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# Assessing the ability to share spatial data between emergency management organisations in the High North

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By

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# ABSTRACT

The decreasing extent of the Arctic sea ice has opened up new areas in the High North for industrial and commercial activities. These areas contain large reserves of oil and gas, and the region is home to some of the world's richest fishing grounds. The region is of key strategic importance, and maintaining a Norwegian presence in the Arctic areas is considered to be a national priority. A major restructuring of the emergency management services in Norway is underway to accommodate the expected increase in commercial and industrial activity within the High North region. As part of this process, it is necessary to assess the current status of spatial data within the emergency management (EM) process.

This project aims to fill the gap that exists in the current research on the Norwegian emergency management system, as little work has been done to assess the current ability to share spatial information between organisations participating in the emergency management process in the High North. This has been accomplished through a variety of methods, including a detailed GIS-analysis of the communication infrastructure, interviews with stakeholders in the emergency management process and analysis of modern research within the spatial data infrastructure (SDI) domain.

The results shows multiple issues with the sharing of spatial information. These issues are both organisational and technological. Investigations into the organisational structure of the EM process revealed a complex hierarchy with varied spatial data needs and spatial data production responsibilities. This structure is highly dependent on pre-existing data sharing agreements, making it difficult to implement new data or additional stakeholders into the spatial data information networks. The lack of real-time sensor information and insufficient communication infrastructure also creates difficulties in acquiring and sharing up-to-date spatial information within the High North region.

Possible solutions to the gaps and barriers from the investigate phase of the research was explored, with the aim of providing possible initiatives to augment the planned integration of emergency management spatial data into the Norwegian national SDI. A series of short-term initiatives aimed to resolve current gaps in functionality is suggested, as well as, potential longer-term development focuses, with the goal of implementing advanced GIS and SDI functionality into the next generation of SDI infrastructure.

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| | |
|---|---|
| AIS: | Automatic Identification System |
| CRS: | Coordinate Reference System |
| DSS: | Decision support system. |
| EM: | Emergency management. |
| INSPIRE: | Infrastructure for Spatial Information in the European Community. |
| GIS: | Geographical Information Systems. |
| GMDSS: | Global Maritime Distress Safety System |
| MF: | Medium frequency (radio frequency) |
| Metocean: | Meteorological and oceanic data. |
| NOFO: | Norwegian Clean Seas Association for Operating Companies |
| SAR: | Search and rescue |
| SARiNOR: | Search and rescue in the Northern Areas (The High North) |
| SDI: | Spatial Data Infrastructure |
| VHF: | Very high frequency (radio frequency) |

# 1 INTRODUCTION

## 1.1 BACKGROUND

The decreasing extent of Arctic sea ice has opened up new areas in the High North for petroleum exploration. These areas are expected to contain some of the largest unexplored reserves of oil and gas. Moreover, the region is home to some of the world's richest fishing grounds. This makes the Arctic one of the primary strategic areas for exploration and development in the near future, and maintaining a Norwegian presence in the Arctic areas is considered to be a key priority for the Norwegian government (Norwegian Ministry of Foreign Affairs, 2006).

The Arctic region is also home to some of the most inhospitable climates in the world and vessels operating in the area face extremely low temperatures, high winds and drifting sea ice. The vast distances involved also complicates the traditional model of shore-based infrastructure and emergency response resources, as the installations will be outside the operational range of these resources. The conditions faced when operating in Arctic environments presents unique challenges and stretches the existing infrastructure past its breaking point.

A major restructuring of the emergency management services in Norway is underway to accompany the increased level of activity within the High North region, with multiple research projects ongoing to overhaul the entire EM system (Maritimt Forum Nord SA, 2014). During this work, stakeholders have commented on the need to acquire spatial data from a single point of access, as the current decentralised model presents difficulties for many of the stakeholder organisations participating in the EM regime.

Geospatial information makes up one of the cornerstones of maintaining the situational awareness, and it must be viewed as one of the key components in a well-functioning emergency management system. In the present-day situation, access to updated and relevant data is limited and few means of communication exists between land-based infrastructure and vessels operating in the remote areas of the High North. Having access to up-to-date data on weather, asset locations and other geographic information demands a well-functioning spatial data infrastructure, access to a distributed sensor network and a developed organisational framework that enables various forms of spatial data to be collected, shared and analysed.

Current maritime digital communication systems were not designed to cover the Arctic. Distance from land makes it impossible to utilise existing infrastructure in the form of wireless and fibre connections, while stable satellite communication has traditionally been difficult to achieve with satellite systems in geosynchronous orbit (GEO). A similar situation exists with the various data gathering systems, which at the current time does not provide spatial data sufficient data quality within the study area. A third challenge is the lack of an established framework that guides the usage and sharing of spatial data between organisations participating in the EM process. Overcoming these difficulties puts an even greater emphasis on the ability to share spatial data for analysis and decision-making between organisations participating in the emergency management process in the High North.

The research focuses on assessing the efficiency of the present-day infrastructure, mapping out the processes that influence these systems and potential initiatives that can improve the ability to share spatial information between organisations to maintain operational awareness.

## 1.2 OBJECTIVES

The overall aim of this research project is to assess the current ability to share and use spatial data between organisations participating in the emergency management process in the High North. This is done through a combination of existing research in related fields, interviews with stakeholders and analysis of influencing factors like geography and infrastructure. The results from the initial research phase are used to assess the requirements of an SDI specialised for emergency management in the High North.

Specifically, the four main objectives of the research are to:

1. Assess the current ability to use and share spatial data in organisations participating in the emergency management system in the High North.
2. Assess the ability to create a comprehensive sensor network to improve the access to meteorological and oceanic sensor data by utilising buoys, installations and vessels in the High North as providers of sensor data.
3. Assess the planned integration of spatial data used in the emergency management process into the NSDI, and look at short-term initiatives that would improve the access to spatial data for auxiliary organisations.
4. Assess the possibility of implementing newer SDI concepts and state-of-the-art GIS technology into the emergency management process in the High North as a long-term development path.

## 1.3 STRUCTURE

The thesis is structured into 6 chapters.

Chapter 1, Introduction, gives a general description of the document, and gives an introduction into the general state of the related fields, objectives of the research and the scope of the report.

Chapter 2, Background, describes the existing research into areas that are relevant to the emergency management process in Norway. It also describes the current state of the art in relation to SDI-research and links SDI-concepts into the broader emergency management setting.

Chapter 3, Methods, describes the overall approaches taken to assess the state of the field, outlines the interview process and the system design process used to conceptualise an SDI-system for emergency management in the High North.

Chapter 4, Results, describes the results from the initial information-gathering process and outlines the effects and limitations that these present for spatial data sharing between emergency management organisations.

Chapter 5 discusses the process and findings from each phase, and looks at how newer GIS-technologies can influence the long-term development path for spatial data within emergency management.

Chapter 6 contains the conclusions drawn from the entire process, including system designs and a discussion on future work. This includes potential expansion of the previous work and ideas that incorporates concepts such as ontologies and semantic concepts for more advanced web-based spatial data processing.

# 2 BACKGROUND

To understand the structure of Norwegian emergency management and search and rescue operations (SAR), it is necessary to have a basic understanding how the geography, economy and population is distributed. These factors have forced the creation of a unique approach towards emergency management, with a focus on collaborative approach that utilises local resources. This has a major effect on the emergency management systems in use, and how the accompanying spatial data infrastructure is designed.

## 2.1 EMERGENCY MANAGEMENT IN NORWAY

Emergency management in Norway has traditionally been the domain of multiple agencies and organisations. The guiding principles of the Norwegian approach has been the concept of cooperative and collaborative response (Ministry of Justice and Police, 2002) – *The response to an incident should be decided by available resources within response range, not a strict hierarchical organisational structure.*

The length of the mainland coastline is 2,650 kilometres measured from a baseline in the outer Norwegian Archipelago at a 1:50,000 scale. Most of the coastline is sparsely populated, with small, scattered settlements. The situation is further complicated by challenging weather conditions and vast areas with little activity. This combination of factors makes it unrealistic to maintain full emergency management capacity along the entire coastline, and has forced the creation of alternative solutions. These challenges, coupled with the maritime traditions found in the coastal communities, have created a sophisticated system based on voluntary principles.

While the main capacity of the emergency management services is the professional rescue services, including specialised assets such as the SAR-helicopter of the Squadron 330 and SAR response vessels from The Norwegian Society for Sea Rescue, private contributions are key for maintaining local SAR capacity along the entire coastline. To coordinate this combination of local and specialised assets, two rescue coordination control centres exist – The Joint Rescue Coordination Centres (of) Southern Norway and Northern Norway. Rescue leaders from these coordination centres take overall command of emergency response situations within their areas of operation, and coordinate the available assets. This role is a multi-disciplinary one, and places a high emphasis on training and experience. Users of decision support systems in use within these organisations can be expected to be knowledgeable of the field in general, and well-trained in the use of various tools used. This allows (and necessitates) the use of complex tools to maintain situational awareness and enable rescue leaders and coordinators to perform their tasks. Spatial data is an integrated part of the decision support systems (DSS) currently in use, and most of the data that is handled during an emergency situation is handled through a spatial data interface (JRCC and Delbekk, 2015).

### 2.1.1 The Norwegian Search and Rescue Service

In the 2002 report "The Norwegian Search and Rescue Service the Ministry of Justice outlines the 8 main challenges and focal points for organisations maintaining SAR capabilities in Norway (Ministry of Justice and Police, 2002):

> The rugged topography and harsh climate,
> heavy coastal shipping traffic,
> extensive commercial fishing,
> offshore oil and gas installations,
> heavy industrial activity in certain parts of the country,
> extensive transport activity on land,
> substantial tourism and recreational activity on land and sea,

and natural disasters due to floods, storms, landslides and avalanches.

It is important to understand that the Norwegian approach to emergency management involves a large number of organisations, both public and private, which all contribute operational capacity during response situations. Since the organisational hierarchy will vary drastically based on incident type and location, systems and standards must be structured in a manner that lets a wide variety of organisations and data systems communicate and share information efficiently. A 2002 report from the Ministry of Justice and Police outlines the organisational chart of the Norwegian Search and Rescue Service (Figure 2.1 & Figure 2.2).


*Figure 2.1: Rescue sub-centre – Structure (Ministry of Justice and Police, 2002). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by Ministry of Justice and Police.*

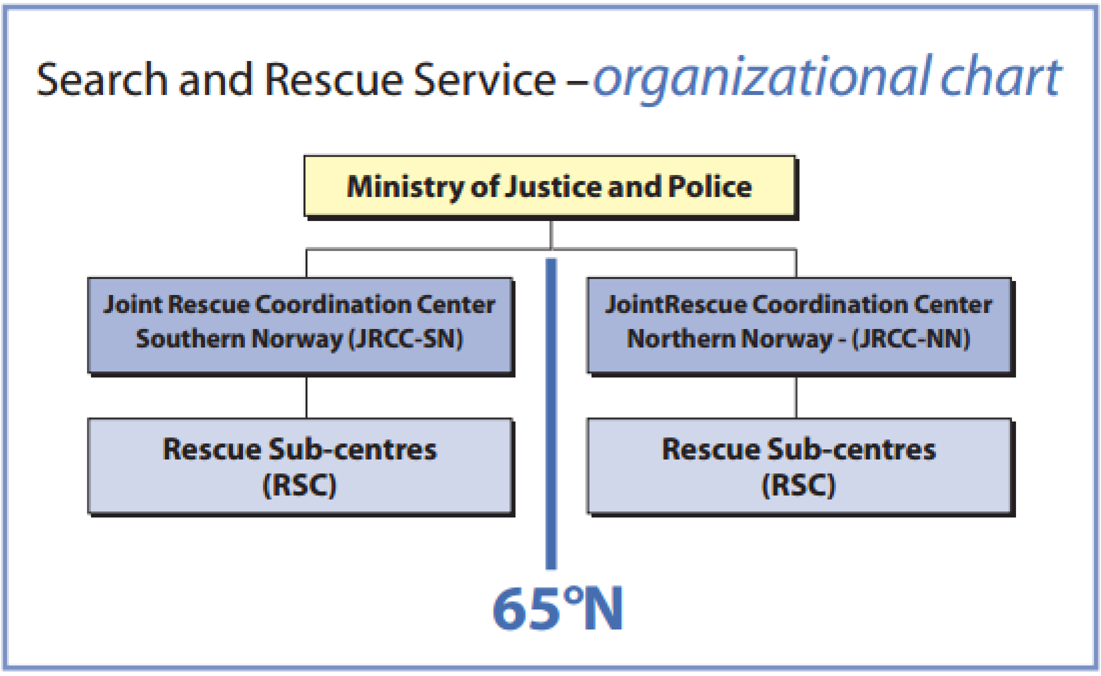


*Figure 2.2: Search and Rescue Service - Organisational chart (Ministry of Justice and Police, 2002). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by Ministry of Justice and Police.*

An important concept that is needed to understand the structure of the Norwegian emergency management regime is the concept of ***core*** and ***auxiliary*** organisations. The cooperative nature of emergency management domain has led to the involvement of a wide variety of organisations and institutions (Maritimt Forum Nord SA, 2014) (Hartviksen, 2015). A core organisation serves a clearly defined role in the EM process, and is often both a producer and consumer of spatial data. An auxiliary organisation has a more diffuse role in the EM regime, and often refers to local, voluntary assets like vessels from the fishing fleet. These organisations are often not considered to be users of spatial data whatsoever, and generally have few ways to make use of available spatial data. The lack of a unifying SDI has led to voice-based communication being the centrepiece in response planning with many types of auxiliary organisations, which lack the ability to participate in the existing initiatives for spatial data sharing (Marintek and Sintef, 2015) (JRCC and Delbekk, 2015).

## 2.2 THE MARITIME GEOGRAPHY – NORWAY

With roughly 2650 kilometres of coastline, measured at a scale of 1:2,000,000 for the mainland and 1:1,000,000 for the Svalbard Isles, Norway covers a large geographical area. Additionally, the Norwegian maritime territory is enormous, stretching from the 58$^{th}$ to 82$^{nd}$ north parallels (Ministry of Justice and Police, 2002). The maritime area under Norwegian jurisdiction is divided into a complicated patchwork of zones with different legal rights and responsibilities. The economic and legal rights and responsibilities vary with proximity to shore, geology and international law (Figure 2.3). Nemeth et al. (2014) outlines the zones of maritime areas under Norwegian administration:

Internal waters – Complete sovereignty.
Territorial waters – Areas up to 12 nautical miles from shore, complete sovereignty.
Contiguous zone – 12 to 24 nautical miles from shore, right to exert limited control for the purpose of preventing infringement.
Exclusive Economic Zone – Ranges 200 nautical miles from the territorial sea baseline. Full control of all economic resources within the EEZ. Cannot deny passage to foreign vessels.
Norwegian Continental Shelf –The legal definition of the continental shelf guarantees that a coastal country similar rights to the EEZ within a minimum of 200 nautical miles, but can be extended to a maximum of 350 nautical miles depending on geological factors.
International waters (not under Norwegian administration, still under coverage of SAR due to proximity)

This legal structure, coupled with geographical factors outlined in 2.2.1 creates the fundamental conditions for the overall approach towards use of the Norwegian maritime areas, and provides a basis for the long-term development of these areas. Any development, whether organisational, technological or legal, is built upon an understanding of the geographical and legal status of the Norwegian maritime areas.

### 2.2.1 Geography – The Barents Sea and the High North

One of the key concepts in the Norwegian Arctic policy is the concept of the High North. While the northern areas of interest are geographically a part of the Arctic, the geographical concept of the Arctic is too imprecise to use for policy development in the areas covered by the High North concept. The most common geographic definition of the Arctic is that it is compromised of the part of the Earth lying to the north of the Arctic Circle at 66° 33’ N (Skaggestad, 2010). This is obviously not a very precise definition, as this is a gigantic area that contains varying geography and climate. In addition to this, the region is home to everything from highly industrialised societies to native tribes, and large parts are not populated at all. A different concept was required to define the Arctic areas that could be a potential target for further industrial development (Skaggestad, 2010).

The concept of the High North originates from the Norwegian term “Nordområdene” – Literally “The Northern Areas.” This term is used in both a geographic and political context, and is used as a catchall to refer to areas under Norwegian administration north of Trøndelag. The lack of any precise definition does not prevent it from being used as the main term when it comes to development of the northern areas. *The High North Strategy* (Norwegian Ministry of Foreign Affairs, 2006), released in 2006, outlines the Norwegian state's approach towards the northern areas, and serves as the framework for the developments that have been undertaken since to develop the northern areas. One of the more common definitions of the High North is the areas with The Norwegian Sea and The Barents Sea, as found in Figure 2.4. This is the definition used by The Norwegian Environmental Agency, and are used for the GIS analysis conducted in this research.

The USGS estimates that the Arctic areas to contain an estimated 11 billion barrels of crude oil, 11 trillion cubic meters of natural gas, and 320 million cubic meters of natural gas liquids (United States Geological Survey). This estimation means that roughly 20% of the world's oil reserves (United States Geological Survey, 2009) can be found in Arctic areas, making the region of key geopolitical importance. Additionally, the region is home to some of the world's richest fishing grounds, and is also expected to contain significant reserves of other resources (Noreng, 2011).

While actual development of these areas will be highly dependent on market factors like the oil price, the region is of key geopolitical interest, and maintaining sovereignty in the High North can be expected to feature heavily on the agenda of countries that are hoping to participate in the development of these areas.

While the legal and geographical situation in the southern parts of the Norwegian Continental Shelf was settled during the first stages of Norwegian petroleum development, the situation has historically been a bit more complex in the High North (Noreng, 2011). It was not until June 7$^{th}$, 2011 that a treaty defining the Norwegian – Russian border of the Barents Sea was ratified, after decades of negotiations (Nemeth et al., 2014, Yearn Hong, 2014). A similar process has been ongoing on a larger scale between the states participating in the Arctic Council: Canada, Denmark, Finland, Iceland, Norway, Sweden, Russia and the USA. Interestingly, the High North concept has started seeing usage beyond the Norwegian borders, as other countries has gradually adopted the term (Skaggestad, 2010).

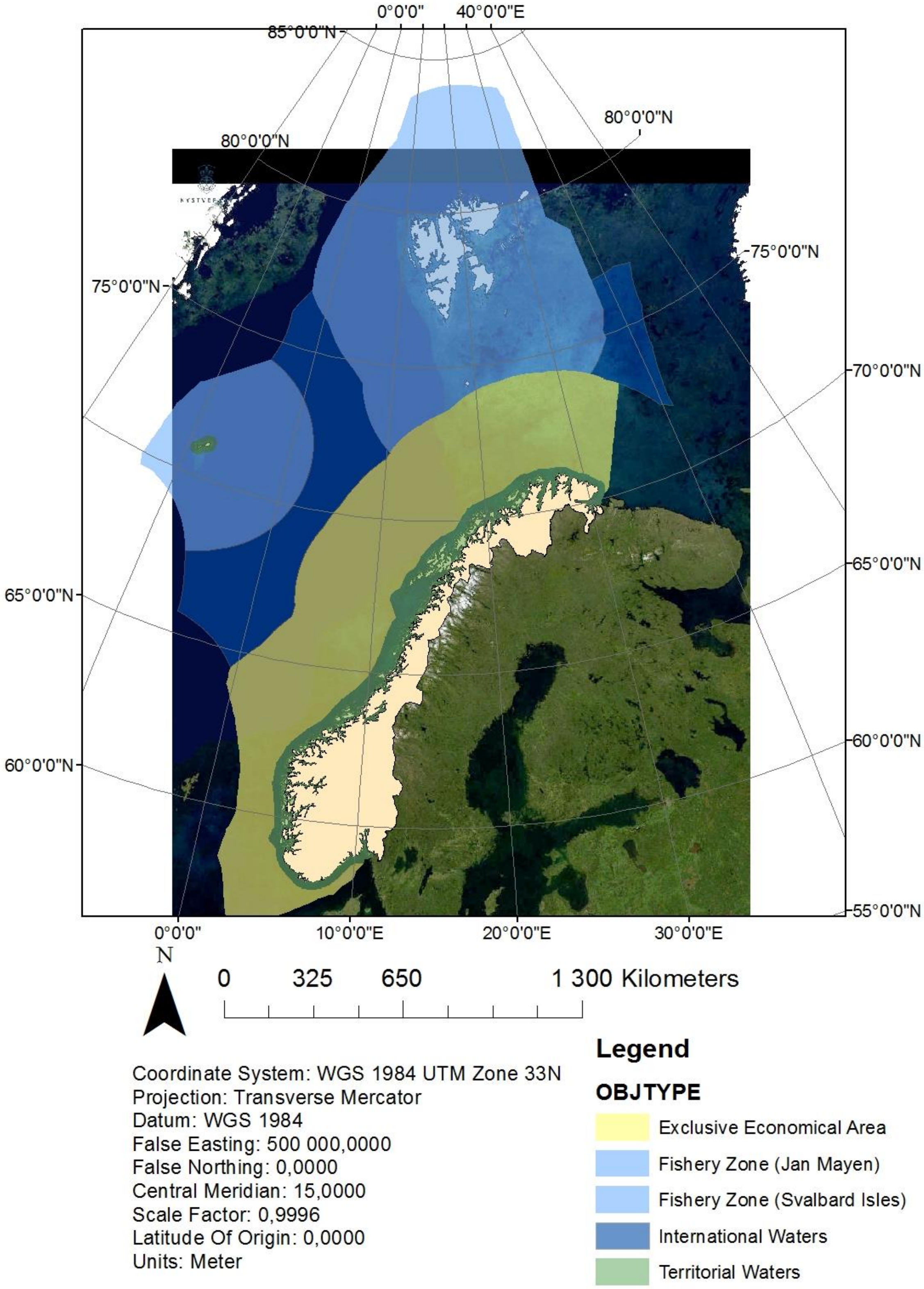


*Figure 2.3: Norwegian maritime administrative areas (The Norwegian Mapping Authority, 2015b). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Mapping Authority. Lars Ole Grottenberg has changed the information by cross-cutting it with user-generated content.*

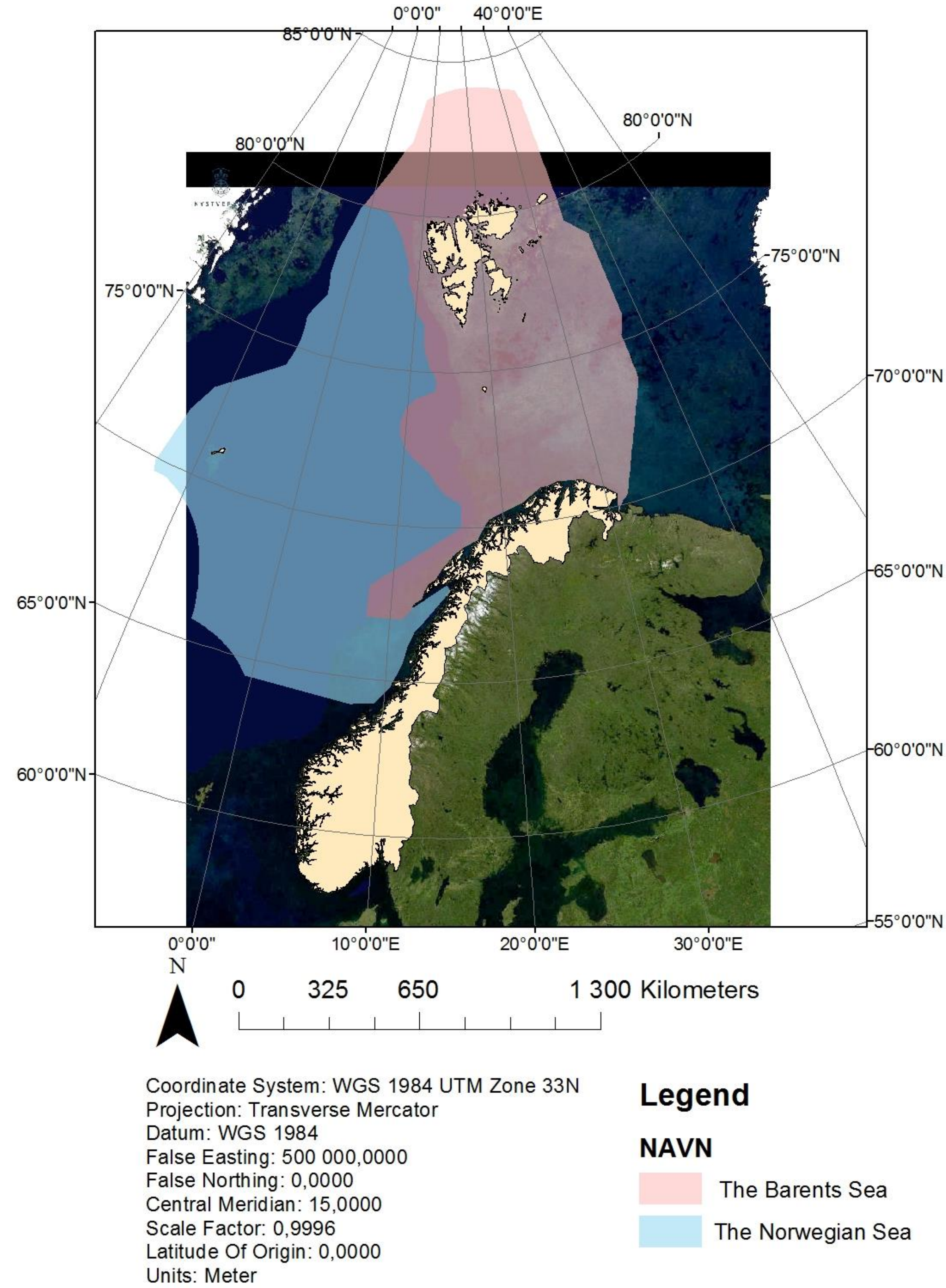


*Figure 2.4: Maritime High North areas*

## 2.3 MARITIME OPERATIONS IN THE HIGH NORTH

Vessels operating within Norwegian maritime areas can generally be assumed to be users of preparedness and response services. While vessels of all classes are expected to contribute to nearby response efforts, these vessels have few ways to participate in the overall preparedness process, instead being limited to contributions in the response stage of emergency management efforts. A lack the equipment and training necessary to contribute to the overall or spatial awareness has also been noted, particularly among leisure class vessels operating in coastal areas (UIT et al., 2015).

Ship classes operating in a more professional capacity, such as fishing vessels and passenger crafts, can be expected to have the technological capacity and training necessary to contribute efficiently in response efforts, and contributes some data in the form of AIS and other automatic location data to improve the situational awareness for preparedness and response services (Marintek and Sintef, 2015). Improving the level of participation of ships outside the current emergency preparedness regime has the potential to increase the level of situational awareness in the areas of the High North that currently falls outside the land-based infrastructure.

### 2.3.1 The Norwegian fishing fleet

The Norwegian fishing fleet is the main operator in the Barents Sea, and consists of numerous vessels operating both in coastal and oceanic areas. The movements of the Norwegian fishing fleet in the Barents Sea is shown in Figure 2.5. This clearly shows that the fleet is active across the entirety of the Barents Sea. The tonnage statistics indicate a clear increase in the efficiency of the fishing fleet, even with the large loss in fleet size (Table 2.1). This suggests a move towards newer, more effective vessels, something that is supported in the 2015 report on the state of the Norwegian fishing fleet (Standal and Hersoug, 2015).

Fishing vessels are expected to be one of the major users, stakeholders and participants in an emergency management system in the Barents Sea (Marintek and Sintef, 2015). Vessels in the Barents Sea are one of the primary sources of information regarding weather, and nearby vessels are often among the first responders in the case of incidents in the High North due to proximity to the incident location. Assessing the needs and capabilities of the fishing fleet in the High North must be one of the highest priorities, given the complex role as user, stakeholder and participants in emergency management systems that the fishing fleet has. This process is ongoing in multiple research projects, particularly in SARiNOR and Barentswatch, and the results from these projects must be taken into account.

*Table 2.1: Active fishing fleet - Finnmark and Troms counties (Directorate of Fisheries, 2015)*

| **Year** | **Finnmark** | **Troms** | **Total** |
|---|---|---|---|
| **2001** | 1 100 | 1 410 | 2 510 |
| **2004** | 957 | 1 187 | 2 144 |
| **2007** | 793 | 971 | 1 764 |
| **2010** | 798 | 819 | 1 617 |
| **2014** | 794 | 705 | 1 499 |

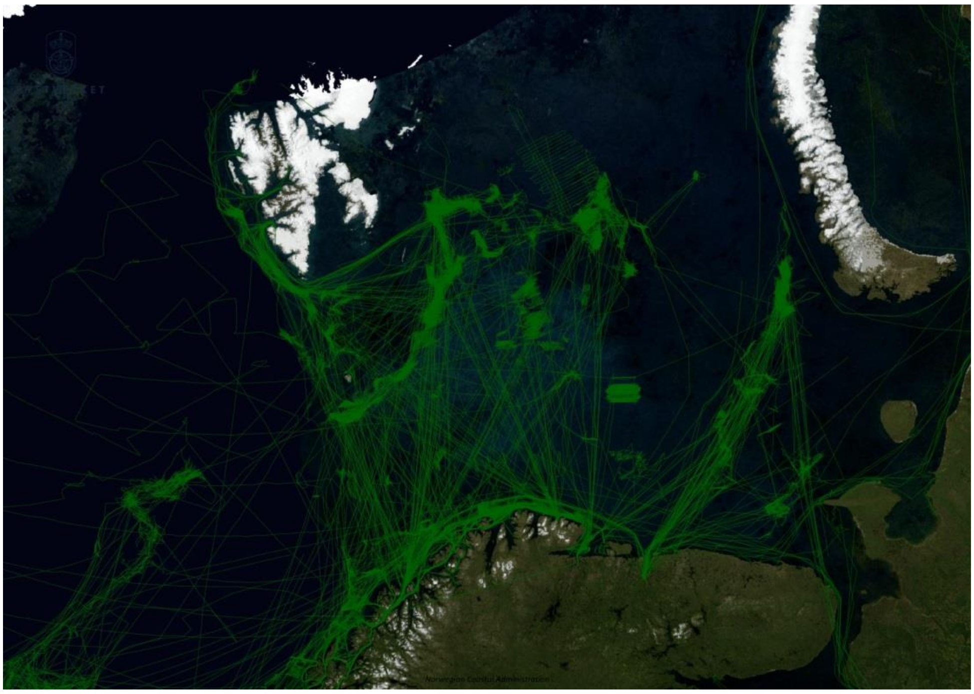

*Figure 2.5: Movements of the Norwegian fishing fleet in the Barents Sea, July 2014 (Norwegian Coastal Authority, 2015). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Coastal Authority.*

The technological standard of the fishing fleet varies. At one extreme are the large vessels with state-of-the-art navigation and information systems manned by trained officers. The other extreme are small fishing boats equipped with an aging VHF-radio, often operated by a single fisherman. The lack of uniformity in the Norwegian fishing fleet makes it difficult to ascertain the base level of technological capability across the fleet. A certain baseline has been mandated by the Directorate of Fisheries, ensuring that all vessels in the Barents Sea have basic communication equipment, AIS and VHF radio. The move towards newer and more effective vessels has increased the presence of this equipment across the fishing fleet.

These capabilities should be utilised to a larger degree to help raise the overall level of situational awareness within a geographic area. Additional measures should also be investigated, as it may be possible to leverage the existing capabilities of the fleet to help fill the black hole in climate, weather and sensor data in the remote areas of the Barents Sea. New technologies and standards may also increase the overall level of participation from the fishing fleet in maintaining spatial awareness over the Barents Sea. While heavy-weight sensor systems is infeasible for the lower end of the commercial fishing fleet, more light-weight sensor suites may be possible to implement (Aptomar and Håkon Skjelten, 2015).

### 2.3.2 Maritime tourism and cruise ships on Svalbard

One of the major causes for the increase in traffic in the Arctic areas is the increase in tourism over the last decades (Sysselmannen på Svalbard, 2014). The High North is an attractive tourist destination that is being heavily marketed both at home and abroad. The number of visiting cruise ships are expected to remain stable in the foreseeable future, as interest in the Svalbard Isles and the *very* High North remains high. While the number of ships will most likely stay relatively static, the last years have seen a clear increase in the number of visitors. Tourism can be expected to remain as one of the main sources of ship traffic in certain areas of the High North. Figure 2.6 shows the traffic patterns for passenger vessel traffic in the High North. It is clear that the traffic is concentrated along the Norwegian coastline and on the Svalbard Isles.

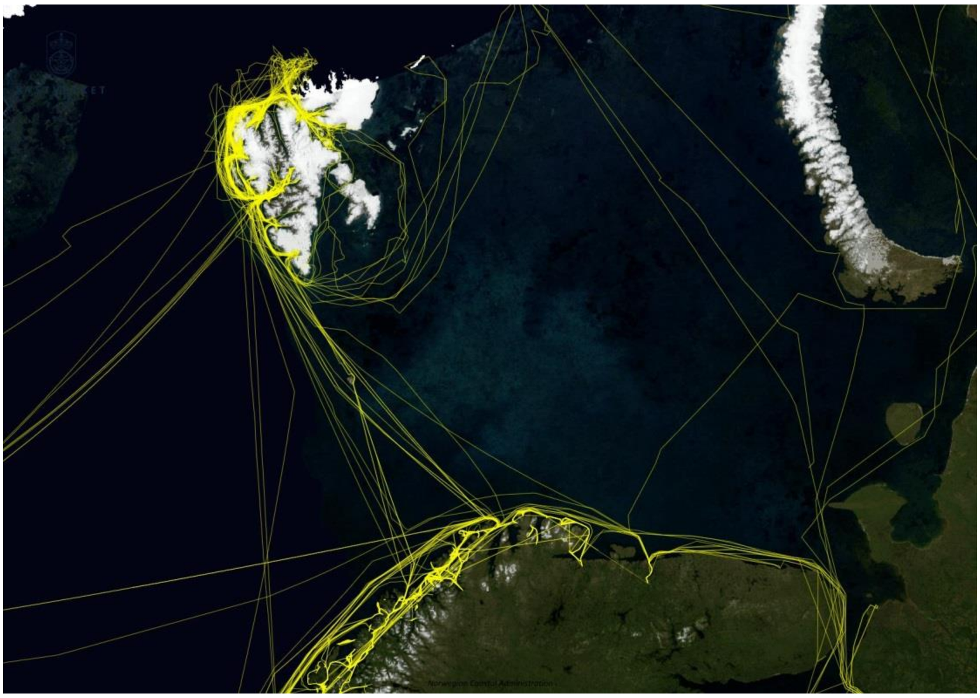

*Figure 2.6: Passenger vessel traffic routes in the High North in July 2015 (Norwegian Coastal Authority, 2015). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Coastal Authority.*

The Svalbard Isles are the most problematic to provide coverage for, as they fall outside the range of the conventional SAR network. As of today, SAR and emergency management services are not equipped to handle incidents with larger passenger ships near Svalbard. There is neither the technological capacity nor access to the necessary equipment to conduct large-scale response efforts for passenger vessels outside of the range of the Norwegian mainland, and medical facilities on Svalbard completely lack the capabilities to respond to a serious incident involving passenger vessels. Given the sheer scale and potentially catastrophic effects of incidents with these ships, building capacity for response to these issues is a priority, and this has been one of the main concepts behind the SARiNOR project (Maritimt Forum Nord SA, 2014).

### 2.3.3 Other classes of vessels

Other classes of vessels operate within the Barents Sea. The two most notable classes of vessels, outside of fishing and tourism vessels, is cargo ships and petroleum support vessels. Implementing cargo vessels as an active part of the EM process is difficult, as these vessels rarely operate solely within the High North region, and are often just on transient voyages through the region. Due to this, it is difficult to integrate spatial data and sensor data from these vessels into the SDI.

Petroleum vessels are often stationed as supporting ships to static installations, and efforts should be made to include these vessels into the spatial data awareness and preparedness regime. This will require major efforts at the organisational level, however, and should be viewed as part of the broader expansion of stakeholder organisations in the SDI structure. The issue with implementing these organisations into the SDI structure is not technological, as these companies tend to use highly advanced DSS and sensor systems to support their operations. Getting detailed information regarding these types of vessels would have required a significant effort with multiple petroleum companies, and was viewed to be outside the scope of the project as a result of the initial communication coverage analysis showcased other factors that would prevent the implementation of these vessels into the sensor network of an SDI. These organisations are generally advanced users of GIS, however, and further research should implement these actors to a larger degree.

## 2.4 Operating in Arctic environments

The challenges presented by environmental conditions, communication, infrastructure and logistics have a major effect on both commercial operations and public services. Shell's failed 2012 offshore exploratory drilling program off the coast of Alaska (Shell Oil Company, 2013) showcases some of the difficulties in operating in Arctic environments. The expedition was an attempt to perform exploratory drilling in the Beaufort and Chukchi Seas, and aimed to confirm the discovery of commercially-viable quantities of oil in the Alaskan Arctic Ocean. While there were many reasons for the lack of success, one of the key points of failure was outlined to be the lack of ability to collect, manage and share the various types of data necessary to safely manage complex industrial-scale operations across numerous organisations and sub-contractors operating in challenging Arctic environments.

> *"Reliable weather and ice forecasting play a significant role in ensuring safe operations offshore Alaska, including but not limited to the Arctic. Robust forecasting and tracking technology, information sharing among industry and government, and local experience are essential to managing the substantial challenges and risks that Alaskan conditions pose for all offshore operations." (Shell Oil Company, 2013)*

Another lesson learned from Shell's failed 2012 expedition was the need to develop an Arctic-specific operational model for offshore petroleum operations, with a focus on a collaborative consortium-based model to increase access to information, resources and emergency response assets among all participating operators.

> *"Arguably the need for mutual assistance and resource sharing covering both operational and emergency response assets and resources may be even greater in the Arctic." (Shell Oil Company, 2013)*

Investigations into expansion of the current operational model in the Norwegian offshore petroleum sector, Integrated Operations, encountered similar conclusions, particularly emphasising the need for collaboration and data sharing between operators maintaining exploration or extraction operations in the High North (Reegård, 2014).

### 2.4.1 Weather

The Meteorological Institute outlines the main challenges they face in providing meteorological services for the High North area (Tangen, 2014a):

- Fewer occurrences of strong wind in the Arctic Ocean, relative to the North Sea
- Instances of strong storms or hurricanes
- Higher degree of rapid changes and unpredictable weather patterns, particularly polar lows
- High incidents of fog during summer
- Lower significant wave heights in the Barents Sea
- Less quality of observations and accuracy of models due to low access to data.
- Need for complex tools to model ice drift, object drift and other oceanic processes.

Operating in Arctic environments requires additional preparation and services. A major part of this requirement is to ensure access to high accuracy meteorological data and complex tools that models ice and object drift in the ocean (Tangen, 2014b). These are not currently present, with the High North region lacking the necessary coverage to ensure accurate predictions (Figure 2.7).

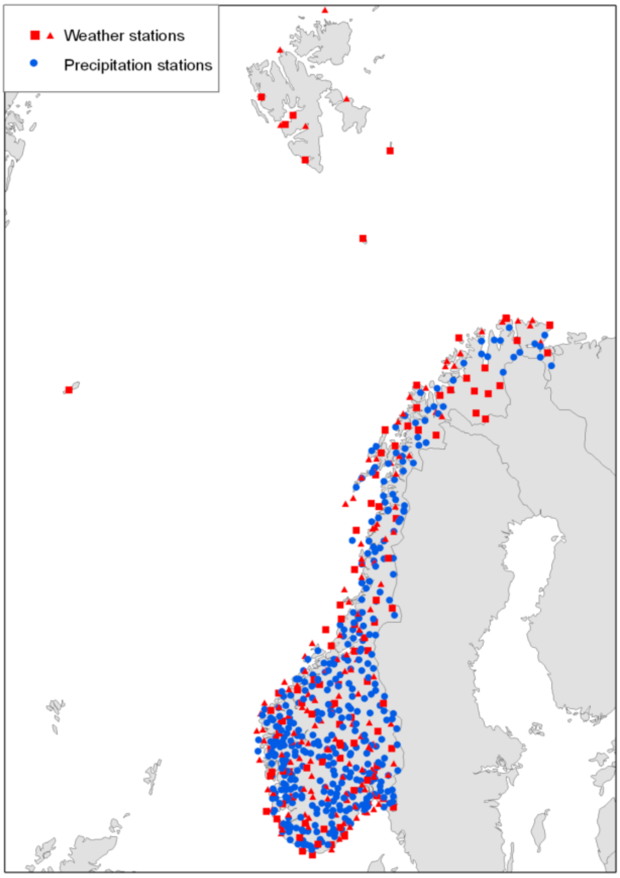


*Figure 2.7: Weather stations in Norway, Met.no (Tangen, 2014b). Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Meteorological Institute.*

### 2.4.2 **Communication – Standards and infrastructure**

The Norwegian High North communication infrastructure consists of a complex patchwork of communication networks and standards, with a large number of systems being in use within the region. The 2015 Marintek report for the SARiNOR project (Marintek and Sintef, 2015) outlines the current status of communication within the High North region, and current deficiencies of the present-day systems and organisation. A similar process was performed in the 2012, with Marintek analysing the 2012 status of communication in the High North (Marintek and Sintef, 2012). Their work resulted in the gap analysis found in Table 2.2.

*Table 2.2: Gap-analysis, the MARSAFE research project (Marintek and Sintef, 2012)*

| **Area** | **Challenges** |
|---|---|
| Navigation | Poor ENC (Electronic Navigational Chart) and information on weather and ice conditions with low quality |
| Positioning and DP operations | The need for ice management imposes the need for more advanced and energy demanding DP operations. Thrusters need more power due to extra ice load. |
| Data analysis | Increased exploration operations will lead to increased demands for data transfer from ships to data analysis on shore. This is not possible in many Arctic areas today due to a lack of proper |

| | |
|---|---|
| | communication infrastructure. |
| Gathering and analysing environmental and metocean data | Oil and gas companies need to gather their own data in order to have sufficient decision support in their planning phase since the data quality on metocean data is very low in most part of the Arctic. |
| Supporting vessel navigation | Poor ENC, poor access to navigational information such as metocean. |

#### *2.4.2.1 International systems and standards*

The Global Maritime Distress Safety System (GMDSS) provides a set of internationally agreed-upon set of procedures for safety, equipment and communication protocols. This helps ensure global conformity in procedures, standards and equipment within maritime rescue and emergency coordination (Vance, 2011). The GMDSS sea area describes the availability of services and the type of necessary equipment to ensure safe operation within the area. The GMDSS sea areas are divided into the following sub-categories:

A1: Areas inside the coverage of land-based VHF-stations (20 – 30 nm).
A2: Areas inside the coverage of MF-stations (100 – 150 nm).
A3: Areas inside the coverage of Inmarsat (70 degrees N and 70 degrees S).
A4: Areas not within A1 – A3, including the High North

The global standards established by the GMDSS ensures that a technological minimum can be assumed be present in all ships operating within Norwegian maritime areas, and ensures that commercial vessels will be able to utilise the communication systems available in the Norwegian parts of the High North (Brindusa-Cristina, 2015).

### 2.4.3 High North radio infrastructure

The coastal network of VHF stations is maintained by Telenor Maritime Radio, as part of their infrastructure mandate. Telenor Maritime Radio maintains five permanently manned stations, located in Vardø, Bodø, Florø, Rogaland and Tjøme. These stations are part extensive network of stations and installations that ensures VHF, MF and Navtex coverage within Norwegian administrative areas. The coverage extends over most of the Norwegian mainland, The Svalbard Isles, and large parts of the Norwegian High North region, as shown in Figure 2.8. Usage statistics for the various communication methods is shown in Figure 2.9.

#### *2.4.3.1 Marine VHF*

The marine VHF band ranges from 156.0 to 162.025 MHz, and is the designated radio band for equipment installed on seagoing vessels. VHF allows for two-way communication, and is used for a wide variety of purposes within maritime communication.

While the theoretical maximum range of VHF transmissions can be roughly 60 nautical miles, the Norwegian coastal radio provides VHF coverage to a maximum of 30 nautical miles from shore. Within this range, VHF radio is the primary means of communication between vessels, and also the primary means of contacting emergency services.

The limited range of VHF radio means that it is not reliable for most of the High North, with the coastline being the main exception. Other forms of communication must be used to cover the longer distances in the High North. It remains the most common communication method, however, and accounts for roughly 55% of the calls at Bodø/Vardø Maritime Radio. (Marintek and Sintef, 2015)

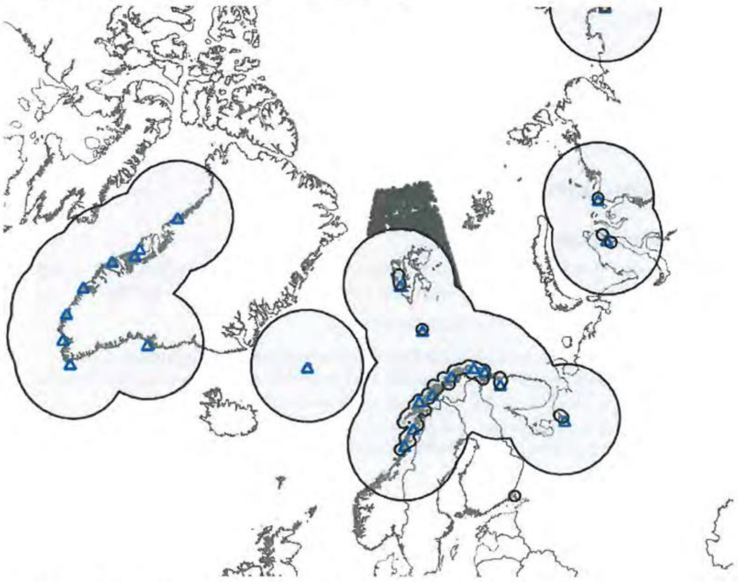

*Figure 2.8: Coverage for land-based VHF- and MF-stations (Marintek and Sintef, 2015).*

***2.4.3.2 Medium frequency communication***

Medium frequency radio ranges from 300 kHz to 3 MHz, and the maritime communication occupies varying frequencies across the entire spectrum. Medium frequency communication extends the capability from the 30 nautical miles, provided by land-based VHF-stations, to 150 nautical miles. This allows for most of the southern and western Barents Sea to be covered by land-based communication.

While MF-radios are not used nearly as much as VHF-radios, they do help extend the capabilities of the land-based communication infrastructure to areas that would be impossible to cover with VHF. Additionally, the MF-stations helps to provide redundancy to other communication methods (Marintek and Sintef, 2015).

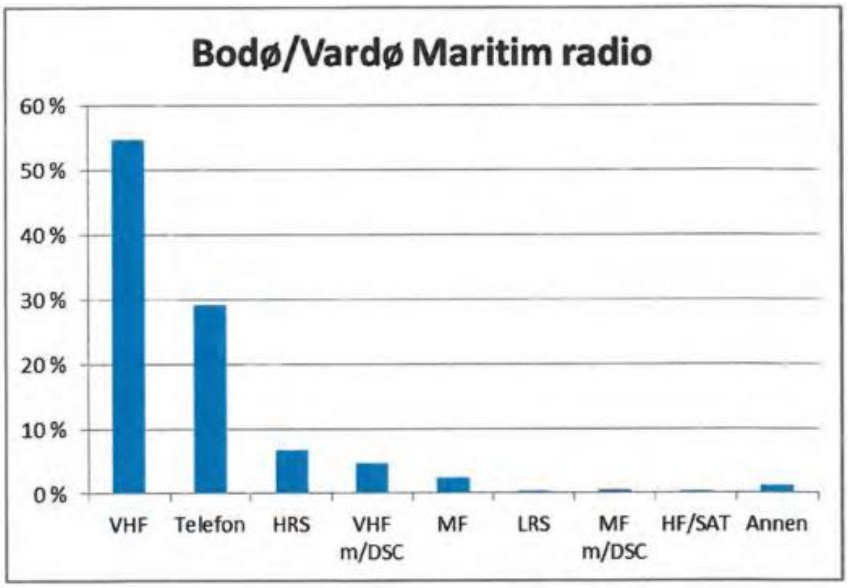


*Figure 2.9: Contact method statics, Bodø/Vardø Maritime radio (Telenor Maritime Radio).*

***2.4.3.3 Iridium***

The Iridium system is a satellite system consisting of 66 active satellites distributed in low orbit to ensure global coverage. It is one of the few satellite systems that provide good coverage in the entirety of the High North. This makes it one of the fundamental systems in maintaining communication capabilities in Arctic areas.

While Iridium is one of the few communication systems that provide true coverage extending to the High North, it is limited by slow transfer speeds and low overall capacity. In large-scale incidents, Iridium by itself cannot be expected to fulfil the demands for data transfer capacity. Users of the system have also reported reliability issues during rough weather (Marintek and Sintef, 2015).

#### *2.4.3.4 Telephone*

In near coastal areas, use of mobile telephones has started to replace VHF. Modern smartphones provides an easy and generally reliable way to communicate, both in normal operations and emergencies. While this is obviously not optimal in terms of range and reliability, it remains in use, and must be facilitated for in standards and operations (Marintek and Sintef, 2015).

The increasing prevalence of smartphones and mobile devices also offer possibilities to increase the general access to spatial data to stakeholders that have traditionally lacked access to these types of data. Maps, meteorological and oceanic data (metocean), search plans, and text-based information are all examples of spatial data that can be distributed through mobile devices to enhance the overall level of awareness in emergency situations.

#### *2.4.3.5 AIS*

The Automatic Identification System (AIS) was originally developed for collision avoidance, but has over time become one of the cornerstones of maritime operational awareness. The data broadcast by the AIS can be divided into three different types (Last et al., 2014): Static data (e.g., vessel name, dimensions, etc.), dynamic data (e.g., vessel position, course over ground, and heading), voyage-related data (e.g., current draught, cargo contents, and destination).

The AIS infrastructure consists of land-based receiver stations, satellites and inter-vessel communication, and allows for accurate tracking and monitoring of vessel movements. This ensures that vessels are able to broadcast voyage information, regardless of position in the world. (Papi et al., 2015)

In 2003, to conform to EU Directive 2002/59/EC (The European Parliament and of the council of Europe, 2002), the Norwegian Maritime Directorate forced the adaption of new rules regarding AIS. This directive ensures that all vessels above 300GT in the following classifications must be equipped with AIS transponders. The coverage of the AIS infrastructure is limited, however, and decreases in efficiency further than 20 nautical miles from the coastal infrastructure. This limits the functionality available in the High North area, as some of the more advanced capabilities require access to the land-based AIS infrastructure. While a ship will always be able to transmit Mayday regardless of location, more advanced features, such as heading, draught and destination may not be available.

## 2.5 SPATIAL DATA INFRASTRUCTURE

A Spatial Data Infrastructure (SDI) is an initiative to manage and provide spatial information through a platform that integrates and distributes spatial data (Chaowei Yang, 2010). The main purpose of an SDI is to facilitate for the use and transfer of spatial data among multiple organisations, and create the framework necessary to integrate spatial data into the capabilities of the participating organisations (Steiniger and Hunter, 2012).

The term *Spatial Data Infrastructure* covers all the components necessary to enable the distribution and usage of heterogeneous spatial data. This includes the technical components needed to facilitate the collection, categorisation and distribution of spatial data. Examples of technical components are software clients, spatial data management services and cataloguing services. Additionally, it also includes the accompanying set of standards, policies, institutional agreements and legal framework necessary to utilise the technical components. Together, these components create the framework that allows for the distribution and use of spatial data for the intended purpose (Chaowei Yang, 2010).

The Circumarctic Portal Framework (Sorensen, 2004) defines the characteristics of an SDI in the 2004 report outlining the construction of an Arctic SDI, specialised for Arctic research:

*'The concept of a Spatial Data Infrastructure (SDI) has been implemented in many parts of the world, and provides a framework of standards, policies, data, procedures, and technology to support the effective coordination and dissemination of spatial information across many sectors and levels of government and society.'* (Sorensen, 2004, p.5).

One of the largest challenges in implementation of SDI-systems lies in establishing the common framework of standards, policies, data uniformity and procedures necessary to ensure the information quality of the spatial data within the broader system (Dahlan et al.) (Bocher and Neteler, 2012). While the exact structure of an SDI will depend on intended use, each SDI-implementation can be expected to contain a basic set of systems, services and policies. SDI-systems can grow complex, depending on scale, usage and complexity, and require a strong focus on policies and standards.

### 2.5.1 Structure of an SDI-system

There are multiple approaches that can be taken when it comes to modelling the structure of an SDI, with the two main approaches being to look at the technical components and services, or to look at the frameworks used to enable the various organisations to contribute and acquire spatial data.

Steiniger and Hunter outlines the technical services and components that an SDI can be expected to contain in their introduction to SDI concepts (Steiniger and Hunter, 2012):

- *Software client - to display, query, and analyse spatial data (this could be a browser or a desktop GIS)*
- *Catalogue service - for the discovery, browsing, and querying of metadata or spatial services, spatial datasets and other resources*
- *Spatial data service - allowing the delivery of the data via the Internet*
- *Processing services - such as datum and projection transformations*
- *(Spatial) data repository - to store data, e.g., a spatial database*
- *GIS software (client or desktop) - to create and update spatial data.*

An alternative approach, which focuses on the relationships between the organisational components, standards and services in Figure 2.10 is suggested by Mansourian et al. (2006). This approach emphasises the importance of the organisational framework surrounding an SDI, and how the technological components must be adaptable to fit the needs of the user community.

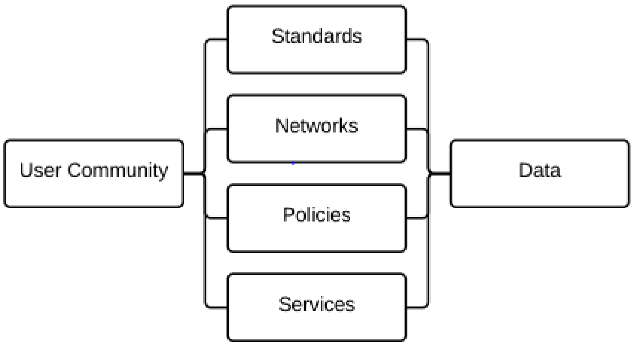


*Figure 2.10: The various components of a Spatial Data Infrastructure*

### 2.5.2 SDI-hierarchy

SDIs operate at different levels of detail and scale, and a hierarchical structure is often used to separate the various levels of SDIs found within governments and organisations (Williamson et al., 2003). The various SDIs operate at scales ranging from global and all the way down to local level, including corporate SDIs. Each level of the SDI hierarchy consists of one or multiple SDIs from the lower level, and aims to create a structure where SDIs can be integrated in the larger hierarchy (Figure 2.11).

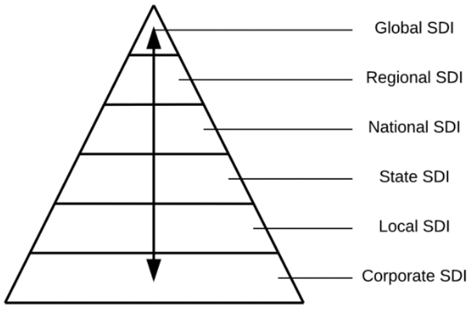


*Figure 2.11: SDI hierarchy*

The Global SDI is represented by the Global Spatial Data Infrastructure Association, which aims to further development of society through the implementation and use of spatial data infrastructure (GSDI, 2015). The regional level contains 22 Regional SDIs at a multinational or continental scale, with the chief example being European SDI-project, The Infrastructure for Spatial Information in Europe (INSPIRE, 2015). Each regional SDI consists of multiple national SDIs, which again contain the various lower scale SDIs.

#### *2.5.2.1 The INSPIRE directive*

The last decade has seen a number of nations, states and region develop SDIs. As part of this process, a complex framework of standards, policies and procedures has been developed to ensure compatibility and conformity of the spatial data across participating organisations. The biggest driver in Europe for this process has been the INSPIRE project, which originates from the European Union's effort to standardise and conform their spatial data services. The directive entered in force in May 2007, with the stated goal of *'establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment.' (The European Parliament and of the council of Europe, 2007, pp.1-2)*

The directive has been not only been key in establishing a shared SDI in European countries – It has also helped to force the standardisation of specific areas (among others: '*Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting')* (Craglia et al., 2012) While the statutes in the directive are still in the process of being implemented INSPIRE has been instrumental in establishing agreements that help the standardisation of the framework found in SDIs, and while not directly related to spatial data management within the emergency management domain, has still been relevant in forcing the adaption of a common set of standards that ensures mutual compatibility of systems and frameworks.

#### *2.5.2.2 Norwegian spatial data infrastructure*

The Norwegian national spatial data infrastructure (NSDI) predates the INSPIRE directive, with Norway Digital being established in 2005. The Norwegian Mapping Authority acts as the main coordinating authority, and is responsible for overseeing implementation efforts for the Norwegian NSDI. The Norwegian SDI framework consists of three major components, SOSI, Norway Digital and Geonorge.

SOSI (Systematic Organisation of Spatial Information) is a Norwegian vector format and spatial data standard. It is an open standard developed and updated by The Norwegian Mapping Authority, in co-operation with public and private GIS organisations in Norway (Moellering and Hogan, 1997). The SOSI file format is the cornerstone of the Norwegian GIS community, and has seen continuous development since it was first released in 1987. The framework is well-developed and supports a wide variety uses, and can be expected to be developed in the future to stay updated. It is ISO/TC211-compliant, and provides the standard framework for the Norwegian spatial data infrastructure. The existence of the SOSI standard means that all aspects of the Norwegian SDI and spatial data organisation is supported by a well-developed set of data standards that have been tailored to ensure that all actors and stakeholders have access to and is forced to provide spatial data compliant with Norwegian and international standards.

Another cornerstone is Norway Digital, was established as part of this initiative, and serves as a link between Norwegian organisations utilising spatial data in Norway (The Norwegian Mapping Authority, 2013). This initiative consists of more than 600 public organisations at all levels and provides the framework necessary to organise the flow of spatial data between participating organisations.

The Norwegian spatial data act was sanctioned in 2010 '*to promote good and effective access to authoritative geographic information for public and private purposes and to strengthen cooperation on the sharing of spatial data between agencies with public duties.*' (The Norwegian Mapping Authority, 2013) This created the legal framework to unify the existing Norwegian NSDI development with the overall goals of the INSPIRE directive. The implementation of the directive has thus been merged into the NSDI development efforts, and is part of the overall national geospatial development strategy (The Norwegian Mapping Authority, 2013). This has led to the creation of Geonorge, the main NSDI (The Norwegian Mapping Authority, 2015). Geonorge acts as the main metadata catalogue and discovery service for Norwegian spatial data, and is part of the expansive European SDI-network outlined in INSPIRE. The overall goal is that all spatial datasets, with the exception of sensitive information relating to national security and the armed forces, should be catalogued and available through this portal, as well as through the SDI of the parent organisation. These initiatives have led to the creation of a robust spatial data infrastructure, which covers most of the needs of governmental, public and private organisations (Figure 2.12 & Figure 2.13). SDI development efforts have generally had a high priority in Norway, and spatial data is well integrated into most aspects of public policy.

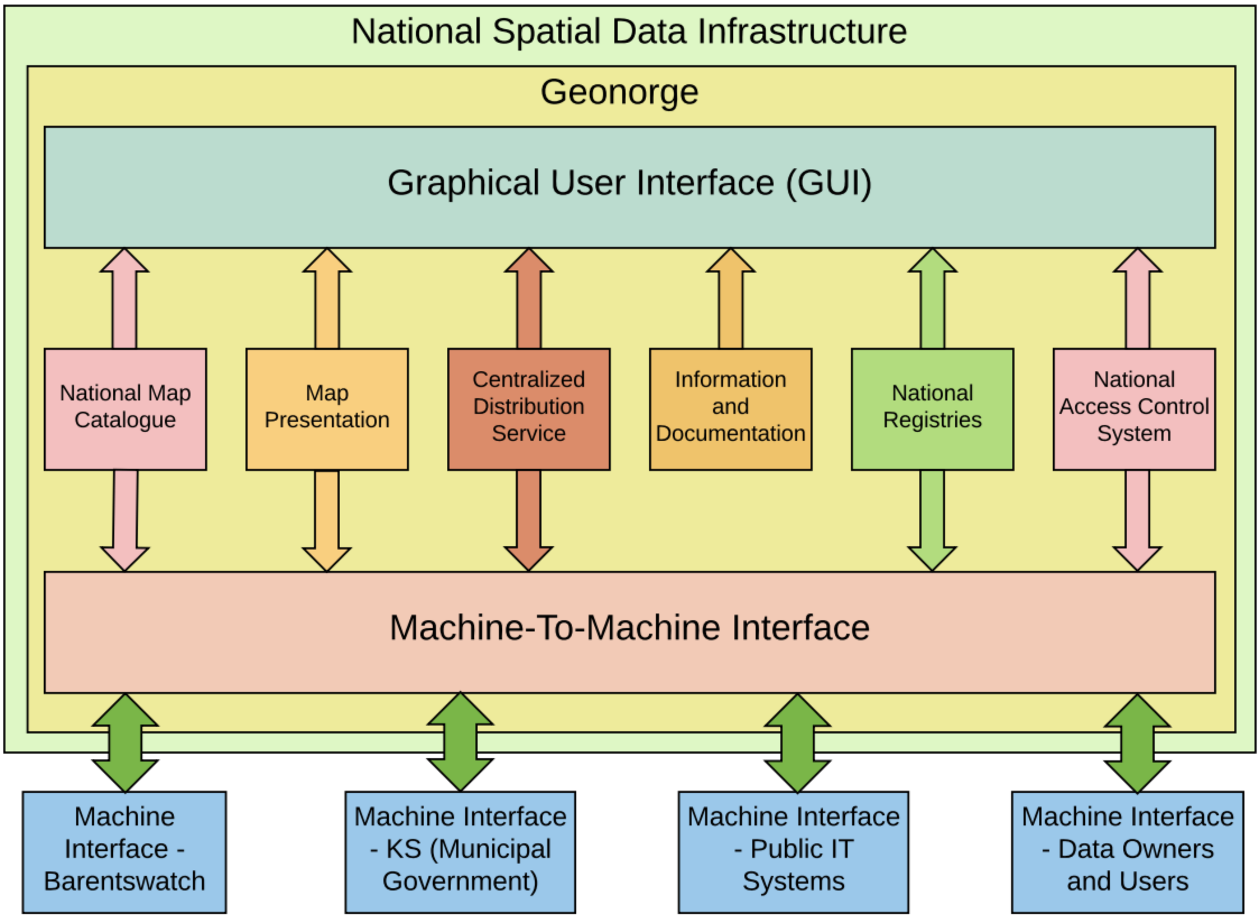


*Figure 2.12: Norwegian SDI hierarchy. Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Mapping Authority.*

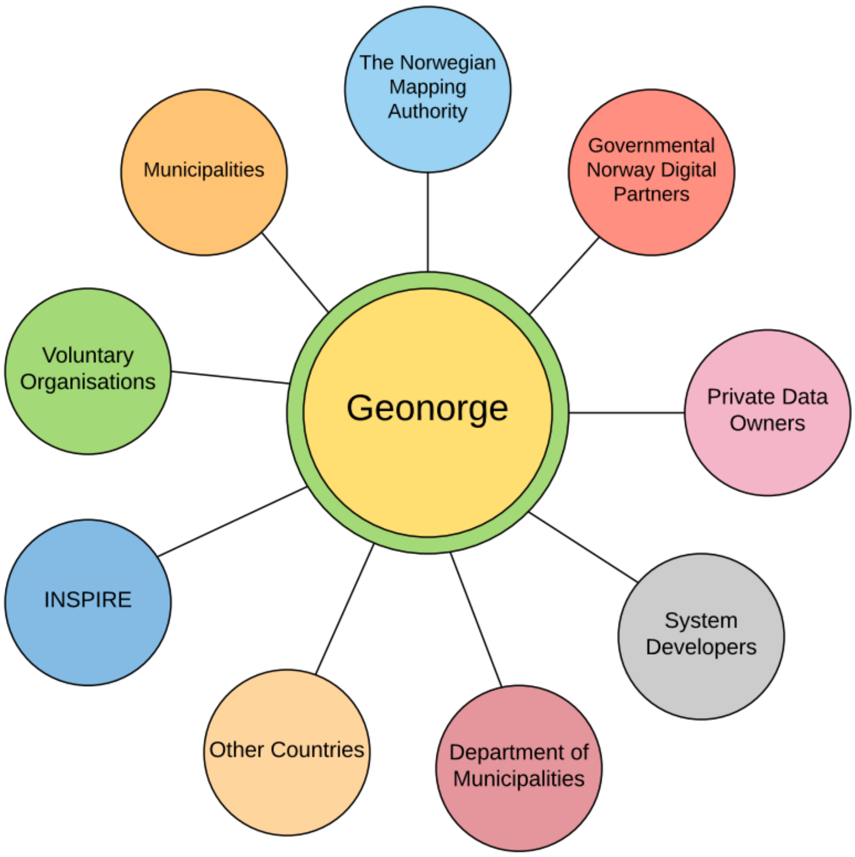


*Figure 2.13: Organisational framework for the Geonorge SDI. Contains data under the Norwegian licence for Open Government Data (NLOD) distributed by The Norwegian Mapping Authority.*

### 2.5.3 Role of GIS and SDIs within emergency management

Managing the information flow required to maintain operational awareness in emergency response is complex process. A wide variety of data must be acquired and distributed to different organisations, and to further complicate matters, the roles and demands of each organisation may develop during the response process. In many cases the data itself will exist, but the mechanics for sharing data between participating organisations is not in place. This is particularly common when it comes to proprietary data, as organisations may be reluctant to share datasets relating to national security and economically sensitive data in an insecure environment.

Ensuring that all participants in the preparedness and response phases of emergencies have access to the necessary data requires a robust middleware system that enables sharing of multiple data types in a robust and secure manner is key in ensuring that all organisations that participate in the emergency management sphere can perform their tasks. In larger incidents, organisational capacity is already strained and data management is relatively low on the list of priorities.

Research within information management in emergency management and disaster response situations emphasise the difficulties relating to complex organisational structures and limited infrastructure, as well as the difficulties in getting access to timely information in response situations (Petrenj et al., 2012). These issues are amplified by the geographical dispersion and ad-hoc nature of participants in response efforts. Another recurring issue is the unpredictable and dynamic operating environment response organisations face in emergency and disaster response situations (Gonzalez and Bharosa, 2009).

#### 2.5.3.1 The Norwegian situation

The distributed approach towards emergency management used in Norway has led to the creation and use of multiple emergency management systems. Data management between these systems are generally handled in a relatively inflexible manner, and transferring data between systems either requires an existing infrastructure or manual data transfers from operators of the participating emergency management systems.

A major revamp of the Norwegian emergency management system is ongoing, with the SARiNOR project (Maritimt Forum Nord SA, 2014) and Barentswatch (Barentswatch, 2015). The SARiNOR project aims to improve the entire SAR-process, while Barentswatch has a mandate to improve the inter-organisational data sharing mechanisms for organisations operating in the High North. The gap-analysis of the SARiNOR project acknowledges the following key factors as the main challenges towards efficient sharing of data between organisations in the emergency management process (Maritimt Forum Nord SA, 2014):

- *Lack of infrastructure*
- *Insecure environment*
- *Lack of interoperability and data conformity*
- *Lack of data reliability*
- *Lack of data history*

#### 2.5.3.2 Relevance of EM and SDI research from other geographical regions

The gradual evolution of SDIs and collaborative decision-making tools has changed the role of GIS in the emergency management domain from being an analytical tool, to an integrated part of the decision support systems (DSS) in use by stakeholders. This has necessitated the development of SDIs to facilitate usage of spatial data between organisations (Mansourian et al., 2006) and other tools that incorporate the various types of spatial data into the emergency management process. These systems ranges from specialised systems aimed at providing emergency warning and location-based information (Choy et al., 2016), to more comprehensive SDIs. A prime example of a more complex SDI can be seen in the SIAPAD project (Molina and Bayarri, 2011). This is a comprehensive SDI meant to aid governments in the Andean countries to minimise the impact of disasters, and to enhance to collaboration across borders.

Publicised research offers the largest insight into the current state-of-the-art within GIS and emergency management, and multiple research groups publicise research within the field. The work by Genc et al. (2013) examines automation of emergency management processes through an SDI, while Farnaghi and Mansourian (2013) examines automation of web services for presentation of thematic spatial data relating to emergency response situations. Choy et al. (2016) has examined the use of satellite navigation systems for distribution of information through satellite navigation systems, though this has been centred on the Pacific Ocean, with a focus on Japanese and Australian areas. Alamdar et al. (2016) provides an excellent introduction into the current state of sensor information integration, and provides a possible approach towards a multi-agency sensor integration through an SDI.

A common feature of all these projects is that they focus on specific geographic regions or urban areas, and generally operates under the assumption that the access to communication infrastructure and updated spatial information is available. While the research within the field is relevant as far as the concepts are concerned, the issues relating to the operating environment and infrastructure in the High North makes it difficult to implement these concepts into an actual SDI specialised for the High North region.

# 3 METHODS

The nature of the emergency management domain, with a complex organisational structure and high technological implementation, required committing to a design approach that included both quantitative and qualitative aspects. A combination of quantitative data analysis, qualitative interviews and background research have been conducted to find the key factors influencing the ability to share spatial data between organisations participating in the EM process in the High North.

The research was divided into three main subject areas – Information gathering, analysis and SDI design. The workflow was then divided into smaller blocks, with each block focusing on an individual aspect of background research or data analysis necessary to successfully create the conceptual structure for an SDI. Figure 3.1 shows the flow of the project, outlining how the research progressed from the initial literature and interview phases and how the individual processes influenced the overall project.

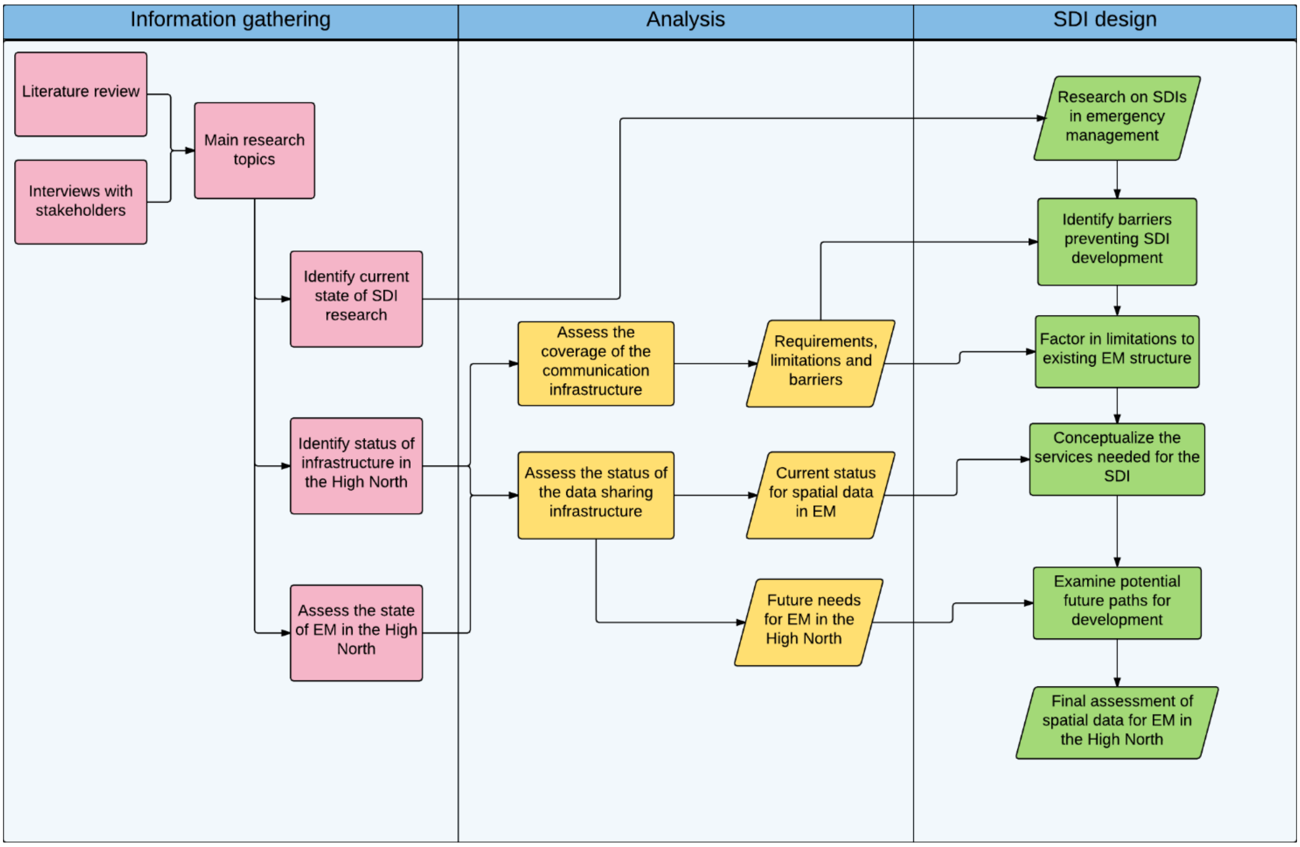


*Figure 3.1: Workflow of activities performed during research*

The investigation phase resulted in an understanding of how the emergency management and SAR operations are structured in the High North, and what the present limitations are to emrgency management operations within the study area. A particular emphasis has been placed on factors affecting the access to operational intelligence, and how stakeholder organisations are able to share data during emergencies. A spatial analysis of the communication coverage was conducted as the first step of a process to assess the possibility of improving the access to sensor data (meteorological and oceanic data) and to see if it was possible to extend the range of the radio infrastructure coverage through static offshore installations.

The results from the investigative phase were utilised to assess the specific needs for an emergency management SDI, and possible initiatives that can improve the ability to share spatial data between organisations in the EM process.

## 3.1 Assessing the current ability to share spatial data in emergency management organisations in the High North

To assess the needs and functionality of a potential SDI system for EM in the High North, a combined approach was used. A major part of this work was to assess the organisational structure in the EM-process, and how the different stakeholders utilised spatial data in their respective organisations. The needs of the participating actors were assessed through correspondence and interviews, and a series of use cases (see Appendix A) to assess the roles of specific assets during emergency situations, to get a better understanding of the spatial data needs for stakeholders involved in the process.

### 3.1.1 Actor-Network analysis methodology

To further expand on the actors involved in the emergency management process, the responsibilities and needs with regards to spatial data was analysed through an actor-network perspective.

Actor-network theory (ANT) is an approach that models all objects within the field as actors (actants), both human and non-human entities. The theory is well-suited for representing complex relationships between multiple organisations, and to model the impact of the various influencing factors. By including non-human objects into the actor network, it is possible to assess the influence that factors such as infrastructure and processes play in a complex network of actors. The method originates in sociology and anthropology, but has seen increasing usage within information sciences and geographical fields (Law, 2009, Alexander and Silvis, 2014).

Information used for the ANT-analysis was acquired through interviews, correspondence and existing research. The organisations and processes were grouped by role, to generalise some of the interactions that are presents. Grouping the actants based on role in the emergency management process is necessary to limit the complexity of the ANT, as the sheer number of actors, objects and processes involved is resource-intensive to model.

### 3.1.2 Contact with participating organisations

The lack of available research and data on use of GIS in the emergency management domain made it necessary to acquire information in other ways. One of the key methods in accomplishing this was direct communication with participants, users and developers in the Norwegian emergency management domain. Multiple participants of the EM domain in the High North were interviewed to assess their views on the current state of the spatial data infrastructure in the High North, and their views on possible improvements to the process. The participating organisations were selected to reflect the different stakeholder groups that can be expected to interact in the emergency management process, with different responsibilities, organisation and technological capabilities. Table 3.1 outlines the general interview questions while Table 3.2 outlines the four organisations that were interviewed and what role they play in the EM process.

For the interviews, a semi-structured interview approach was used. This is a qualitative method of inquiry that follows a loose overall plan. It follows a pre-determined set of questions used to shape the flow of the interview, while still giving a large degree of flexibility on the part of the interviewer (Bernard, 1988). Oates (2015) discusses the use of Skype as a medium for undertaking semi-structured interviews. This discussion helped to guide the interview process, as many of the concern raised in the discussion directly applied to the project. This is supported by Quan et al. (2001) who suggests the use of semi-structured interviews with key informants to allow for the utilisation of their expertise to a larger extent than a more structured interview or questionnaire approach would allow.

*Table 3.1: General interview questions*

| ID | Questions |
|---|---|
| 1 | Role of the organisation being interviewed |
| 2 | DSS or other software systems in use within the organisation |
| 3 | Role of GIS within these systems |
| 4 | Ability to acquire spatial data from other participants in the EM process |
| 5 | Ability to share spatial data to other participants in the EM process |
| 6 | Does the mechanisms exist for sharing and acquiring updated spatial data during a response process exist? |
| 7 | Would a proper framework and SDI enhance the ability to share spatial data with other participants in the EM process? |
| 8 | What features would be necessary in a specialised SDI? |

*Table 3.2: Interviewed organisations*

| Organisation | Role |
|---|---|
| The Joint Rescue Coordination Control (North) | Leadership and coordination responsibility in emergency response situations |
| Barentswatch | Responsible for the development of tools that allows for increased collaboration and data sharing across organisations in the High North |
| Aptomar | Developer and operator of specialised decision support systems |
| Statoil | The largest petroleum company operating on the Norwegian Continental Shelf |

#### *3.1.2.1 Other contact*

Multiple organisations were contacted for specific data or information through mail and shorter phone calls. These were not as structured as interviews or questionnaires, but were rather concentrated on specific topics or data requests. All organisations proved willing to participate to some extent, though some were unable accommodate the requests for data for a variety of reasons. Many of the core participants of the EM process are organisations involved in defence and national security, such as the coast guard, navy and air force. Getting information from these organisations proved difficult, as concerns of operational security prevented the sharing of spatial datasets and operational details.

## 3.2 Assessing the communication infrastructure in the High North

One of the key factors to assess during the investigative part of the research was to analyse the extent and capacity of the communication infrastructure in the High North. This was done as part of the overall process of building knowledge about the operational conditions of the area, in addition to being the key factor in evaluating possible initiatives to expand the access to high quality sensor data from the High North.

The fundamentals of the Norwegian radio infrastructure and satellite communication infrastructure has already been explored in the literature review, which provides a basic overview of the different communication systems in use in the High North. To evaluate the current communication infrastructure, a GIS analysis of the coverage provided by the various communication systems in use within the High North was conducted. The main focus of this analysis was on the coverage provided by the two main communications systems, coastal radio and satellite communication systems. These categories consists of multiple technologies, which each have their respective ranges, data transfer capacity and stability within the High North.

The majority of the spatial data on communication coverage was created based on data provided by the SARiNOR project (Marintek and Sintef, 2015) and the MARSAFE project (Marintek and Sintef, 2012). These projects went into sufficient detail to construct spatial data sets that the range and coverage of the various communication systems. Some of the spatial data used for the analysis were acquired through the national SDI of Geonorge (The Norwegian Mapping Authority, 2013) and from individual departmental SDIs. The sources and format of the various spatial datasets is shown in Table 3.3.

The spatial data was created in (transformed to in the case of already existing datasets) raster format to enable additional calculations, opening for the use of the spatial analysis toolset of the ArcMap software suite.  The spatial resolution of the data was 1,000 square metres per cell, using the UTM zone 33N CRS. This is the projection in use for Norwegian geographical datasets covering the High North and conforming to standardisation efforts with other Norwegian institutions was viewed important.

*Table 3.3: Spatial datasets used for analysis*

| Spatial data | Source | Data format | Resolution/Scale | Timestamp |
|---|---|---|---|---|
| Communication coverage data | Created during project, based on SARiNOR and MARSAFE data | Raster | 1,000m2 | 14.10.2015 |
| Maritime administrative data | The Norwegian Mapping Authority | Vector | 1:50,000 | 08.10.2015 |
| The High North | The Norwegian Environment Agency | Vector | 1:50,000 | 8.10.2015 |
| Traffic data from the Norwegian fishing fleet (WMS) | The Norwegian Directorate of Fisheries | WMS/Raster | 1,000m2 | 09.04.2014 |

### 3.2.1 Analysis methodology

The coverage analysis was conducted through the use of ArcGIS software. The spatial data that was developed to cover the communication infrastructure was divided into categories based on proximity to shore, latitude and presence within the High North area. This resulted in raster data showing the satellite, VHF-radio and MF-radio coverage in the study area, and enabled comparisons to be made between the coverage provided by the various systems.

Figure 3.2 shows the overall approach to the GIS analysis, while the specific approaches to create the radio infrastructure and satellite coverage data can be found in chapter 3.2.1.1 & 3.2.1.2. The process that merges these datasets and enables the final geographical and statistical analysis of the communication infrastructure distribution is explored in chapter 3.2.1.3.

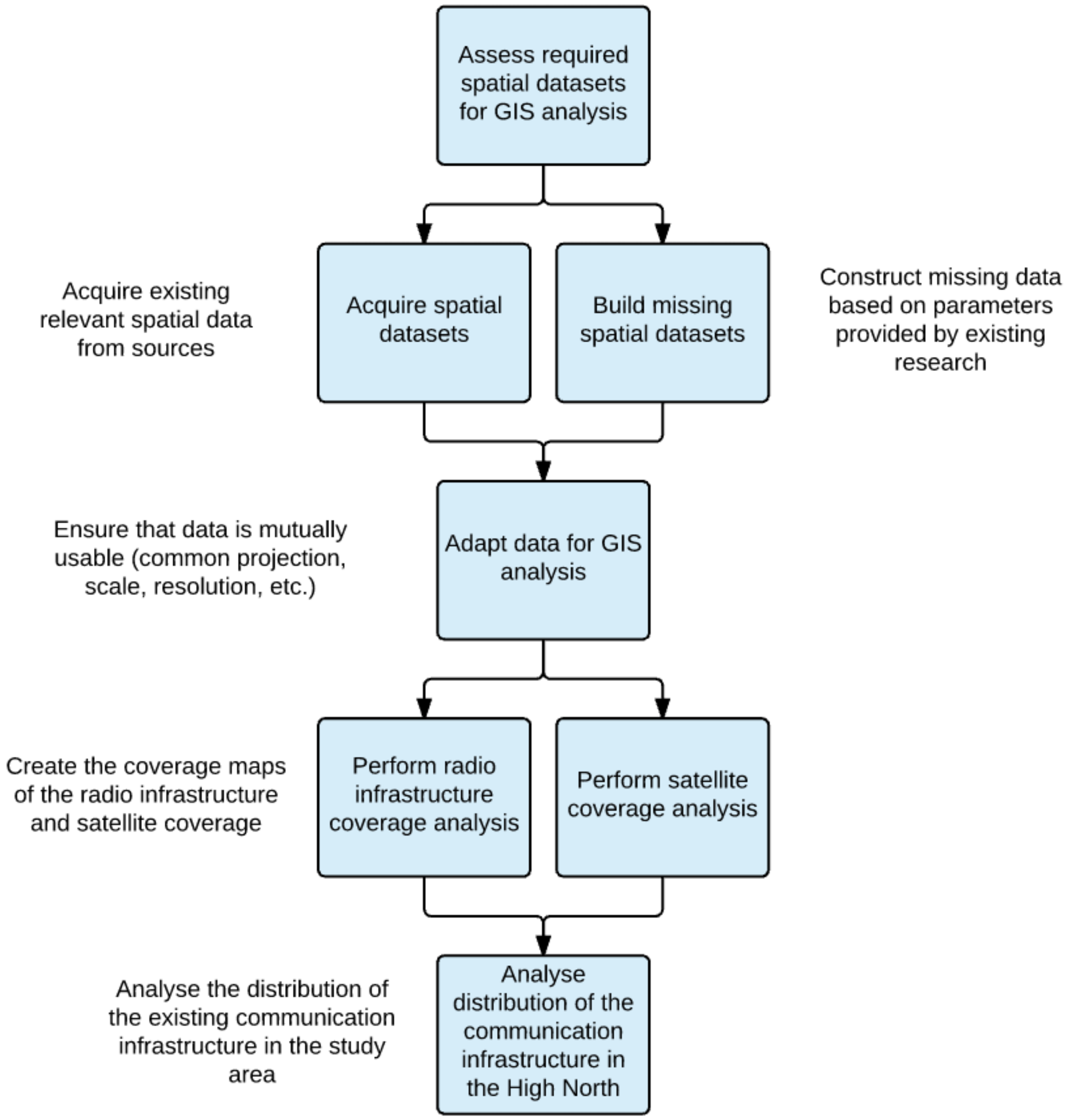


*Figure 3.2: Overall approach used in the GIS analysis*

#### *3.2.1.1 Coastal radio infrastructure*

The initial step in this process was to assess the range and coverage of the coastal radio infrastructure. The coastal radio remains the first line of contact for most vessels in need of assistance, and is the cornerstone of maritime communication in the High North. The radio infrastructure in Norway is well developed, and covers most of the mainland and the Svalbard Isles. Figure 3.3 shows the workflow for the coastal radio infrastructure analysis.

For the purpose of analysing the radio infrastructure, the coastal radio infrastructure was abstracted to extend to 30, 100 and 150 nautical miles from coastal areas, corresponding to the maximum operational range of VHF, realistic operating range for MF radio and maximum operational range for MF radio (Table 3.4).

Three instances of this buffer analysis were performed, with a radius of 30, 100 and 150 nautical miles extending from Norwegian land territory. The cells in the resulting rasters from this step of the analysis process has two values, 1 and 0, corresponding to areas inside and outside the area of interest. To prepare for later stages of the GIS analysis, the results from each buffer analysis were reclassified to ensure that the area of interest for each of the three rasters had a value of 0, while areas outside the radio coverage buffer was changed to a NoData value to prepare for later stages of the coverage analysis.

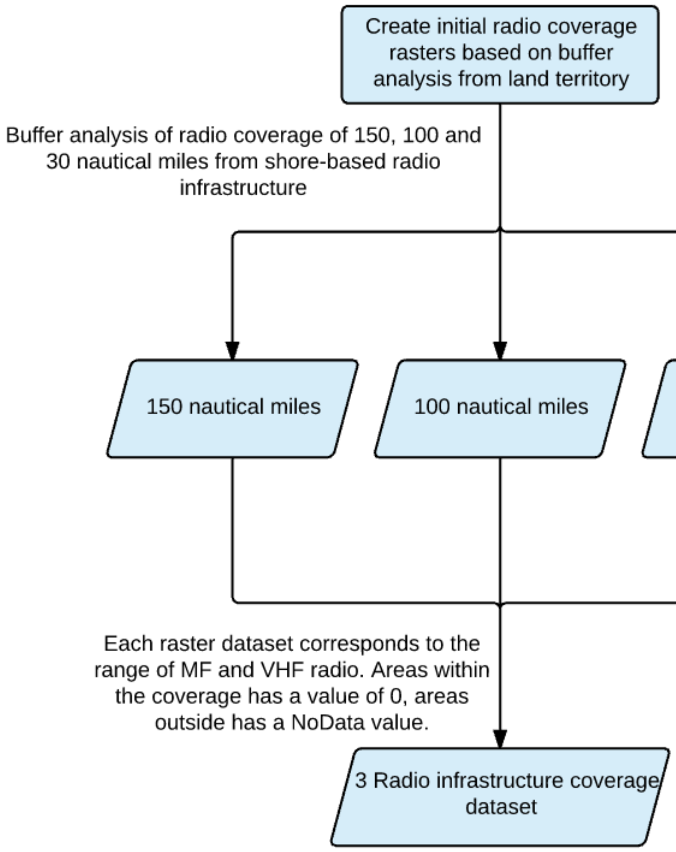


*Figure 3.3: Process to create the radio infrastructure coverage data*

*Table 3.4: Radio communication methods and range*

| Radio communication methods | Maximum radio communication range (As specified in the SARiNOR work package 2) |
|---|---|
| Medium frequency (MF) – optimal conditions | 150 nautical miles |
| Medium frequency (MF) – suboptimal conditions | 100 nautical miles |
| Very high frequency (VHF) – optimal conditions | 30 nautical miles |

#### *3.2.1.2 Satellites*

The coastal radio infrastructure is augmented by a variety of satellite communication systems. Most of these systems operate from GEO-stationary orbits, which present serious challenges to operations in northern areas. As with the coastal radio, the current satellite coverage was analysed in work package 2 of the SARiNOR project (Marintek and Sintef, 2015). The assumptions from this research were used to create spatial data sets that show the current satellite coverage in the High North, in a process illustrated in Figure 3.4.

The theoretical maximum latitude for GEO-stationary communication satellites is 75° north. This assumes perfect conditions. A more conservative 70° north has been suggested as a more practical upper limit on higher capacity GEO-based satellite systems by stakeholders operating in the area. In the areas above the 75° north, the main satellite system in use is low-capacity Iridium system. Based on these factors, the High North area has been divided into the three main zones shown in Table 3.5, showing the spatial impact of these zones in the High North.

A feature layer was created and divided into the three satellite zones based on the latitude zones, as seen in Figure 3.4. This layer consists of three polygons, each representing the satellite coverage zones based on latitude. The extent of each polygon was limited to the High North as defined by The Norwegian Environment Agency and created with tools to automatically create polygons based on the specified latitude lines.

The three polygons were later transformed into binary rasters, with one raster for each satellite coverage zone. The binary rasters for the satellite coverage zones were reclassified to have values from 1 – 3, and a new raster dataset was created by merging these three layers based on the ranking in Table 3.6. The resulting raster showcased the satellite coverage zones, with values ranging from 1 – 3, and could be used for further analysis when combined with the data radio coverage rasters.

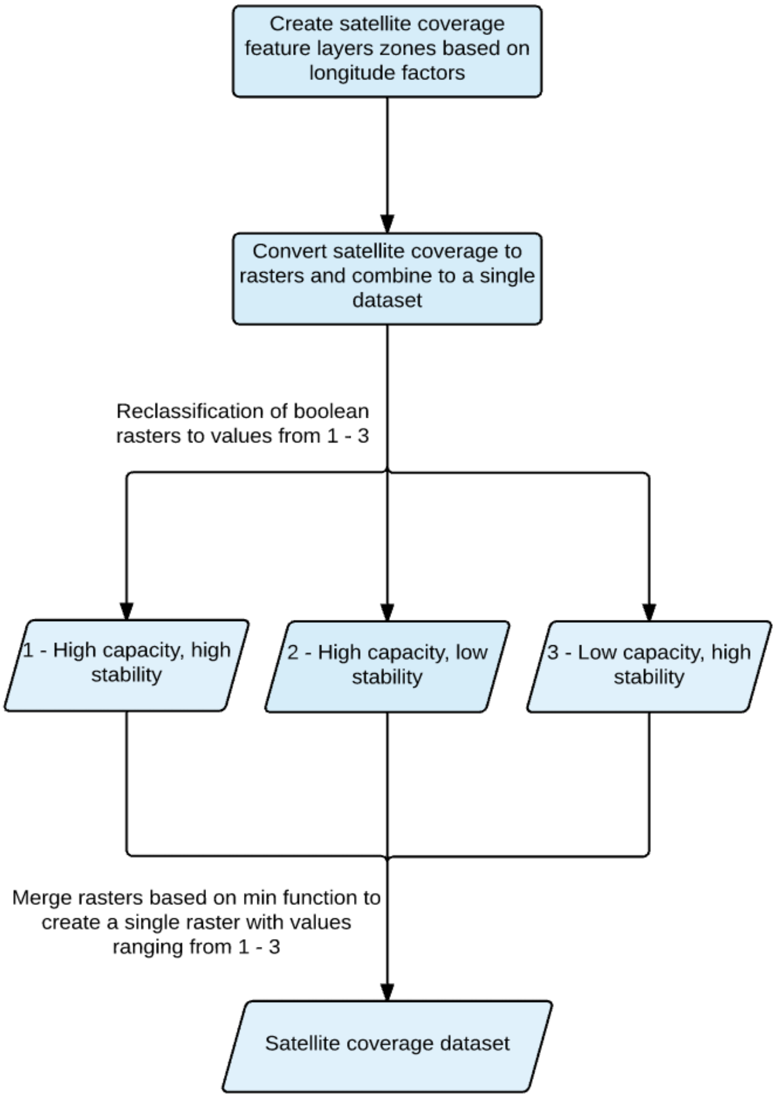


*Figure 3.4: Flowchart showing the process to create the satellite coverage data*

*Table 3.5: Satellite communication coverage zones*

| Satellite coverage zones (latitude) | Characteristics |
|---|---|
| <70° north | Access to GEO systems with a high data transfer capacity |
| 70 – 75° north | Access to GEO systems with high data transfer capacity, significant issues relating to stability in poor conditions |
| >75° north | Only access to select non-GEO systems with poor data transfer capacity. |

*Table 3.6: Satellite coverage zones*

| Communication method | Radio infrastructure | Data capacity | Stability | Value |
|---|---|---|---|---|
| GEO-satellite systems <70° N | No | High | High | 1 |
| GEO-satellite systems 70-75° N | No | Medium | Low | 2 |
| Non-GEO satellite systems (Iridium) | No | Low | High | 3 |

#### *3.2.1.3 Calculating the infrastructure coverage zones*

The final stage of the communication infrastructure analysis was to assess the overall distribution of the communication infrastructure in the High North, and whether it is sufficient to support an expansion of the sensor networks needed to ensure access to updated spatial information in the study area. The input data for the coverage zone calculation consists of the datasets representing the coastal radio buffer (for 30, 100 and 150 nautical miles), as well as the satellite coverage raster produced in chapter 3.2.1.2. The process used to accomplish this is described in Figure 3.5.

The rasters of the radio infrastructure and satellite coverage were ranked based on ability to support high speed and high capacity data transfer in the study area. The ranking criteria are outlined in Table 3.7, with this ranking determining the structure of the binary rasters in the coverage analysis. A value of 0 refers to areas within range of the radio structure, while values 1 – 3 uses satellite communication with decreasing capabilities.

Three rasters were produced as part of this process, with each of the scenarios measuring the communication infrastructure distribution within the study area based on the three ranges of radio coverage (150NM, 100NM and 30NM). The rasters were merged based on the minimum function, leaving the lowest value in every cell of the final rasters used for the analysis of the zone distribution. This corresponds to the ranking criteria outlined Table 3.7, and ensures that each cell shows the communication with the best communication capabilities present in the specific cell. This process was repeated three times, once for each coastal radio scenario. In addition to this the final dataset on satellite coverage from chapter 3.2.1.2 is used to assess the viability of a satellite-only scenario.

The rasters datasets produced in this process contained the coverage zones for the communication infrastructure in each scenario, and allowed for geographical and statistical information to be extracted for each scenario to assess the viability of implementing expanded sensor networks.

*Table 3.7: Infrastructure coverage zones*

| Communication method | Radio infrastructure | Data capacity | Stability | Rank (0 – best capabilities, 3 – worst capabilities) |
|---|---|---|---|---|
| Coastal radio (VHF, MF) | Yes | High | High | 0 |
| GEO-satellite systems | No | High | High | 1 |

| | | | | |
|---|---|---|---|---|
| <70° N | | | | |
| GEO-satellite systems 70-75° N | No | Medium | Low | 2 |
| Non-GEO satellite systems (Iridium) | No | Low | High | 3 |

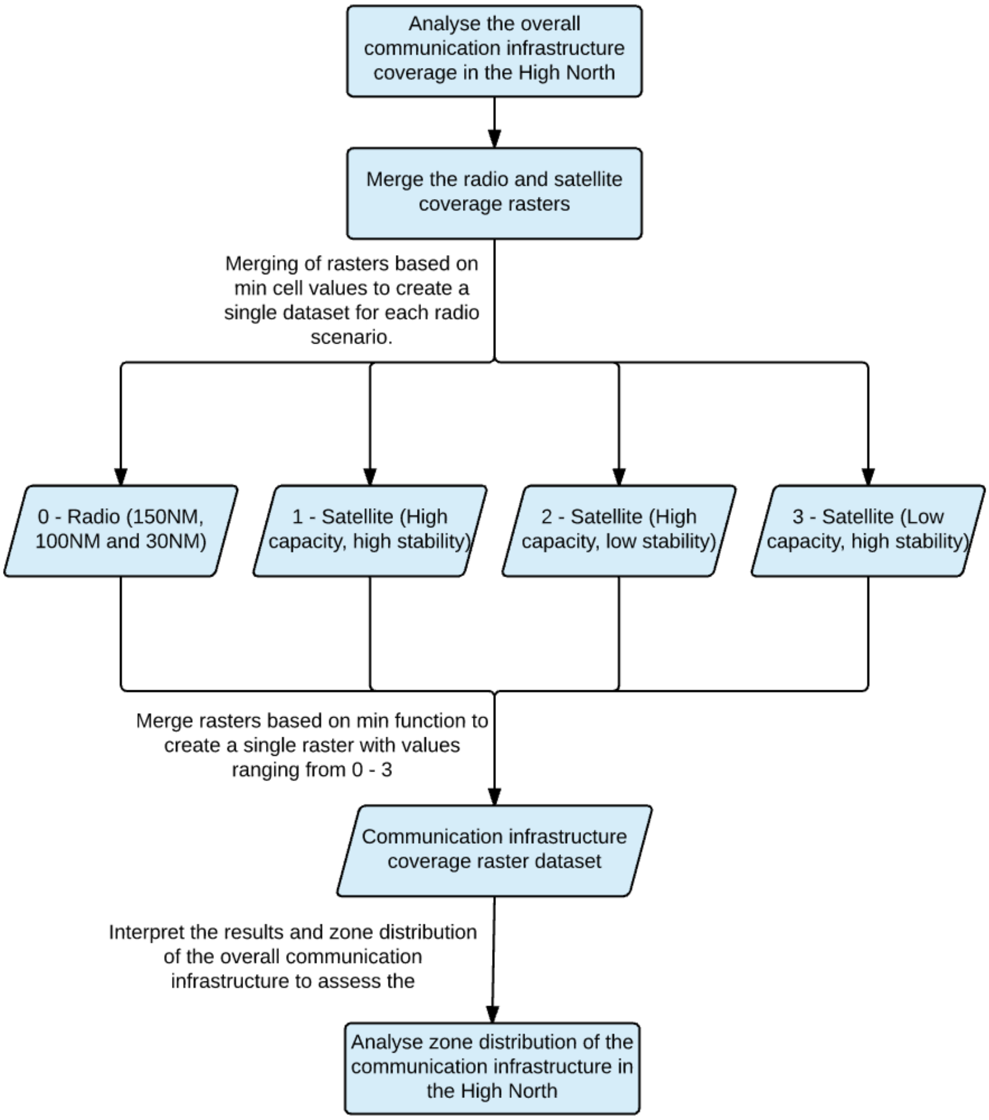


*Figure 3.5: Calculating the distribution of the infrastructure coverage zones in the High North*

## 3.3 DEVELOPMENT PATH FOR EMERGENCY MANAGEMENT WITHIN THE NORWEGIAN SDI

The informal nature of the current framework and infrastructure has necessitated an approach that involves a high degree of participation from stakeholders, including interviews and correspondence, to build an understanding of the current status quo. The roles and responsibilities of stakeholder organisations have been assessed in previous chapters, making it possible to specify the demands and requirements for the various stakeholders.

The intention to implement emergency management data into the NSDI has recently been announced, and can be expected to provide the necessary framework to resolve many of the issues relating to sharing and acquisition of spatial data among the core organisations. Many of the issues relating to auxiliary organisations will not be resolved in the short-term, however, and possible initiatives to resolve this issues is examined. This is done based on current SDI research, which provides possible implementations and ideas that can assist the NSDI in improving the spatial data access for auxiliary organisations in the EM process. Based on these results, three possible initiatives is explored, with the goal of improving spatial data access for auxiliary organisations. An access control scheme to let data owners manage access to their respective datasets is also suggested, as this had been one of the major issues raised in interviews.

# 4 RESULTS

The findings collected over the course of the research have revealed the current state of spatial data within the organisations participating in the EM process in the High North. The chapter outlines the results from the research, and discusses the relevance of the findings in relation to the original research goals outlined in chapter 1.2. Each research goal has a dedicated subchapter, which explores the results from the research process. The broader scope of the results and how this was influenced by the approaches taken over the course of the research is discussed in chapter 5.

## 4.1 ASSESSING THE CURRENT ABILITY TO SHARE SPATIAL DATA IN EMERGENCY MANAGEMENT ORGANISATIONS IN THE HIGH NORTH

Emergency management falls outside the domain of existing Norwegian geospatial infrastructure, and sharing of spatial data is handled in an ad-hoc manner between participating organisations. The current regime, where data sharing between participants is handled through individual data sharing agreements, while functional within the current level of operations, does not facilitate for efficient sharing of spatial data, and has been shown to hamper response efforts (Maritimt Forum Nord SA, 2014).

A long-term development goal for spatial data infrastructure in the Norwegian emergency management process should be to work towards the establishment of a common operating framework and unified development strategy for spatial data in emergency management. In the short-term, other initiatives must be undertaken to improve the access, use and sharing of spatial data within the EM process in the High North.

### 4.1.1 Contact with participating organisations

The interview process served as one of the primary methods of acquiring information over the course of the project. Contact with stakeholders also served as an important method to explore concepts and get opinions on the viability and usability of possible improvements to the process and the surrounding SDI framework. The role of the interview process meant that many of the findings from this phase directly ties into the other research goals, and will be explored further in the chapters relating to the relevant research questions.

The interview process made it clear that all participants were familiar and competent in the use of spatial data within their daily work tasks. Other challenges, like infrastructure and the lack of inter-organisational agreements and frameworks for data sharing, were assessed to be greater barriers for efficient use of spatial data compared to the functionality of the EMS and DSS systems currently being used.

### 4.1.2 Participants in an emergency management SDI covering the High North

The distributed and decentralised nature of the Norwegian EM process has necessitated the involvement of many organisations, ranging in size from individuals to larger organisations like police and other rescue services. While some of these organisations, such as the JRCC, Norwegian Coast Guard and other organisations at the centre of the emergency management process will be active participants, other organisations function in a more auxiliary role.

Core and auxiliary organisations have two main needs from a potential new SDI system: (1) Core organisations should have an increased ability to produce, share and acquire spatial data within a new SDI. (2) Auxiliary organisations should get the ability to acquire and utilise available spatial data. Table 4.1 outlines some of the major stakeholders in the EM process and the role they play during response efforts, while Figure 4.1 shows the organisational structure of these organisations. The criteria for spatial data needs for each type of organisation have been abstracted to the following:

*Complex spatial data* needs refer to organisations operating on the analytical, planning and execution stages, and incorporates multiple types of spatial data into the core decision-making process.

*Specialised data needs* refer to the various assets and institutions that perform little actual analysis, but rather utilise spatial data as part of navigation systems, search patterns, etc. These organisations have little need for access to a formalised SDI system, as all the spatial data used for operations is already integrated into existing systems through other channels. Safety concerns will keep these organisations from actively participating in an SDI as contributors.

*Basic operational information* refers to organisations that have few needs for more advanced spatial data, but could benefit from an access to basic spatial datasets.

The production of spatial data is handled by the individual organisations. Each organisation has the responsibility to produce, maintain and share their respective datasets. These datasets are generally shared through individual data sharing agreements between organisations, with the data owner being responsible for maintaining access control and providing updated data. Some of the datasets are shared through the Norway Digital initiative, though this is mostly limited to analytical spatial datasets.

*Table 4.1: Examples of roles and spatial data needs of organisations in the EM process*

| **Organisation** | **Role** | **Spatial data needs** | **Operational level** |
|---|---|---|---|
| JRCC | Rescue leader | Complex | Core |
| Norwegian Coastal Authority | Analysis, planning and execution of emergency response | Complex | Core |
| NOFO | Analysis, planning and execution of oil spill response | Complex | Core |
| Dedicated SAR-assets (330 squadron, Redningsselskapet, etc.) | Aerial SAR and emergency response | Specialised data needs, tailored for specific operations | Core |
| Norwegian Coast Guard and the Norwegian Navy | Naval SAR and emergency response role | Specialised data needs, tailored for specific operations. | Core |
| Local rescue services | Secondary emergency response role | Basic operational information | Core |
| Private Emergency Response contractors | Secondary emergency response role | Specialised data needs, tailored for specific operations. | Core |
| Fishing fleet | Proximity-based first response | Basic operational information | Auxiliary |
| Local voluntary assets | Ad-hoc emergency response | Basic operational information | Auxiliary |

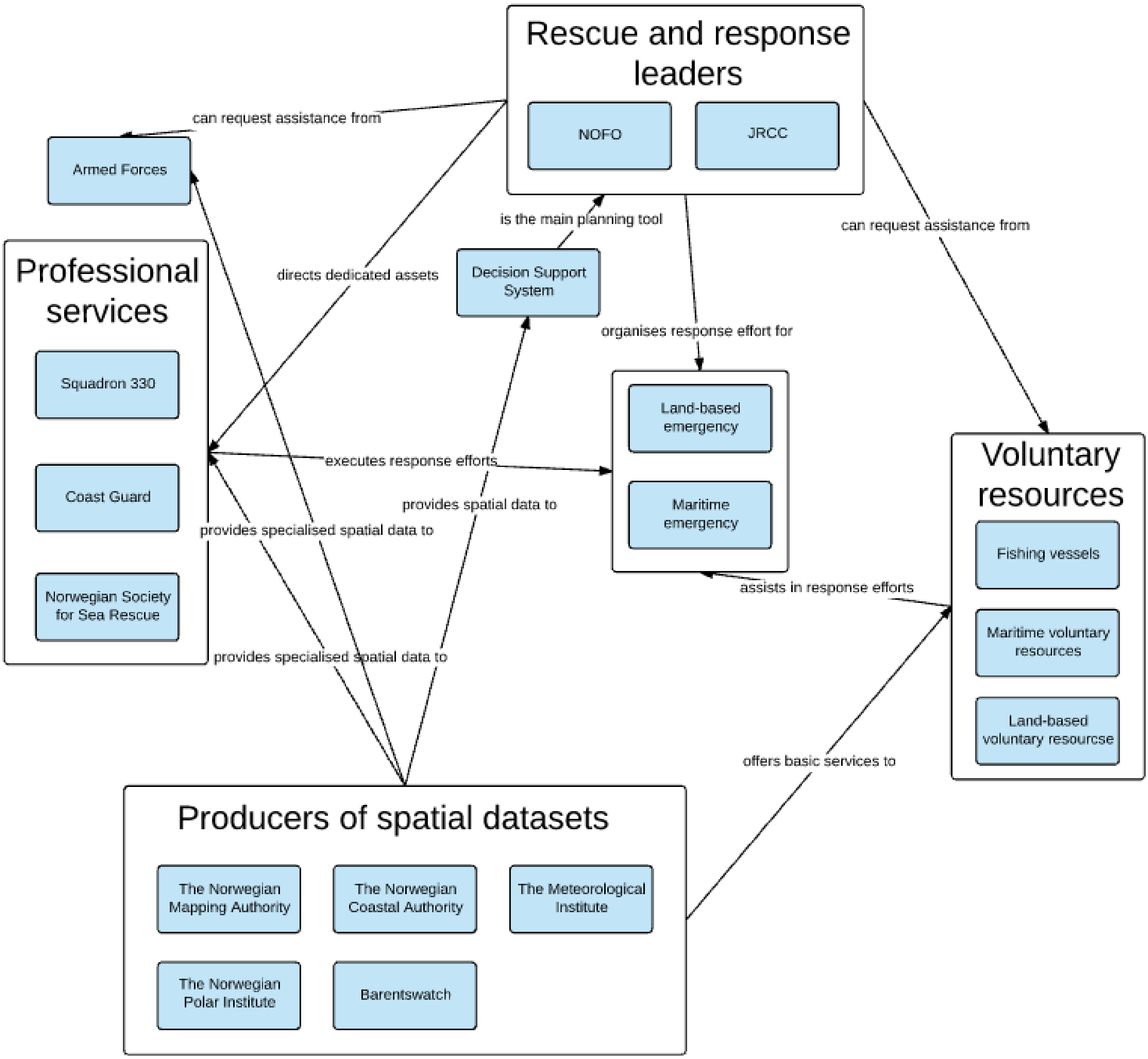


*Figure 4.1: Organisational structure - Norwegian emergency management organisations*

### 4.1.3 Spatial data used in emergency management operations

The spatial data used in EM planning and response is varied, ranging from administrative datasets to weather data. The core organisations are the primary users of spatial data, both for planning and coordination, and navigation and response execution. The datasets used for these purposes are varied, and have different needs for temporal resolution. Administrative datasets can be expected to remain static, while weather data must be continuously updated to be relevant in the planning and response processes. Table 4.2 outlines some of the more common spatial datasets used in emergency management operations.

The spatial datasets have been abstracted to three classes – Static, rare and frequent. Static data can be expected to be unchanging on a yearly basis. The rare class represents data that can be expected to change on a monthly or daily basis. The frequent class represents spatial data that must be updated multiple times per day, such as weather data and operational information. The necessary update frequency of a dataset is highly dependent on real-life conditions, and can in some changes change update frequency to reflect this. Flood zones and hazard mapping is drastically more important during the flood season in spring/summer, and will thus be updated more often in these time periods.

Datasets with an update frequency that is categorised as static or rare can be pre-downloaded locally, reducing the data transfer needs somewhat. Some of the most important data for emergency response needs to be near real-time to be of use, such as incident related datasets and weather data. This leaves pre-storing of spatial data of limited use, as meteorological and oceanic data will still need to be updated regularly.

*Table 4.2: Examples of spatial data in use by emergency management organisations.*

| **Spatial data needed in emergency management operations** | | |
|---|---|---|
| ***Name*** | ***Update frequency*** | ***Function*** |
| **Administrative data** | | |
| Administrative datasets | Static | Display political and administrative information |
| Nautical charts | Static | Display relevant nautical information |
| Land use | Static | Display land use within the area of operations |
| DEM | Static | Provide detailed elevation models within the area of operations |
| Infrastructure maps | Rare | Showcase the location and state of important infrastructure, such as road, rail and ports. |
| **Incident related details** | | |
| Incident details | Frequent | Gives information about incident details. Including variables like location, scenario, scale, etc. |
| Current location of assets | Frequent | Shows current location of assets involved in response operations in the specific incident. |
| Route plan for assets involved in operations | Frequent | Shows destinations and current missions for assets involved in emergency response operations. |
| Search patterns for assets involved in SAR | Frequent | Shows search grids and search patterns for assets involved in SAR missions. |
| **Meteorological and oceanic data** | | |
| Weather | Frequent | Shows weather data within the area of operations |

| | | |
|---|---|---|
| Wind | Frequent | Shows wind conditions within the area operations |
| Wave | Frequent | Shows wave heading, height and speed within the area of operations. |
| Precipitation | Frequent | Shows precipitation data within the area of operations. |
| Projected impact areas (oil spill) | Frequent | Uses tools to create projections on spread of oil and impact zones to support in response efforts. |
| Projected drift paths of objects (ocean) | Frequent | Projects the drift of objects in the ocean based on known weather conditions. |
| **Land-based spatial datasets** | | |
| Population density | Static | Shows population density and other population data to assist in land-based response operations. |
| Flood zones | Rare | Shows flood zones in river areas to support in emergency planning and response efforts. |
| Geological conditions | Static | Shows geological conditions within the area of operations. |
| Hazard map | Rare | Shows known hazardous areas within the area of operations, both natural and man-made. |

### 4.1.4 Actor-Network analysis results

Examining the participating organisations from an actor-network perspective shows the complex interactions between participants in the EM process. More than 20 organisations participate directly in the EM process, either as planners, responders or data providers, with the complexity of the organisational structure and data sharing within the setting was showcased in Figure 4.1. Spatial data is acquired from five main producers, who each produce multiple datasets that are used within all aspects of operations in the High North. In addition to this, other organisations produce specific datasets for operations within the area. Getting access to basic spatial data covering the High North region requires datasets from a minimum of 5 sources, with this number increasing drastically as data needs grows more complex. Spatial data is generally shared through WMS-interfaces and pre-made services, and the lack of an SDI means that this work has to be done through individual data sharing agreements, requiring communication between data producer and user to initiate data sharing.

Providing data through an SDI (Figure 4.2) would allow organisations to acquire spatial data from a single access point. This would lessen the need to rely on pre-defined data sharing agreements between individual organisations and would drastically reduce the complexity of data sharing within the setting. A single point of access would reduce the sources of basic operational information from 5 to 1, and would reduce the resources needed to manage access and organisation of spatial data. It would also provide a mechanism for external organisations to acquire spatial information during emergency response scenarios, which is problematic under the current day situation.

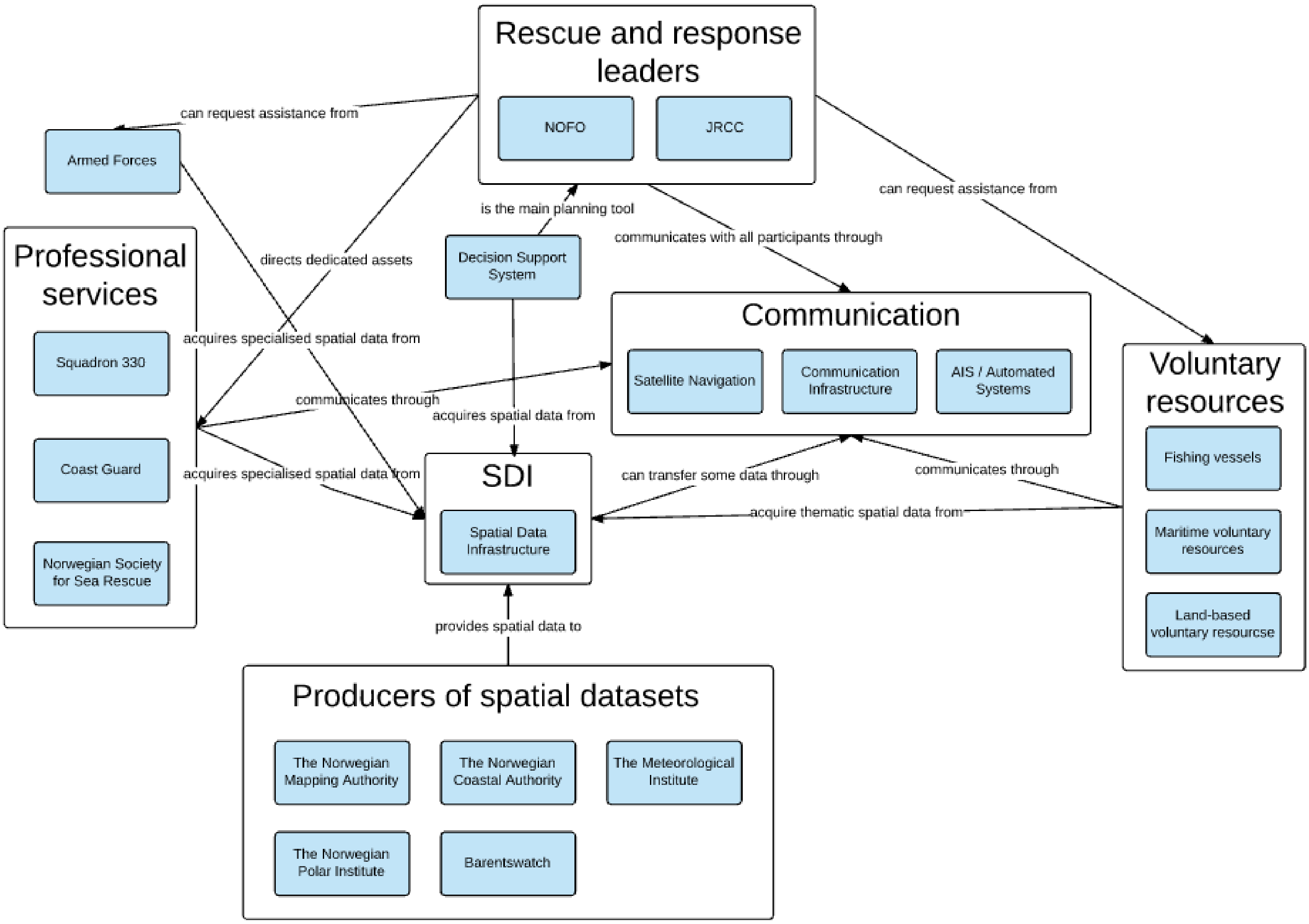


*Figure 4.2: Interactions between EM organisations in the High North*

### 4.1.5 Barriers towards an emergency management SDI covering the High north

Findings from the investigative phase of the research have revealed the following factors to be the key barriers towards the development of a formalised emergency management SDI:

- Infrastructure and communication systems do not provide the range, capacity and stability to reliably transmit spatial data to all participants in the EM process. It is necessary to improve the coverage, data capacity and stability of the communication infrastructure in the High North.
- Meteorological and oceanic sensor data quality and coverage in the High North must increase drastically. Increasing the access to meteorological and oceanic data will allow for improved operational awareness within the operational area, and will increase the efficiency of the EM regime.
- Organisations must have a formalised organisational structure with regards to production and maintenance of spatial datasets.
- The responsibilities and capabilities of each organisation in more complex scenarios must be clearly defined. Templates and procedures during specific scenarios must be developed further to clarify the responsibilities of each organisation within the emergency management regime.

- Stakeholders in the emergency management process from neighbouring countries must be able to participate to an increased degree. Tools that supports the multinational nature of EM in the High North must be developed.
- Data standards, protocols and rules must be developed further and implemented. This process already been initiated through the SOSI standards and direct agreements between participating organisations, but must also be extended towards other infrastructure and data types, such as sensors and metocean data.
- Access to updated information from assets (ships, helicopters, etc.) must improve. The large amount of communication systems, data standards and varying levels of equipment makes it difficult to maintain operational awareness of asset distribution for any
- Development of new decision support systems and other software systems for emergency management must be coordinated between institutions to remove the current gaps of functionality and ensure mutual compatibility of future systems.

## 4.2 ASSESSING THE COMMUNICATION INFRASTRUCTURE IN THE HIGH NORTH

The GIS analysis of the communication infrastructure coverage showcases the issues facing the communication infrastructure in the High North, as large portions of the study area lacks sufficient coverage of high capacity communication infrastructure. Stable satellite communication systems (Figure 4.3 & Table 4.3) are limited to 28%, while 38% of the area is within the "grey zone" between 70 - 75° north, where GEO-based satellite systems can provide some service, but cannot guarantee the necessary stability to serve as the foundation for comprehensive sensor systems. 34% of the area is completely outside the coverage of GEO-based satellite systems, and is limited to Iridium communication, which has severe limitations to data speed and transfer capacity.

The radio infrastructure is also unsuited as the cornerstone of a sensor network, as the coverage extent is insufficient to allow for full coverage in the High North. Optimal conditions, assuming a maximum range of 150nm with MF-radio communication (Figure 4.4 & Table 4.4), leave 82% of the High North area within range of radio communication and GEO-satellite systems with high data capacity and stability. This is reduced to 67% in suboptimal conditions, assuming a maximum MF-radio range of 100 nautical miles (Figure 4.5 & Table 4.5). VHF-radio is limited to 43%, leaving more than half of the High North area outside of the coverage of radio communications or high capacity satellite systems (Figure 4.6 & Table 4.6).

The results from the infrastructure analysis shows that the state of the communication infrastructure is insufficient to support a data transfer increase in the High North. In practice, this means that any plans for increased sensor coverage in the study area must be postponed until sufficient communication infrastructure is present.

#### 4.2.1.1 Zone distribution of satellite communication systems in the High North

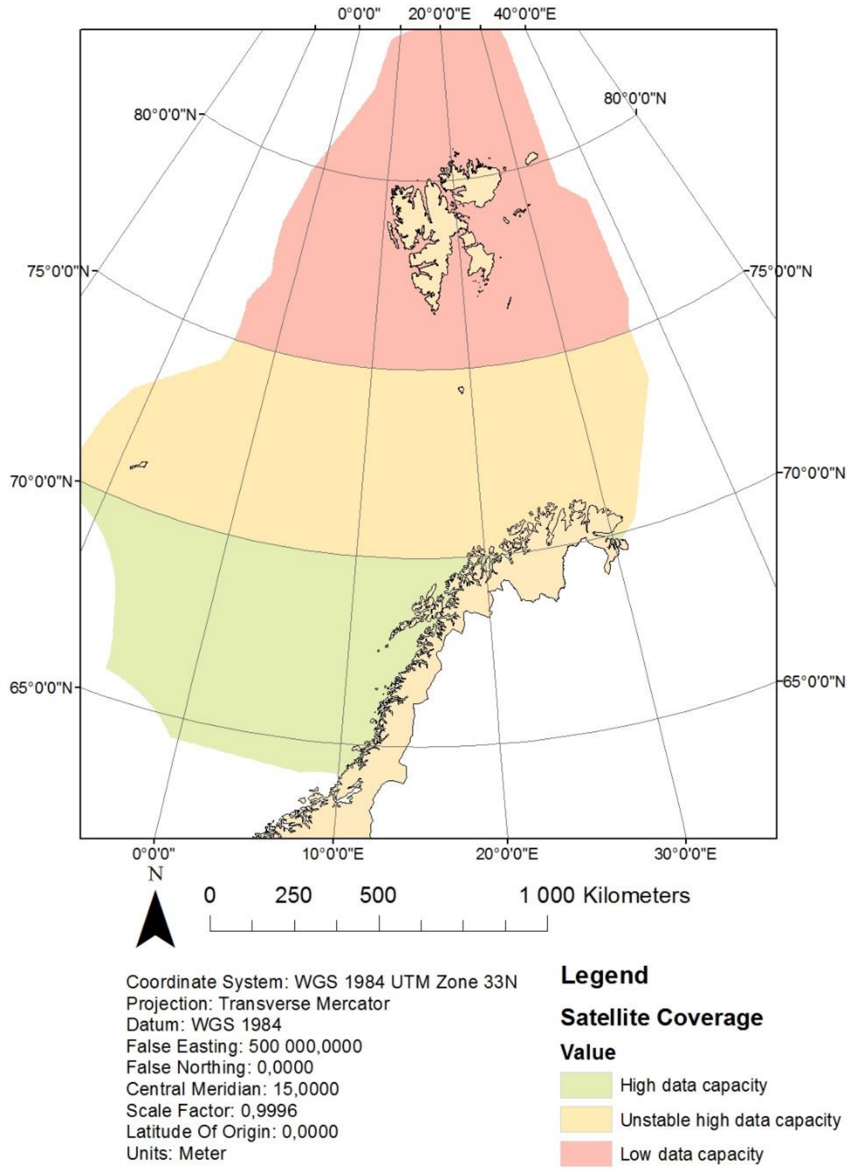


*Figure 4.3: Satellite coverage zones in the High North*

*Table 4.3: Distribution of satellite coverage in the High North*

| Satellite coverage zone | Square kilometres | Area of the High North |
|---|---|---|
| < 70° North | 623 569 | 28% |
| 70 – 75° North | 853 067 | 38% |
| > 70° North | 766 492 | 34% |

#### 4.2.1.2 Zone distribution based on maximum range for MF-radio (150nm)

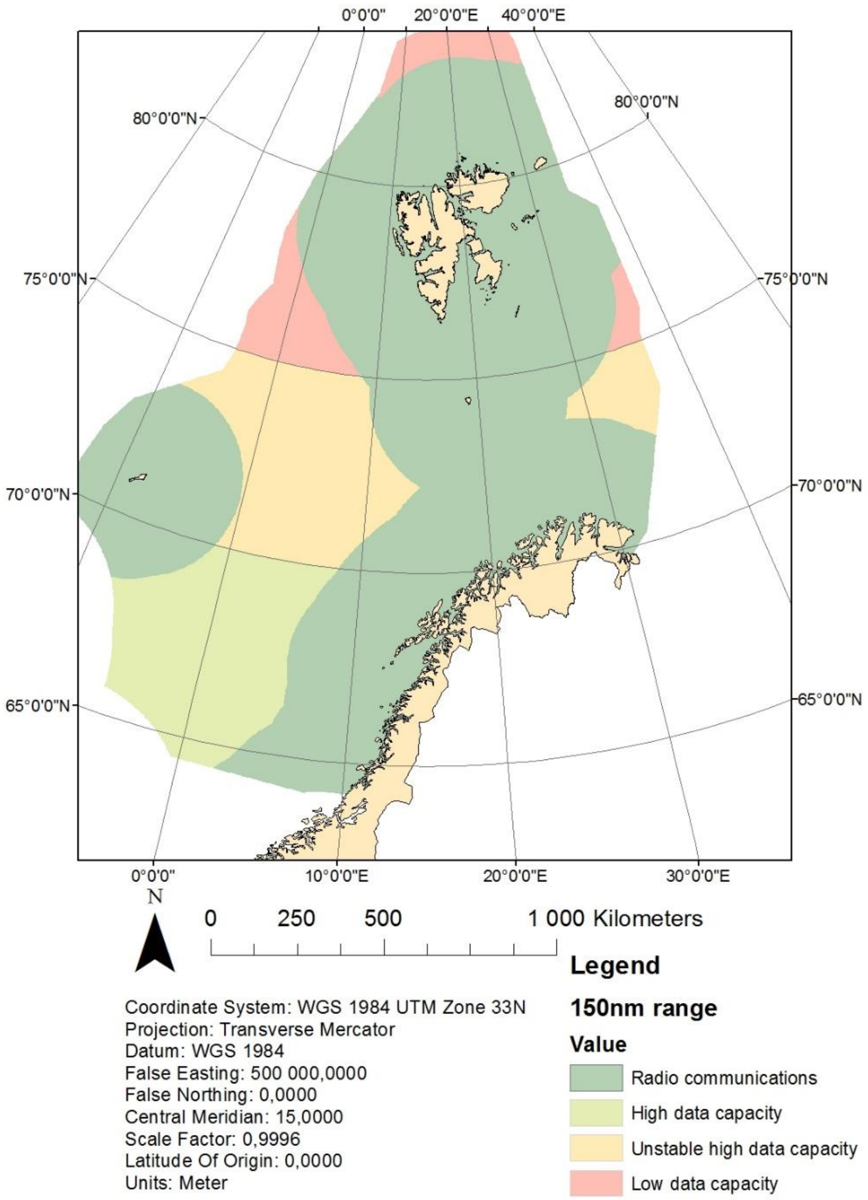


*Figure 4.4: Communication coverage zones in the High North (Assuming a 150nm maximum range of MF radio.)*

*Table 4.4: Coverage distribution, assuming a maximum MF range of 150 nautical mile*

| **Communication coverage (150nm)** | **Square kilometres** | **Area of the High North** |
|---|---|---|
| Radio communications | 1 559 934 | 70% |
| High data capacity satellite | 270 884 | 12% |
| Low stability satellite | 295 458 | 13% |
| Low capacity (Iridium) | 117 343 | 5% |

#### *4.2.1.3 Zone distribution based on MF-radio in poor conditions (100nm)*

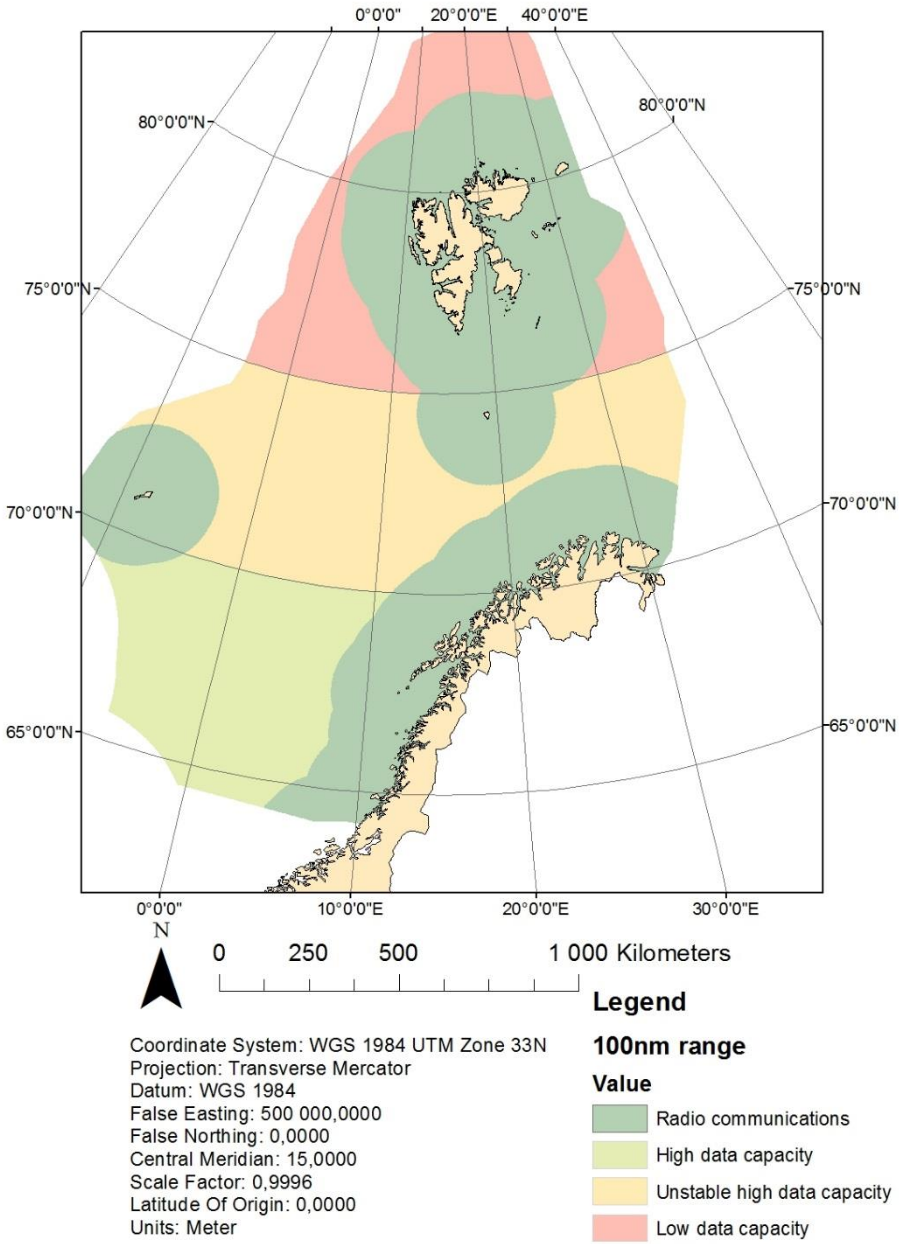


*Figure 4.5: Communication range within the High North (Assuming a 100nm range with MF radio.)*

*Table 4.5: Coverage distribution, assuming a maximum MF range of 100 nautical miles*

| **Communication coverage (100nm)** | **Square kilometres** | **Area of the High North** |
|---|---|---|
| Radio communications | 1 127 951 | 50% |
| High data capacity satellite | 365 680 | 16% |
| Low stability satellite | 485 446 | 22% |
| Low capacity (Iridium) | 263 548 | 11% |

#### 4.2.1.4 Zone distribution based on VHF-radio (30nm)

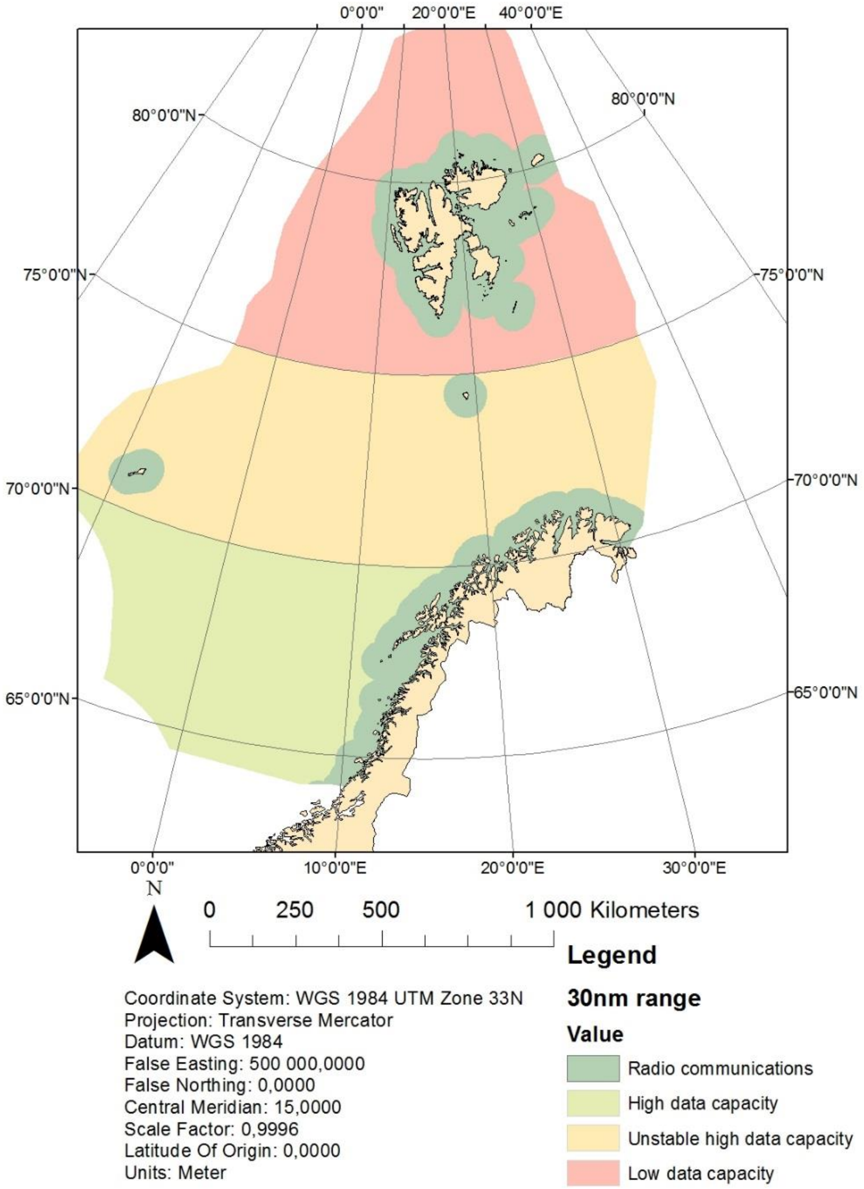


*Figure 4.6: Communication coverage zones within the High North (Assuming the 30nm maximum range of VHF radio.)*

*Table 4.6: Coverage distribution, assuming a maximum VHF range of 30 nautical miles*

| Communication coverage (30nm) | Square kilometres | Area of the High North |
|---|---|---|
| Radio communications | 468,592 | 21% |
| High data capacity satellite | 489,993 | 22% |
| Low stability satellite | 749,048 | 33% |
| Low capacity (Iridium) | 534,760 | 24% |

## 4.3 Development path for emergency management within the Norwegian SDI

At the Geomatikkdagene 2016 conference, The Norwegian Mapping Authority announced their intention to coordinate spatial data sharing between emergency management organisations in Geonorge, with the eventual goal being to make this the main portal for spatial data within the EM regime (Thomas Martin Holtan and The Norwgian Mapping Authority, 2016). This is a recent development (as of late March, 2016), and the project is still in the initial planning phase. It does present the most likely avenue for further development of spatial data within emergency management, and would potentially solve many of the problems related to barriers that is present in the current situation, as presented in 4.1.4.

Using the existing infrastructure ensures that the EM stakeholders will use the same standards, interfaces and systems as the rest of the Norwegian GIS community, as well as ensuring mutual compatibility with other spatial data from other European actors (assuming that they are signatories of the INSPIRE directive).

Some issues are not resolved by using the NSDI. The service-oriented architecture is not well-suited for operations in areas with poor infrastructure coverage, and it is still a question on whether stakeholders with more complex operating requirements (such as helicopters, planes and ocean-going vessels) will benefit from this effort.

The professional SAR services use the military communication systems, can be expected to continue using this system. The other stakeholders operating in the non-coastal areas of the High North is forced to rely satellite systems with poor data transfer speeds, leaving them unable to acquire and share spatial data. Some of these problems can be avoided with preloading of static spatial datasets, but there is still a need for continuous transfer of near real-time weather and oceanic data. The most realistic option to resolve these issues is to wait for the next generation of Arctic satellite communication satellites to come online, with the expected completion date for the Iridium NEXT system being 2017.

Based on the investigate phase of the research, three specific initiatives would be beneficial in building the ability for stakeholders to use spatial data in the short term. These initiatives consists of a resource register of emergency management organisations, outlining the training and equipment for each organisation, a web portal to give auxiliary stakeholders access to spatial data in EM situations and the design of scenario-based spatial data packages. In addition to this, an access and security scheme is suggested, to manage access control for EM spatial data.

### 4.3.1 Resource register

One of the main weaknesses in the current overall emergency management regime is a lack of a common resource register for participating organisations. There is no updated digital system that outlines the capabilities, capacity and responsibilities for each organisation that can be considered a stakeholder in the emergency management process.

Having awareness of the capabilities and resources of other organisations is one of the key factors in maintaining situational awareness, and the development of a resource register has been stated to be a priority in the development of infrastructure in the High North. Multiple research projects have acknowledged the lack of a common resource register to be one of the key factors in complicating current SAR and emergency response efforts. (Maritimt Forum Nord SA, 2014) (Barentswatch, 2015)

Barentswatch is currently working on the development of a resource register, and a prototype version of this was showcased in June, 2015. The register has been suggested to act as a proof of concept of a future series of light-weight services with the purpose of facilitating communication and sharing of operational intelligence between organisations participating in the emergency management process

(Hartviksen, 2015). The initial version has been limited to registering information about available assets from each participating organisation, and serves as an encyclopaedic lookup service of the available resources within each participating organisations (Hartviksen, 2015).

### 4.3.2 Scenario-based spatial data packages

Providing capabilities for packaging of data access and datasets could, in tandem with the other initiatives suggested in chapter 4.3, aid in decreasing the time spent on data acquisition and data management during the time critical awareness and response processes. Spatial data packages would be tailored towards specific scenarios and roles, ensuring that updated spatial data is always readily available for all participating organisations with access to the SDI.

A spatial data package should contain all spatial data needed to fulfil a particular role or spatial data need. The package would content either links to spatial datasets, or act as a download service for the spatial datasets, depending on the structure of the overall system.

One possible method to ensure access to up-to-date data is to utilise a subscription model. This would allow organisations to choose relevant packages, and ensures that the spatial data from all packages would be continuously downloaded. Another option would be to directly implement web services in the form of WMS, WFS, WCS, etc. The actual structure for packages within such a system requires an in-depth knowledge of the resources and responsibilities of each organisation, and is considered to be future work. Two examples are considered, however, to showcase how these concepts would function.

The first example (Table 4.7) showcases the contents of a basic spatial data package that helps fulfil the data needs necessary to maintain a basic awareness of the SAR-capabilities within the High North. This is particularly useful for auxiliary organisations, which currently lack this capacity.

The second example shows a more complex spatial data package, focused on oil spill response. The data needs are more complex, and requires the use of complex external tools to model the spread and drift of oil in oceanic environments. An example of spatial data that could be packaged into an oil spill response package can be found in Table 4.8.

*Table 4.7: Example of a spatial data package, focusing on SAR and operational awareness*

| **Basic SAR operational awareness package** | | | |
|---|---|---|---|
| ***Name*** | ***Type*** | ***Function*** | ***Provider*** |
| Base map | Vector | Map interface | Mapping Authority |
| Sea-going SAR-assets (ships, etc.) | Vector | Location and mission of sea-going assets | Resource register/individual agencies |
| Air-going SAR-assets (fixed-wing, helicopters) | Vector | Location and mission of air-going assets | Resource register/individual agencies |
| Operational bases | Vector | Showcase bases, storage and equipment locations | Resource register/Individual agencies |
| Coverage SAR | Vector | Showcase operational coverage of sea-going and air-going assets | Resource register/individual agencies |
| Incident map | Vector | Showcase active incidents within the area of operations | Resource register/individual agencies |
| Weather | Vector/Raster | Show basic meteorological data | Meteorological Institute |

*Table 4.8: Example of a spatial data package, focusing on oil spill response*

| **Oil spill response – Basic awareness** | | | |
|---|---|---|---|
| **Name** | **Type** | **Function** | **Provider** |
| Base maps | Vector | Map interface | Mapping Authority |
| Ocean-going oil spill response assets | Vector | Location and mission of oil spill assets | Resource register/individual agencies |
| Land-based oil spill response assets | Vector | Location and mission of land-based oil spill assets | Resource register/individual agencies |
| Incident map | Vector | Showcase active incidents within the area of operations | Resource register/individual agencies |
| Weather | Composite | Show basic meteorological data | Meteorological Institute |
| Waves and currents | Composite | Show basic hydrological data | Meteorological institute |
| Oil spill drift analysis | Raster/Vector | Show potential oil spill projections | NOFO/individual agencies |
| Coastal impact analysis | Raster /Vector | Show potential coastal impact zones | NOFO/individual agencies |

### 4.3.3 Web-based tool to assist in building operational awareness

Many of the participants in the Norwegian emergency management process, including local land-based first responders and external organisations, have few ways to utilise spatial data in the current situation. This is particularly true for land-based first responders, which often lack the communication equipment found in sea-going assets.

The increased prevalence of portable electronic devices, such as smartphones and laptops, has opened up new possibilities for implementing these organisations into the spatial data network. Utilising this capability to provide basic spatial data services would help to increase the spatial awareness of these user groups, and would be beneficial to their ability to respond to emergencies (Schunke et al., 2015).

Ensuring that these organisations have a web-based portal to acquire spatial data from would increase the operational awareness of these organisations and give them the ability to participate more actively in the planning of response efforts. A web portal would also serve as an auxiliary tool for private vessels that lack the advanced communication systems of larger, professional vessels. The web portal must contain the spatial data outlined in chapter 0 to fulfil the spatial data needs of potential users, and should consider to utilise spatial data packages (chapter 4.3.2) to give users all the relevant spatial data to the specific scenario that they are responding to.

Implementing a web-based client that displays thematic spatial data relating to EM would not be technologically difficult, but it would require a number of larger initiatives to be undertaken. Chief among these are the creation of a centralised resource register and spatial data register, which will provide the foundation for the spatial data provided through a web-based view service, accessible on laptops, smartphones and tablets. Multiple examples of web-based spatial processing services can be found in SDI-systems, with the research Farnaghi and Mansourian (2013) being a prime example of providing spatial data services needed in an emergency management context through a web portal.

#### *4.3.3.1 Access and security*

Datasets containing spatial information are often of sensitive nature, and maintaining strict access control to their spatial data is a priority for many organisations. Maintaining control over the spatial data within the system environment and managing the access to these data can be considered to be two of the primary conditions for participation for many of the organisations, and is one of the major barriers for efficient data sharing between the organisations participating in the emergency management process.

The Earth System Grid Federation (Cinquini et al., 2014) outlines a possible approach to these challenges, utilising a distributed and federated software architecture. A robust security service ensures that access data is authenticated and controlled. The S2D2S (Genc et al., 2013) presents another option. This system uses a policy-based approach, with a tiered structure that limits access based on group access policies.

Based on these systems, a model for maintaining access control to spatial datasets has been outlined. Overall access to data is controlled by a tiered access level, while group policies adjust the data access for specific organisations. The domain manager takes overall responsibility for access and security within each organisation, and acts as the main link between the organisation and the SDI.

##### Group policies

The main mechanism for controlling organisation access to datasets is group policies. Using a tier-based group policy system is a common method to manage rights and access in software, and can be found in a wide variety of systems. Group policies are used for more advanced rights and access management, and allow the domain manager to give specific organisations access to datasets tied to a specific access level. This helps to provide access and rights management in the cases that are too complex to manage with access levels alone. Table 4.9 shows a potential access level scheme, which controls the default access policy level for specific categories of spatial datasets.

Overall access levels can be managed by the domain manager of each organisation, and makes it possible to control the general access level of all participating organisations in the SDI environment. This creates the ability to maintain a standard ruleset for organisations to follow, and provides a mechanism quickly changing the access level to datasets based on individual emergency situations.

Organisations also have a default security level, which gives access to a specific tier of datasets. Domain managers have the option to adjust the security level of individual organisations. This makes it possible to react quickly to changing conditions, and give or remove access to the owned datasets, should circumstances require it. An example of a security level layout can be seen in Table 4.10.

*Table 4.9: Proposed access levels in a potential SDI*

| **Default access levels** | | |
|---|---|---|
| **Dataset categories** | **Access policy** | **Access** |
| Open datasets | Full access | All participating organisations have access |
| Controlled datasets | Controlled access | Limited to core organisations |
| Confidential datasets | Case-by-case | Owner maintains full ownership and access control |
| Private/Proprietary data | Case-by-case | Owner maintains full ownership and access control |

*Table 4.10: Proposed security levels in a potential SDI*

| **Security levels** | |
|---|---|
| Security class | Access level |
| A | Full access for core organisations<br>No access for auxiliary organisations |
| B | Full access for core organisations<br>Basic access for auxiliary organisations |
| C | Full access for core organisations<br>Extended access for auxiliary organisations |
| D | Full access for all organisations |

Most of the spatial data used in emergency management is not at all problematic. This includes administrative data and most types of spatial data, such as DEM, various planning data and meteorological data.

The primary example of datasets with controlled access is information on location and details of assets from the emergency services. This is information that is not available in the public sphere, and access to these datasets needs to be controlled.

Data from the Norwegian Armed Forces generally fall under the category of confidential datasets, as these datasets falls under the national security umbrella. Spatial data from the rescue helicopters from No. 330 Squadron, such as location, mission, radar and other sensor data is included in this. The same is true for Coast Guard vessels, which are often active in SAR-operations in the High North.

Finally, proprietary spatial data is focused on the petroleum industry. This industry often have spatial data of extremely high quality, but maintain strict control over said datasets due to competitive concerns. Providing a mechanism for these organisations to manage access to their datasets might make them more inclined to participate with spatial data in an EM-focused SDI.

# 5 DISCUSSION

The results from the research were outlined in chapter 4, while this chapter discusses the results in a larger context. The chapter also looks at strengths and weaknesses of the approaches used to accomplish each research goal and why the specific approaches were chosen.

The research covers a large thematic area, and time limitations forced the research to focus on a more conceptual level. Further studies should go more in-depth into the technical aspects of SDIs, to investigate possible solutions to some of the issues encountered during the research.

## 5.1 ASSESSING THE CURRENT ABILITY TO SHARE SPATIAL DATA IN EMERGENCY MANAGEMENT ORGANISATIONS IN THE HIGH NORTH

The participants in the EM process and the roles of the various groups is described in 4.1.2. The participants have been generalised into four main groups of stakeholders, based on the background research and interview process. Each of these groups occupies different niches in the emergency management regime, with examples found in the use cases (See Appendix A). These organisations have different needs for spatial data to support their operations.

The stakeholders involved at a planning and coordination level requires access to large amounts of information. These groups are responsible for analysing, planning and coordinating response situations, a role heavily dependent on maintaining situational awareness. The information used by these institutions must be of high quality, both spatially and temporally, as poor data will directly impact the ability to plan and execute response situations. Spatial data for these organisations must come in established formats, to ensure that they can be integrated in the various software systems in use.

Maritime and aerial response assets utilise spatial data actively in operations, as advanced navigation systems implements spatial data at an integral level. The nature of these assets means that they can be expected to have the technical systems and skills to use spatial data efficiently. Closer examination of these organisations was unfeasible, as the dedicated maritime and aerial emergency response units utilise military communication systems.

Land-based response organisations generally have a much lower degree of access to and need for spatial data. Current access is limited to basic GPS and smartphone systems, and it is unlikely that the various organisations will get access to more advanced equipment. These assets have a need for basic operational information to assist in decision making in response operations, and are among the groups that do not currently get their spatial data needs fulfilled.

Civilian maritime vessels are often called to respond to incidents at sea, as proximity to incident may require the assistance of nearby vessels. These assets are often equipped with good navigation systems, but lack the access to the military communication systems in use by the professional rescue services. These organisations rely heavily on verbal directions from rescue coordinators during emergency response and SAR operations.

The ability to share information between organisations and stakeholders in the emergency management process in the High North is severely limited by a variety of factors. The lack of sufficient communication infrastructure coverage is the key issue, which prevents the construction of a more complex system that incorporates up-to-date spatial information from vessels, installations, and other objects operating in the High North area. The participating organisations and agencies often have closed-source solutions, including AIS and satellite communication, to handle the surveillance and tracking of internal assets, but these solutions do not scale well beyond the individual organisations.

Expanding the focus to cover a larger, systematic expansion of capabilities across the participating organisations and infrastructure will require a larger degree of time, manpower and resources. The focus must instead be on laying the groundwork for an SDI-structure that enables a larger degree of spatial data sharing between the core organisations in the EM process, in addition to exploring possible avenues for including auxiliary organisations and assets in the future.

## 5.2 ASSESSING THE COMMUNICATION INFRASTRUCTURE COVERAGE

The GIS-analysis of the communication infrastructure coverage was performed as the first step of a process to assess if it would be possible to use fishing vessels and strategically placed buoys with sensor equipment to capture meteorological and oceanic data in the High North. Some pre-conditions were placed on this process, the chief of them being that most of the High North area must have access to stable communication infrastructure with the ability to transfer meteorological and oceanic sensor data.

The work was also complicated by the lack of available spatial data. Data requests and direct requests to the owners of specific key spatial datasets revealed little interest in contributing with spatial data, outside thematic data published through their respective data publishing portals. As a consequence of the lack of data, the planned ship traffic pattern analysis became impossible to perform, and with it, a more in-depth look at asset-based sensor network expansion within the different areas of the High North became difficult to achieve.

As the pre-conditions for the sensor network was not present, further investigation into this avenue was shelved. This avenue of research could be examined further with regards to expected improvements to the satellite communication infrastructure. This was deemed to be outside the scope of the research due to time concerns.

### 5.2.1 Issues and challenges towards performing a comprehensive infrastructure analysis

The analysis of the communication infrastructure coverage revealed that large portions of the study area fall outside the existing coverage infrastructure. To further complicate matters, ocean-going vessels operating in the area are highly mobile and travel across the entirety of the High North. The approach used to create the radio coverage spatial datasets has also been used in previous research within EM in the High North, and while it leads to inaccuracies in the spatial data, the loss in accuracy was viewed as acceptable on the scale that the analysis was performed on.

The *very* High North (areas north of the Svalbard Isles) has not been included in the communication infrastructure analysis. This region falls outside the coverage of all but a handful of specialised satellite systems, and operates under a completely different environment relative to the other zones. The challenges faced when operating in the *very* High North are unique, and the region is unlikely to be a direct part of the initiatives to expand capabilities in the general High North.

While the approach used for this research should be sufficient for conceptual work, it is clear that any later work that expands on the technical aspects of the communication infrastructure must be performed with a much higher degree of access to spatial data and cooperation from the relevant organisations.

## 5.3 DEVELOPMENT PATH FOR EMERGENCY MANAGEMENT WITHIN THE NORWEGIAN SDI

Most of the initiatives raised chapter 4.3 will require the establishment of a common framework for sharing of spatial data. The concepts are based of requested features from stakeholders, such as cross-borders functionality and package generation. Increasing the ability to collaborate across borders and nationalities, as well as ensuring easy access to comprehensive datasets that fulfil the data needs for specific roles was both features that came up in multiple interviews. The concepts was determined to be concepts that was feasible either within the current SDI and EM organisation, or as part of the planned integration into the NSDI.

The planned integration of EM spatial data into Geonorge presents an interesting path for further development. The service-oriented nature of the NSDI will provide difficulties in giving the non-traditional actors access to spatial data, but will provide many benefits for core organisations. The new framework will include the core planning and rescue coordination organisations, as well as emergency services and organisations tied to the armed forces, creating a unified operating environment where all core stakeholders can acquire and use spatial data from all participating organisations.

It can also be expected that thematic spatial data will be made available for download and web processing services. Merely opening up for third-party use of web processing services and download services to pre-store spatial data will do little to aid the situation, as many of the spatial datasets used in EM is highly reliant in being updated frequently. It remains to be seen whether The Norwegian Mapping Authority intends to create a solution that allows auxiliary stakeholders to acquire spatial data during emergency management situations.

### 5.3.1 Spatially integrating the resource register

One of the major questions that needs to be asked is if the functionality of the resource register should be limited to encyclopaedic information, or whether more advanced concepts like spatial data can be included in a future version. While the encyclopaedic solution is a step forward relative to the current day situation, it does not offer any infrastructure improvements and does little to improve the access to operational intelligence for stakeholders that are low in the EM hierarchy.

A spatially enabled resource register add spatial functionality to the existing resource register, giving the opportunity to present the information stored in the resource register through a map interface. Spatially integrating the assets and vessel registers would at minimum need to provide spatial information on the available assets and vessels for each organisation. Examples include variables like type, location, capacity, range, mission, etc., in addition to mechanics that allows for communication with the individual assets. This would require relatively complex information from assets and vessels that may be actively deployed, and may be unfeasible based on current communication and navigation systems.

Spatially integrating the resource register also gives vehicles and vessels involved in emergency management the opportunity to include the information from this register directly into their computer and navigation systems, with most of the information being suitable for pre-storing, and not relying on the variable communication infrastructure.

### 5.3.2 Generating and distributing spatial data packages

One of the key questions to solve is how to structure the spatial data packages. This requires answering the question of '*What spatial data is needed within each role in each scenario?'* The spatial data needs for rescue leaders in the JRCC differs drastically from the needs of SAR assets, or even press officers responsible for communication to the media and public. All these roles serves a purpose, and requires certain information to be able to fulfil their tasks.

While the spatial data needs will also be highly dependent on circumstances, it should be possible to generalise basic spatial information needs within each scenario and role, and prepare templates that can serve to fulfil the basic needs of each instance. A possible future goal would also be to lay the foundation for automatic package generation. This would require the construction of a fairly complex semantic ontology to handle the interactions between weather, conditions, assets and resources.

## 5.4 LONG-TERM DEVELOPMENT AVENUES

Newer research in GIS and SDIs offers interesting avenues for further development. Some of these avenues would increase the capabilities of an emergency management SDI, and would enable the usage of advanced GIS-functionality in the next generation of DSS. The focus has been on newer GIS-concepts can enhance the use of GIS within the EM process, while still being realistic to implement. The broader scope of SDI research is also be considered, as there is multiple avenues of research that could potentially increase the ability to share spatial data between organisations (Benjamin Adams, 2013).

### 5.4.1 Establishing a common framework for sharing of spatial information

One of the key initiatives needed to implement the next generation of SDIs and collaborative data systems in the High North is to establish a common framework among the organisations using and providing spatial data within the EM process. In the current day situation general Norwegian guidelines are followed, which generally corresponds to OGC standards. This is not sufficient when it comes to specialist data, however, as the standards rarely incorporate specialised use of sensor systems and the role they play in DSS. The lack of a common operating framework also complicates the incorporation of newer concepts, such as ensuring that all participating actors have access to information. Examples of processes and responsibilities that need to be defined are the following:

- Operational needs for each organisation.
- Clarify spatial data provider role for each organisation.
- Work towards standardising the standards, data formats and software currently in use.
- Formalise the overall structure of standards, goals and technological level to be used in next generation of DSS.

### 5.4.2 Usage of non-spatial data to enhance information quality

The newest generation of decision support systems have started to incorporate additional types of information into their analysis tools. Multiple research projects have analysed the potential to use spatial data in tandem with other types, among the data types that have been mentioned repeatedly is the following:

- Integration of complex sensor data.
- Integrating video data to enhance the operational intelligence.
- Automatic analysis of radio activity and cellular data.
- Utilise the increased prevalence of smartphones to push general information to non-traditional actors within the affected areas.

Conversations with Håkon Skjelten from Aptomar (Aptomar and Håkon Skjelten, 2015) detailed the important role that infrared and daylight video plays to support their decision support systems, and the potential value of the tools if improved standards could be developed for handling sensor data in spatial data systems by the OGC.

### 5.4.3 Gazetteers and cross-borders functionality

Another key goal is to improve the ability to share spatial data and operational intelligence across borders. The High North shares maritime borders with multiple nations, and the closest assets may belong emergency services and first responders from neighbouring nations. One of the major issues that have been encountered within the multinational EM process is the language barrier. Communication with Russian vessels and personnel is a particular problem, as it often requires the presence of a translator (Marintek and Sintef, 2015, JRCC and Delbekk, 2015).

A possible initiative to alleviate some of these issues is to introduce basic multilingual gazetteer functionality to ensure that basic data is available in multilingual formats (Laurini, 2015). This is particularly relevant when it comes to processes and procedures, and having access to these types of data in a variety of languages should be viewed as part of the core information requirements. This would be a major step in improving the level of communication and access to spatial data between stakeholder organisations in the nations border the High North area, and would play a role in improving the long-term ability to collaborate across borders and systems.

### 5.4.4 Automated workflow and package generation

One of the major focal points of SDI research within disaster management during the last years has been workflow generation and thematic spatial datasets. This is one of the more time consuming parts of the initial crisis response phase, and drastically increases the workload for planners during the time-critical response phase.

Farnaghi and Mansourian (2013) suggests a system that implements OWSs based on a web service composer. The WCS uses a semantic engine to automate the construction of workflow and OGC web services. This requires a complex engine based on semantic principles, and a robust semantic language.

A different approach focuses software agents handling access management and workflow generation based on sensor data (Zulkuf Genc, 2013, Genc et al., 2013). This requires comprehensive sensor coverage to give the software agents large amounts of sensor data to build automated workflows, while also benefitting from the more defined EM response process that is found in urbanized areas. Both solutions implement a template-system, which simplifies the creation of workflows and services by generalising operations and tasks based on pre-configured scenarios.

Correspondence with the maritime DSS developer Aptomar and Håkon Skjelten (2015) emphasised the lack of sensor data of sufficient quality and the lack of infrastructure to support such data, while correspondence with the JRCC emphasised the need to keep a large degree of freedom within new systems as the conditions for emergency and disaster response in the High North was variable to such an extent that enforcing a more automated and structured system may negatively affect the response ability to respond efficiently to emergencies (JRCC and Delbekk, 2015).

### 5.4.5 Implementing semantic concepts to enhance spatial data structures

One of the most interesting concepts to emerge during the last decades has been the usage of semantic concepts to enhance the capabilities of software systems. While the ability to implement these concepts have varied across disciplines, GIS has incorporated many of the concepts into the current and next generation of standards and systems, as semantic concepts offers ways to create relationships between spatial datasets in a way that enhances the ability to query and extract spatial information from datasets (Laurini, 2014).

There is a multitude of projects currently ongoing to develop and standardise the concepts and capabilities of these systems. One of the more notable standards that have developed through this work is the GEOSPAQL query languages, which drastically expands the query capabilities relative to regular SQL and PostGIS. This language has its roots in the RDF framework, developed by the W3C, which has been one of the cornerstones of the semantic web functionality.

### 5.4.6 Ontologies

A key future step in enhancing the spatial data community in the High North should be to develop a specific operating ontology for Arctic emergency management. A geographic ontology gives the formal naming for the types, properties and relationships between the spatial datasets and accompanying data that exists within an SDI (Laurini, 2015). Geographical ontologies have their roots in the Egenhofer topological relations, which outline the spatial relationship between objects (Egenhofer and Franzosa, 1991). These topological relations make up the cornerstone of ontological modelling, but has later expanded to be able to map more abstract relationships.

A prime example of a complex ontology that compromises of the various fields within a system can be found in the work done by W. Li (2010). In their efforts to create an SDI for Arctic research, a specialised ontology for scientific datasets in Arctic and Antarctic areas was created (Figure 5.1). This ontology helps to link scientific datasets together within an Arctic SDI, and enables advanced data querying based on spatial principles. The ontology is linked through a variety of properties, including physical processes, spatial properties and physics.

This can also be seen in SIAPAD project, which is a multinational SDI-based system that increases visibility and access to information to improve disaster risk management in the Andean countries (Molina and Bayarri, 2011). The SDI makes use of a thematic knowledge-based search engine. This engine uses an ontological knowledge base based on the RDF format. This has created an ontology specifically based on disaster management terminology that allows users to query information through a more intuitive language for users within the field of disaster management.

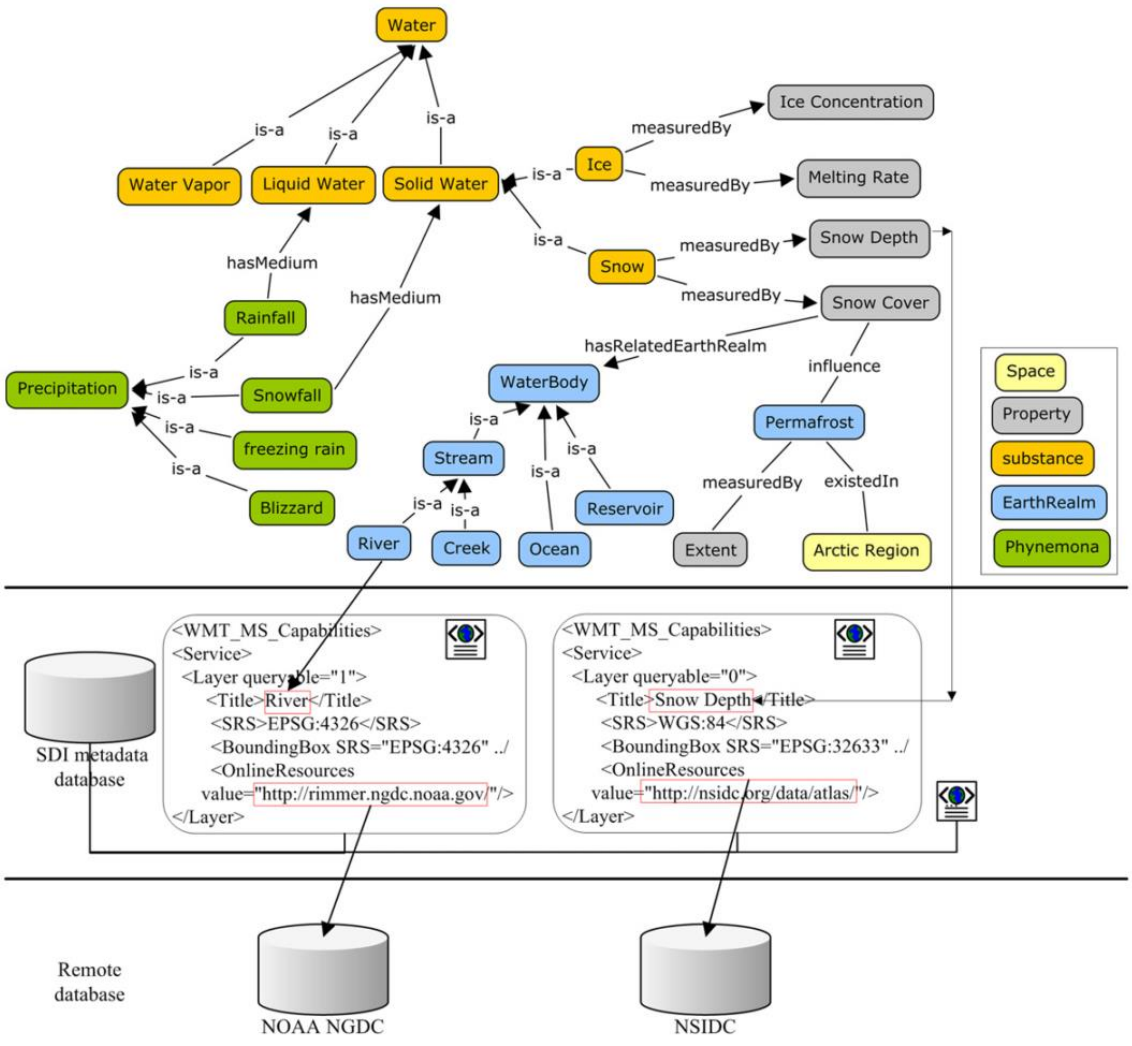


*Figure 5.1: Arctic ontology and linkage to metadata and scientific data (W. Li, 2010). Reprinted with permission from Elsevier Limited.*

# 6 CONCLUSIONS

The findings revealed that while the current ability to use spatial data is well-developed in many organisations participating in the EM system in the High North, this is not the case for sharing spatial data between organisations. There are no existing initiatives or infrastructure to handle sharing spatial data between participants at a larger level, limiting access to external spatial data to specific agreements between individual organisations. Furthermore, there is no framework for sharing of updated spatial and sensor data during response situations to external organisations in use. To further complicate matters, the hierarchy of emergency management organisations in Norway is extremely complex, with dozens of organisations operating in different roles, under different departments. There is a big difference in equipment, level of organisation and resources between the different organisations operating within the High North, and few tools to efficiently share operational data, spatial or otherwise, between these organisations. As a consequence of this, the various organisations participating in the EM process are highly dependent on pre-configured data streams and internal datasets, and have few ways to distribute operational data efficiently in larger-scale emergency response situations that requires the participation of organisations normally outside the traditional EM framework.

One of the major issues relating to spatial data sharing in the High North is the lack of communication infrastructure. Traditional GEO-based satellite systems does not provide coverage in the most parts of the High North, and the coastal radio infrastructure does not have the range necessary to provide coverage for the entire area. A low transfer speed and data capacity system exists in the form of Iridium, but this system does not provide the capabilities necessary to transfer anything but simple text-data. Any effort to incorporate sensor data and spatial data from vessels, installations and sensor buoys in the High North will require a drastic expansion of the communication infrastructure coverage to provide the stability, transfer speed and transfer capacity necessary in all areas of the High North. Major communication infrastructure improvements is ongoing, with the Iridium NEXT satellite constellation with a scheduled deployment in 2017. This could potentially make it possible to drastically increase the access to meteorological and oceanic sensor data from the entire High North region.

The newly announced integration of spatial data within the emergency management domain into the Norwegian NSDI, Geonorge, has the potential a game changer when it comes improving the ability of core stakeholders to share and utilise spatial data. The initiative will ensure that all core stakeholders have a unified infrastructure to share and use spatial data. It also forces standardisation of data and services, and can be expected to shape further development of tools and datasets within the respective organisations to ensure mutual compatibility. The role of auxiliary stakeholders within this project still needs to be clarified, as the needs for these actors is unlikely to be fulfilled through the framework provided by the NSDI.

Over the course of the project, multiple ideas and concepts relating to SDIs have been evaluated, with the goal being to find initiatives that can be useful for the EM process, regardless of specific SDI implementation. These ideas and concepts have been weighed against the issues relating to the organisational structure of the stakeholders operating in the High North. A web portal containing thematic spatial data adapted to emergency response scenarios should be created to ensure that these groups gain improved access to spatial data in emergency response situations.This includes further developing the resource register developed by Barentswatch, creating spatial data packages based on DHSA scenarios and constructing a web portal to give auxiliary stakeholders access to EM spatial data. Potential long-term development avenues has also been examined, including concepts like semantic data structures and automatic generation of spatial datasets. These are concepts that fall outside the direct sphere of an SDI dedicated for the EM process in the High North, but could play a part in improving the next generation of decision support systems.

Based on the findings over the course of the research, a series of potential avenues for further work has opened up. The focus should be on initiatives and functionality that would directly influence the ability to construct an SDI, and would by necessity include a large degree of involvement by the various stakeholder organisations. A major point of priority should be to enforce the creation of a long-term development strategy by the various actors involved in the EM process, accompanied by a discussion on standardisation efforts and clarifying the information and data responsibilities of the core organisations. These initiatives would help to ensure that the future systems has an increased level of integration, and would allow for increased collaboration across DSS and disciplines. This would allow for the development of specific features that can be used in the broader EM regime, such as a specialised ontology and web-based spatial processing services.

Further work within the field should expand on the following areas:

- Larger scale interview process with stakeholders to define spatial data needs
- Assess the spatial data needs in specific DHSA scenarios and build spatial data packages based to support response efforts in these scenarios
- Construct a series semantic ontologies for EM operations in the High North
- Collaborate with core organisations to create a unified development strategy for spatial datasets and tools that supports usage of GIS within emergency management.

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# APPENDIX

## Appendix A

### Use cases to explore the flow of various emergency management operations

| | | |
|---|---|---|
| Use Case ID: | 1 | |
| Use Case Name: | Fishing vessel acting as first responder in maritime emergency response incident (vessel in distress, oil spill, etc.) | |
| Main Actor: | Fishing vessel in close proximity to incident location. | |
| Additional Actors: | The JRCC, other vessels responding to call for assistance, airborne assets, land-based emergency response assets. | |
| Description: | Fishing vessel is asked to assist a ship in distress in close proximity. As the first asset on the scene, the fishing vessel has need for basic operational information during the transit period to ensure that the vessel is able to provide assistance during the time-critical response phase. | |
| Preconditions: | The JRCC has requested the participation of the specific fishing vessel.<br>The Main Actor is in a position to contribute to response efforts. | |
| **Desciption:** | **Step** | **Action** |
| | 1 | The JRCC requests assistance from fishing vessel in close proximity to the incident location. |
| | 2 | Fishing vessel acknowledges request, acquires basic information on GPS (position, heading, etc.) and starts heading towards incident location. |
| | 3 | Main actor acquires other relevant information (weather, metocean, etc.) from other sources – Maritime radio, local radio, weather services. |
| | 4 | Main actor is first responder on the scene of the incident, able to initiate rescue or response efforts thanks to previously acquired information. |
| | 5 | Other actors arrive at the scene, and The JRCC coordinates efforts between all participating actors during the response operation. |
| | 6 | Emergency response operation is successfully completed. |
| Success End Condition: | Main Actor is able to contribute efficiently in emergency response efforts. | |
| Failed End Condition: | Main Actor is unable to contribute efficiently in emergency response efforts. | |
| Assumptions: | Main Actor and incident location is within the range of communication infrastructure.<br>Main Actor has access to spatial data from multiple sources.<br>Main Actor is able to respond to incident within a timely manner. | |
| Notes and Issues: | Main Actor is completely dependent on information from external sources to contribute in response efforts.<br>Requires pre-planned data sharing agreements.<br>Unrealistic to expect that this level of preparation is present for civilian assets within the | |

| | |
|---|---|
| | High North. |

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| Use Case ID: | 2 | |
| Use Case Name: | Land-based emergency services acting as first responders to incident on land. | |
| Main Actor: | Coordinating leader of disaster response and fire services. | |
| Additional Actors: | Fire services, The JRCC, other emergency responding to call for assistance, airborne assets, and other land-based emergency response assets. | |
| Description: | A large and uncontrolled wildfire rages in the Norwegian interior. The situation is unclear, and quick action is necessary to get the wildfire under control.<br>All available emergency services is requested to assist with wildfire suppression efforts, requiring the coordination of a large number of assets. These assets also include a large number of volunteers, which must be efficiently integrated into the firefighting effort. | |
| Preconditions: | The Main Actor is able to coordinate emergency services to mount an efficient firefighting effort to get the wildfire under control. | |
| **Desciption:** | **Step** | **Action** |
| | 1 | Main actor acquires information to build situational awareness (weather, projections on spread of fire, population density, etc.) Forms a plan to minimise casualties and damage to areas with human activity. |
| | 2 | Main Actor assesses the available resources in terms of manpower, equipment and volunteers. |
| | 3 | Main Actor requests assistance from all available emergency services. |
| | 4 | Emergency services begin firefighting efforts. |
| | 5 | Main Actor continues directing the efforts of firefighters and volunteers, to contain the wildfire. |
| | 6 | Firefighting efforts is successfully completed. |
| Success End Condition: | Main Actor is able to direct firefighting efforts to get the wildfire under control. | |
| Failed End Condition: | Main Actor and firefighters is unable to get the wildfire under control. | |
| Assumptions: | Main Actor has access to spatial data from multiple sources to make the decisions necessary to minimise spread of the fire and damage to areas of importance.<br>Main Actor is able to coordinate large numbers of emergency services, both land-based and aerial, as well as implementing volunteers into the firefighting process in a manner that utilises their resources. | |
| Notes and Issues: | Main Actor is completely dependent on information from external sources to be able to direct firefighting efforts.<br>Requires pre-planned data sharing agreements.<br>Will require the mobilisation of all emergency services, as well as large numbers of volunteers. | |

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| Use Case ID: | 3 | |
| Use Case Name: | Large scale oil spill threatens to impact the shoreline in a sea bird reservation | |
| Main Actor: | Norwegian Clean Seas Association for Operating Companies (NOFO) | |
| Additional Actors: | The JRCC, other vessels responding to call for assistance, airborne assets, land-based emergency response assets. | |
| Description: | A medium scale oil spill from a petroleum installation has led to a habitat for endangered sea birds being threatened. The area is of critical importance, and response efforts is launched to contain as much of the oil spill as possible. | |
| Preconditions: | Main Actor has received information of an oil spill in progress. Main Actor has the manpower necessary to lead oil spill response efforts. | |
| **Desciption:** | **Step** | **Action** |
| | 1 | Main Actor acquires information to build situational awareness (weather, wave conditions, oil spread projections, expected impact zones, etc.) Forms a plan to minimise damage to critical environmental habitats. |
| | 2 | Main Actor mobilises the dedicated oil spill response assets, as well as coordination with local emergency services. |
| | 3 | Requests assistance from nearby sea-going vessels. If request is acknowledges, transfers basic information on GPS (position, heading, etc.) and gives details that outlines the role of the individual assets. |
| | 4 | Other actors arrive at the scene. NOFO coordinates efforts between all participating actors during the response operation. |
| | 5 | Deployment of oil spill equipment, coordinating effort to ensure that all participating assets are able to efficiently contribute to response efforts |
| | 6 | Oil spill contained with minimal damage to coastline areas. |
| Success End Condition: | Main Actor is able to successfully direct oil spill response efforts to minimise the impact on coastal areas. | |
| Failed End Condition: | Main Actor is unable to prevent the oil spill from destroying vulnerable coastal sea bird habitats. | |
| Assumptions: | Incident location is within the range of communication infrastructure, as well as within the range of oil spill response assets.<br>Main Actor has access to spatial data from multiple sources.<br>Main Actor is able to respond to incident within a timely manner. | |
| Notes and Issues: | Main Actor is completely dependent on information from external sources to contribute in response efforts.<br>Requires pre-planned data sharing agreements.<br>Short timeframe to save vulnerable natural areas, requires a massive mobilisation of manpower and resources to minimise the damage. | |

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