See *Section 3.3*
Data sharing will require a regional/national standard	To be investigated further in pilot scheme. Options for data sharing identified (see *Section 3.4, Appendices K-L*)

3.3 Residents Workshop

A residents workshop – comprised of thirteen people from flood warden and community flood groups - was necessary to further understand current practice for flood mitigation and response in West Yorkshire from the perspective of communities who have previously flooded and are actively volunteering to mitigate flooding in their locality. We wished to learn about what kind of system would be required to improve flood mitigation and response for persons volunteering. Attendees represented Garforth Flood Support Group, Hebden Bridge Flood Action Group, Todmorden Flood Group, and two organisations who were unable to attend the first workshop; Dales Land Net and Yorkshire Wildlife Trust.

Again, the workshop was held at the University of Leeds as a neutral party, over 3-hours to enable networking over lunch, presentation of the DSFWS project with time for questions, and discussion of opportunities, needs and risks. As fewer people attended, discussions were held all together. One member of the DSFWS team facilitated discussions with aid from a facilitation guide created by iCASP; another member of the DSFWS facilitation team took notes from the discussion. The key questions discussed were as follows:

1. What data and/or information would you ideally have access to prior to and during a storm? How would you ideally like to receive that information? (text/app/email/call etc)
2. Should this data/information be widely available to all, or accessible to flood wardens/specific community representatives only? Why?
3. Have you been flooded before? How far in advance did you know about the possibility of a flood? Do you know what caused the flood – river level rise or surface water flooding?

Compared to the Service Providers, flood wardens and community group representatives identified a need for a localised approach to flood management, gaining information from sensors focussed on specific locations only. Attendees highlighted need for real-time data which gave information about the flood status in specific catchment locations; from this, management recommendations could be made to members of the public. Much of the current response relies on in-person information transmitted via walkie-talkie; many of the volunteers contributing to the service are elderly and unable to travel long distances in potentially dangerous flood conditions to report on flood status. Sensors would enable information to be collated quickly and verified by able persons on the ground – this would increase time to set up flood defences, move valuables and aid vulnerable persons. Ultimately, a system different from that of the service providers was deemed necessary; as a result, the DSFWS project began to consider a two-dashboard approach.

Table 3.3 summarises the key learnings and knowledge gaps identified at the resident's workshop.

Table 3.3: Key learnings and knowledge gaps identified in the residents' workshop.

(New) Key learnings/topics well-represented:
• Attendees were keen to have access to real-time sensor data for information only. Consistent and clear messaging is key – attendees recommended the real-time data is presented without 'required action' – not as a flood warning, but to raise awareness of specific sensor activity.
• Flood wardens/community groups require local knowledge only as opposed to the regional view preferred by service providers.
• Better to have false alarms than no alarms for flood risk

3.4 Consultation meetings

Consultation meetings enabled the DSFWS project team to approach organisations with specific queries to help answer the identified knowledge gaps and to understand alternative perspectives on setting up a LoRaWAN for flood mitigation. Each organisation was approached differently depending on need, and meeting were curated to facilitate efficient knowledge exchange.

3.4.1 Norfolk County Council

Norfolk County Council (NCC) was approached as a local authority with a well-established LoRaWAN which has multiple use cases, including for fluvial flooding (but not surface water flooding) in the Broads National Park. Simon Cowen has previously contacted NCC when establishing the LoRaWAN in Leeds, therefore conversations were initiated through him, and intentions established prior to the meeting. We sought to understand more about possible use cases, any existing applications to flood mitigation, set-up and maintenance of a dashboard at local authority level, possibilities surrounding data sharing, and any lessons learned from mistakes made.

At the 1-hour online meeting, an overview of the DSFWS project was given, followed by NCC presenting on their current use cases with lessons learned from establishing their own network; opportunity for questions followed. Table 3.4 outlines the key learnings and knowledge gaps identified.

Table 3.4: Key learnings and knowledge gaps identified in a consultation meeting with Norfolk County Council

(New) Key learnings/topics well-represented:
• LoRaWAN is inter-operable and has precedence as a multi-use system in Norfolk
• LoRaWAN has good efficiency of scale – once the gateway and dashboard has been established, it is relatively simple to add further sensors/gateways when needed
• An efficient system will allow for creation of multiple use cases in the future (wide area coverage which has been carefully considered).
• NCC used a third party to initially set up the platform but now operate/maintain/develop the system themselves
• NCC have collaborator accounts to enable data sharing, but this is only available within NCC

(New) Key knowledge gaps identified:	Addressing knowledge gaps
A pilot scheme would need to identify the best locations for gateways within LAs to maximise efficiency of network coverage	To be investigated further in pilot scheme. Hotspots have been identified, but not linked to current gateway coverage or optimum future coverage.

3.4.2 Andel, Alliot and Probado

Where the interview with Simon Cowen and consultation meeting with Norfolk County Council were able to identify what LoRaWAN is and what the current set-up is for councils with a LoRaWAN-trained expert and funds to maintain that network, we needed to scope all possible options for creating a new network. Sustainability in the long-term is important for a viable sensor network. Therefore, an understanding of all options is required, especially as many local authorities are down-sizing and reducing budgets.

Andel, Alliot and Probado are companies which work in collaboration to provide a LoRaWAN service for many different use types, including the option of flood and water level monitoring. The companies were approached separately, but each agreed to a joint meeting to discuss the DSFWS project. A joint meeting enabled open conversation about what services could be provided. From the beginning, it was made clear that the DSFWS team were not seeking to procure a service, but rather to understand the range of options for setting up a LoRaWAN in West Yorkshire.

Table 3.5: Key learnings and knowledge gaps identified in a consultation meeting with Andel, Alliot and Probado

(New) Key learnings/topics well-represented:
• Flexible service – option for councils to set-up elements of the system themselves to save cost
• Multiple data sharing options. Andel, Alliot and Probado would provide a website with log in for each organisation.
• Partnership approach would be a requirement
• Ongoing costs are difficult to identify

(New) Key knowledge gaps identified:	Addressing knowledge gaps
Costs not able to be provided without full project scope	To be investigated further in pilot scheme.

3.4.3 West Yorkshire Fire and Rescue Service

Emergency services were not able to attend the workshops. In mid-November, iCASP were approached by the West Yorkshire Fire & Rescue Service (WYFRS) who had seen the DSFWS project promoted on social media and wished to learn more. Initial conversations were held in-person at the iCASP Annual Confluence (Conference); following this a 1-hour online meeting was scheduled.

In the meeting, the DSFWS project was presented with options thus far established for pilot stage, including a hotspots approach, and knowledge gaps – primarily data sharing agreements and a suitable platform for data access. Discussion included requirements of a LoRaWAN if accessible to the WYFRS (likely to be similar for other emergency services) and options for sharing the sensor information. WYFRS presented a new platform option called Resilience Direct which was unknown to the project team. If a sensor-based early warning flood system is viable and successful regionally, Resilience Direct has potential to share data not only in West Yorkshire, but also nationally.

Following the meeting, the WYFRS forwarded a link for Resilience Direct, enabling category 1 and 2 responders within the DSFWS team to sign up to the platform.

Table 3.6: Key learnings and knowledge gaps identified in a consultation meeting with West Yorkshire Fire and Rescue Service

(New) Key learnings/topics well-represented:

• Resilience Direct is a platform which could potentially be used to share data in real-time between all organisations, and partners including emergency services and northern power.
  ○ Resilience Direct is a GIS viewing tool with displays and shares relevant information, for example, Met Office weather warnings, EA flood alerts, real-time traffic congestion, frequent satellite data (show extent of surface water flooding). Tools enable analysis of properties/businesses at risk based on area identified.
  ○ Many different data types are accepted to Resilience Direct – photos and videos could be uploaded to support sensor data
  ○ All organisations currently have access to this free platform, however it is not currently available outside of emergency planning departments

• Importance of real-time flooding data to create a proactive response: WYFRS currently experience more deaths due to flood-related drowning than fire
• Options for future funding

(New) Key knowledge gaps identified:	Addressing knowledge gaps
Possibility of Resilience Direct as an accessible resource	Project team and WYFRS have contacted Cabinet office who manage Resilience Direct – sensors would need to meet specific requirements and Cabinet Office would have to approve the new feed of information. To be investigated further in a pilot scheme.

3.4.4 West Yorkshire Resilience Forum Severe Weather Group

Emergency responder organisations in West Yorkshire are members of the West Yorkshire Resilience Forum (WYRF). Following the meeting with West Yorkshire Fire and Rescue, the DSFWS team were contacted by the Severe Weather Group within the WYRF. A one-hour consultation meeting was arranged to discuss the DSFWS project and potential for future collaboration.

In the meeting, the DSFWS project was presented with options thus far established for pilot stage, including a hotspots approach, and knowledge gaps – primarily data sharing agreements and a suitable platform for data access. The WYRF Severe Weather Group Chair agreed that Resilience Direct – the software identified

in the consultation meeting with WYFRS – would be a suitable platform, however a public-facing system should also be established. For maximum impact going forwards, the DSFWS team was invited to present at the next WYRF meeting and receive feedback and steer from members. WYRF Severe Weather Group would be interested in further project updates and may wish to support an alpha stage of the project as collaborators, key stakeholders or partners.

Table 3.7: Key learnings and knowledge gaps identified in a consultation meeting with the West Yorkshire Resilience Forum

(New) Key learnings/topics well-represented:
• West Yorkshire Resilience Forum Severe Weather Group Chair supported the project on behalf of the Severe Weather Sub Group.
• Agreement that Resilience Direct is a promising option for data sharing
• Agreement that a public warning system would be useful in the long-term

(New) Key knowledge gaps identified:	Addressing knowledge gaps
Wider project support from all Emergency Services	The DSFWS team will present the project, including findings and potential next steps, at the next West Yorkshire Resilience Forum meeting and receive feedback/steer from members.

3.5 Hotspot mapping

Based on locations identified in project team interviews, workshops and consultation meetings, and through incident report data collected by Leeds, Kirklees and Wakefield Local Authorities, hotspot locations for surface water flooding were mapped (some locations are close to rivers or ordinary water courses but the primary flood risk is from surface water). As identified in the interviews, extent and type of data held for flood incidents vary significantly between Local Authorities. Maps produced for this project were made based on a methodology used by Leeds City Council. For future work, local authorities have agreed on the data required for mapping. Table 3.8 shows the hotspot locations identified with a description of the primary flooding issue per location; Hotspot maps are presented in Appendix P, Figures N1-6.

Table 3.8: Hotspot flood locations identified in the DSFWS project.

Local Authority	Location	Description
Kirklees	Gynn Lane, Honley	Properties are at risk of flooding from Ludhill Dike. N: 414484, E: 412158
Kirklees	Manchester Road between Slaithwaite and Marsden	Main road between Huddersfield and Manchester is regularly flooded from Badger Gate Clough. N: 406572, E: 412872
Kirklees	Ravensthorpe	Allotments and public footpath are flooded to waist-deep levels from Canker Dike. N: 422286, E: 420862
Kirklees	Whitehall Road, near J26 of the M62	Motorway junction roundabout floods from Sugden Beck & Stubs Beck. N: 418168, E: 426611
Kirklees	Hagg Lane, Lower Hopton	Properties and road at risk of flooding from Liley Beck. N: 421159, E: 418914
Kirklees	Middlemost Pond, Birkby	Properties at risk of flooding from Grimescar Dike. N: 413863, E: 418496
Leeds	Barnsdale Road, Allerton Bywater	Regular flooding to the highway- road to be closed to avoid incidents. N:442616, E:427378
Leeds	Troydale Lane, Pudsey	Regular flooding to the highway. N423590, E:432647
Leeds	Mill Lane Collingham	low lying road that floods when beck levels rise- nowhere for water to go. N:438686, E:445904
Leeds	Farnley Lane, Otley	Blocked gullies causing flooding highway. N:420509, E:446318
Leeds	The Hollies, Pool in wharefdale	Surface water run off flooding road and outbuildings. N:424661, E:444984
Leeds	Town Street, Guisely	Surface water runoff floods garage and limits residents' access to houses. N:419492, E: 442469
Wakefield	Reid Park Beck	Watercourse adjacent to pumping station. N:418154, E:428302
Wakefield	A638 Doncaster Road	Flooding under railway bridge. N:415861, E:444504
Wakefield	Minsthorpe Grille	Flooding from watercourse onto highway. N:410849, E:446516
Wakefield	River View, Castleford	Flooding from floodplain, River Calder. N:425979, E:441911
Wakefield	Agbrigg FAS	Agbrigg flood scheme watercourse levels. N:419260, E:434947
Wakefield	Bleakley Lane	Flooding of highway from open land. N:412404, E:435945

4. Recommendations & Next Steps

The DSFWS Digital Discovery Project has identified need for an improved, proactive response to surface water flooding in West Yorkshire. The current, reactive management for flooding is resource inefficient and does not enable a joined-up approach by multiple organisations; surface water sensors would enable a targeted, proactive approach which facilitated infrastructure maintenance, flood incident response and pattern analysis of incidents over time. LoRaWAN is a viable and reliable system for sensor data collection which is recognised internationally, has precedence for use by local authorities in the UK and has potential to mitigate flooding.

Our Digital Discovery project recognised a council owned LoRaWAN as the best option for data collection, with data accessible to both service providers and members of the public, specifically flood wardens and community flood action groups in the first instance. With no current network of flood-related sensors, we recommend the initial approach targets known hotspots which have been identified based on incident report data. Data should be available in real time as 'information-only' to inform decision making; any 'alerts' should be indicative of a change in sensor readings (e.g., rising water level) as opposed to a flood warning, and public-facing messaging should be carefully managed. As a database is built over time, it may be possible in future to identify patterns in surface water flood extent and timing at specific locations and thus create an early flood warning system.

All organisations should have access to the data in real-time via a shared platform, with historical data saved for post-incident and long-term pattern analysis. This may be in the form of an internal dashboard with sharing capability, an app, a website or via existing software such as Resilience Direct; a decision on which platform depends on permissions granted.

Remaining unknowns to be investigated during a pilot stage include:

- Costs for full system development
- Minimum viable product: Dashboard and sensor configuration, installation of physical system, and maintenance per Local Authority. Consensus on responsibility for system continuance, security, control and updates.
- Use of existing data sharing platform, Resilience Direct
- Best locations for gateways to optimise wide area coverage for multiple uses of the LoRaWAN
- National/regional standards for data sharing

A business case for a pilot scheme has been produced detailing alpha stage requirements, a benefits management plan and risk register. These documents will be used to apply for funding for a pilot scheme.