CabinetOffice

Emergency Planning College

A Guide to GIS Applications
in Integrated Emergency Management

EMERGENCY PLANNING COLLEGE

Version 1.0

This is version 1.0 of this guide, issued on November 30th 2005. Revised versions (as they are published) will be available on the Emergency Planning College website www.epcollege.gov.uk

Summary Version of the Guide

A summary version of this guide, intended for senior staff and those only requiring a familiarity with the key issues, will be published by the Emergency Planning College early in 2006. This will be available for download from the EPC website www.epcollege.gov.uk

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Referencing this document

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Note on the Use of Mapping in Scenarios

In addition to a series of case studies, a number of hypothetical scenarios are used in this guide and Ordnance Survey Strategi™ data are combined with fictional data to illustrate these scenarios. However, no backdrop mapping is used as the scenarios are not intended to be place-specific. Perseverance would of course allow a reader to identify which area the data relate to, but they are intended to remain generic and so assumptions about the availability or accuracy of the data must not be made.

Acknowledgements

A large number of people in a wide range of agencies supported the writing of this document, supplying material for case studies, providing illustrations and discussing and helping to formulate the ideas. There are too many to mention by name, and acknowledgements of source are given where relevant in the text, but sincere thanks go to all who supported the project.

Contents

Glossary of Abbreviations

5 C's	Command, Control, Co-ordination, Co-operation and Communication
3D	Three Dimensional
AGI	Association for Geographical Information
C2	Command and Control
CCA	Civil Contingencies Act
CCTV	Closed Circuit Television
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CD	Compact Disk
COMAH	Control Of Major Accident Hazards
COP	Common Operational Picture
COTS	Commercial Off The Shelf Software
DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DLM	Discovery Level Metadata
DNF	Digital National Framework
DPA	Data Protection Act 1998
EOC	Emergency Operations Centre
EPC	Emergency Planning College (www.epcollege.gov.uk)
FEMA	Federal Emergency Management Agency
FOI	Freedom of Information
FoIA	Freedom of Information Act 2000
FMD	Food and Mouth Disease
GI	Geographical Information
GIS	Geographical Information System(s)
GI/S	Geographical Information and Geographical Information System(s)
GML	Geographical Markup Language
GP	General Practitioner
GSM	Global System for Mobile Communications
HCl	Hydrogen Chloride
HTTP	Hyper Text Transfer Protocol
IEM	Integrated Emergency Management
IGGI	Intra-governmental Group on Geographical Information
IRMP	Integrated Risk Management Planning
JACC	Joint Agencies Control Centre
KM	Knowledge Management
LAN	Local Area Network
LRF	Local Resilience Forum
MAFF	Ministry for Agriculture, Fisheries and Food (now DEFRA)
NSCWIP	National Steering Committee on Warning & Informing the Public
NYC	New York City

OS	Ordnance Survey
OSAPR	Ordnance Survey Address Point Reference
OSS	Open Source Software
OSLO	Ordnance Survey Liaison Officer
PC	Personal Computer
PDA	Personal Digital Assistant
PSI	Public Sector Information
QA	Quality Assurance
RAM	Random Access Memory, or just computer ‘memory’
RRF	Regional Resilience Forum
SDI	Spatial Data Infrastructure
SESMIC	Surrey Emergency Services Major Incident Committee
SOP	Standard Operational Procedure
SVG	Scaleable Vector Graphics
SWIM	Severe Weather Impacts Model
TOID	TOpographic IDentifier
UPRN	Unique Property Reference Number
VMDS	Vehicle Mounted Data System
WAN	Wide Area Network
WTC	World Trade Center
XML	eXtensible Markup Language

Section One

Introduction

Summary

This guide is intended to establish authoritative guidance on the application of GIS in civil protection, to assist users in the specification, acquisition and maintenance of a GIS and to stimulate debate in the user community about the future development and application of GIS and related technologies.

The primary audience is anticipated to be staff in Category One responders identified in the Civil Contingencies Act 2004, most notably in Local Authority Emergency Planning Units. However, it is also suited to a much wider audience as it assumes no significant prior knowledge of either GIS or civil protection. The structure and style of the guide is such that it can be worked through from beginning to end, dipped in and out of as required or used as a reference source. It is, very deliberately, a wide ranging document that is not restricted to technical issues, and the coverage of data, information and decision making and interoperability issues are very significant.

1.1 Aim of the Guide

The aim of this document is to provide authoritative guidance on the application of GIS to managers and end-users operating in the joint, multi-agency civil protection environment in order to:

1. maximise the potential benefits of GIS to the process of planning for and managing emergencies and disasters, thereby enhancing national resilience to such events;
2. establish a wide base of understanding of common applications, methods and terminology as the first step towards improving interoperability between users working in civil protection;
3. assist users in making sound decisions within the process of scoping, specifying, acquiring, updating and maintaining GIS;
4. stimulate wider understanding and debate within the user community as a basis for more effective relationships with the technical domain to guide research and development of applications and interoperability solutions.

This is a wide-ranging document that takes the perspective that GIS is a tool to generate information from a wide range of different datasets. In common with any tool, effective use is dependent upon the quality of what might be termed the ‘raw material’, in this case data, the skills and insight of those that use it and the wider organisational context within which it is employed. All of these issues are covered in this guide.

1.2 The Demand for Information

Those involved in preparing for, responding to, and recovering from emergencies have a need for information. However, that need is more precise, for information that is relevant, appropriate, accurate, timely and delivered in a form that is appreciable under their circumstances. However, this need, or demand, for information is often only partially met as, and when, it is most needed.

> *The quality of the response is only as effective as the reliability of the information which is available* (Neil Macintosh, local authority Chief Executive, speaking about the Lockerbie disaster, 1988).

Although there are a range of issues relating to the nature and transfer of information (see Section 5), Figure 1 illustrates the fact that demand for information, most acutely during an emergency, accelerates at a rate far above that of supply. This leads to what may be termed a demand-provision gap. In most cases this is not because the information, or at least the data from which the information could be generated, does not exist, but because it is not accessible at the point and time of need.

Box 1: GI and GIS

In some text books 'GIS' is disaggregated, and this can be helpful:

***G**eographical* – the 'spatial key' or location of features is central to data handling, analysis and reporting, which sets GIS apart from other data base management systems.

***I**nformation* – without data and information GIS can have no role to play and good quality data are critical if the results of analysis are to be reliable.

***S**ystems* – at a basic level they are computer-based systems, but it is important to remember that GIS are rarely personal technology, so an understanding of how organisations manage data and use information is critical to understanding and achieving effective use of GIS.

More recently Geographical Information (GI) as a term has become more widely used in its own right. GI handling has become much more tightly embedded into a wider range of technologies than ten years ago and GIS as a term is being precisely defined as desktop systems with a powerful range of functionality. GI handling technologies including, for example, addressing software which is used by call centre operators who ask for postcode and house number only, and indeed such technologies are instrumental in the increase in both amount and quality of GI that is available for application and analysis in a GIS. The term GIScience has also become widespread in recent years, and is defined as the set of scientific principles that should govern the use and analysis of GI in GIS (see Longley *et al.*, 2005 in Appendix 2).

This is of course a generic issue, and one that is far wider than GIS alone, but the need for information is the key driver for the development and implementation of GIS in Integrated Emergency Management. The specific value of GIS is that many of the issues that need to be considered in preparing for, responding to and recovering from emergencies are explicitly geographical: roads, rivers, floodplains, industrial hazards, towns and cities are all geographically distributed in a way that is of clear relevance to emergency planning and management. In short, where things are matters a great deal if something may, or does, go wrong there. GIS is a tool that enables us to account for geography, and geography is critical in understanding, planning for and communicating hazards, risks and vulnerabilities.

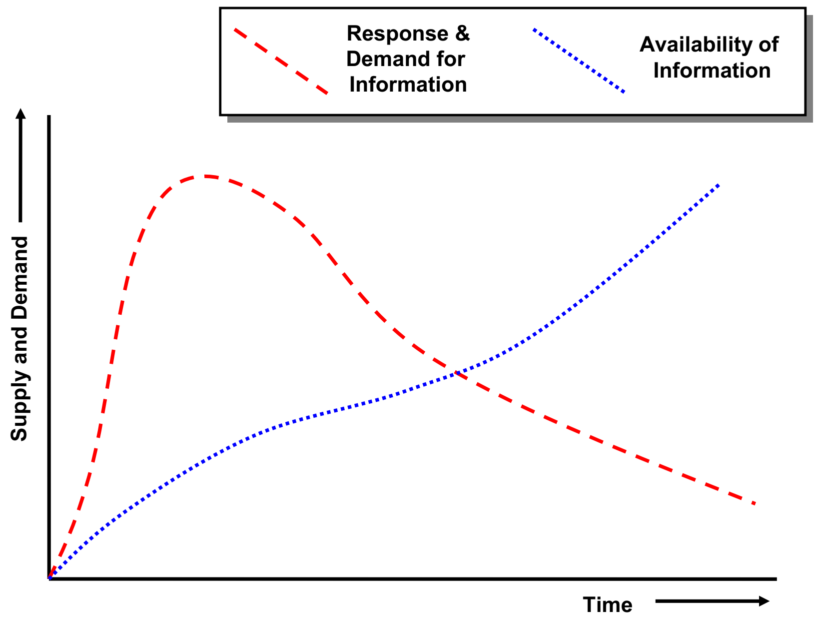


Figure 1: The Information Demand-Provision Gap following an emergency event (based on work by Peter Power, Visor Consultants, 2004)

1.3 Integrated Emergency Management and the 5 C's

The guide also explicitly places GIS applications within the principles of Integrated Emergency Management and the framework of the Civil Contingencies Act 2004. One of the underpinning considerations in IEM, which is elaborated in detail in section three, are the '5 Cs':

- **Command** – the ability to effectively direct operations at levels from the strategic, through tactical to operational;
- **Control** – the ability to ensure that directions are implemented in line with the command instructions;
- **Co-ordination** – the ability to ensure that activities of individual agencies and personnel within agencies are working in concert towards common objectives;
- **Co-operation** – the ability for individuals and organisations to work effectively and efficiently together in pursuit of common objectives;
- **Communication** – the ability to derive and pass information between individuals and organisations in such a way that:
    - Command decisions are appreciated and understood;
    - Control directions are appreciated and understood;
    - Multiple agencies involved in a response are informed of their role and responsibilities and their resources and constraints are known to other agencies;
    - Situational information that is pertinent to higher levels of command (e.g. the failure of allocated resources to control a fire or a building collapse) is passed up the command chain and between agencies as appropriate (in pursuit of what is termed a 'Common Operational Picture');
    - The media are supplied with appropriate, suitable and sufficient information to meet their requirements;
    - The public, affected businesses and other individuals and agencies are warned and informed about the developing situation and any actions that they may be advised to take.

It will be demonstrated in this guide that data, information and GIS have a critical role in the effective discharge of these functions in preparing for, responding to and recovering from emergencies. None of these functions, of course, take place for the first time in an emergency situation and the Civil Contingencies Act and the associated regulations and guidance focus to a large degree on preparing for emergencies.

> Consider the findings of two reports of 2004:
>
> *The FBI's information systems were woefully inadequate. The FBI lacked the ability to know what it knew: there was no effective mechanism for capturing or sharing its institutional knowledge.*
>
> The 9/11 Commission Report, July 2004
>
> *We should never forget how important apparently dry looking systems can be – and we should never undervalue the people who administer them. The consequence when these systems go wrong can be devastating.*
>
> Sir Michael Bichard, Press Conference on the release of the Bichard Inquiry Report, June 2004

All of the processes of IEM are 'information hungry' and much of the required information is Geographical Information (GI). It is for this reason that GIS represents a significant tool to decision makers at all levels in an IEM context, not only because GIS supports the effective management of existing data, but also because analytical and modelling tools support the generation of new information, and permit the integration of data from multiple sources. In an information management context this is termed 'adding value' or 'leveraging' information; in an IEM context it supports evidence-based decision making and the development and maintenance of a Common Operational Picture, the cornerstone of a co-ordinated approach.

Box 2: The Geography of an Emergency

Longley *et al*. (2005) in their book *Geographic Information Systems and Science*, offer a case study of how critical geographical factors are to decisions made in responding to an emergency. On the evening of 21st May 2001 a major fire broke out in an old building in City University, London. A series of geographically-related decisions had to be made during, and in the aftermath of the incident at a variety of different scales and levels of authority and responsibility:

- Staff and students were evacuated safely, using map-based instructions and a geographical awareness of the layout of the building;
- Local fire crews were dispatched using address and street-based routing systems;
- The police closed nearby streets and re-routed local traffic;
- Additional fire crews were dispatched, as risk assessments permitted, from other parts of London;
- Aerial thermal imagery of 'hot spots' in the fire were digitally relayed from helicopter to fire crews on the ground;
- Micro-scale mapping of building damage which included the emergence of secondary hazards, including exposed asbestos;
- The planning and implementation of room allocations for scheduled examinations, including publicity posters to guide students to the new venues;
- The search, by commercial firms using GIS, for appropriate and suitably located office space to house displaced staff during the reconstruction work;
- The decision to target publicity in the international press on the basis of coverage of the fire: many overseas newspapers gave the impression that the University had all been destroyed so students might look elsewhere for degree courses and where that coverage had been highest, so the positive publicity also had to be highest;
- The restructuring programme in the aftermath of the fire achieved positive gains in the use of space, in part facilitated through space-planning software.

This example illustrates the geographical dimensions of a single emergency and this is typical of emergencies in general. As there is a clear geographical dimension to emergencies, GIS as a set of tools that enable planners and responders to account for this dimension is of critical importance. This guide elaborates this point and sets out in detail how to capture Geographical Information and develop GIS for effective and integrated emergency management.

Section Two

Emergencies and Disasters

Summary

Emergencies and disasters usually have a very clear geography to them: they happen in places or in areas, affecting other places or areas and the severity of the impacts depends upon the spread of the impacts in relation to the distribution of vulnerable communities, individuals, facilities, resources, infrastructure and environments. Before moving on to GIS it is important to consider the geographical dimensions of emergencies and Integrated Emergency Management.

2.1 The Nature of Emergencies and Disasters

Emergencies can, by their very nature, be extremely diverse. Some of the key variables are:

- whether the incident(s) and impact(s) are localised or widespread
- whether the cause is simple or complex, which has implications for its management
- whether it was a single incident or a repeated incidence
- whether the emergency was predicted (and if so over what timescale) or unforeseen
- whether it was accidental, deliberate or 'natural'
- whether it was rapid onset (acute) or slow onset (chronic) in character
- whether they have an identifiable scene or not (see table 1).

As a consequence of this, there are widely varying requirements of planners and responders at different levels of command, and within and between multiple agencies. For instance, a rapid onset emergency such as a serious fire and chemical release demands rapid and decisive action in a timeframe that does not necessarily allow for a highly detailed analysis of potential consequences and the implications of different response scenarios. In contrast, a 'creeping crisis' or slow onset emergency, especially where there is prior warning of key characteristics such as magnitude, severity, location and timescale, may permit a detailed analysis of the various options for possible prevention, mitigation and response. Indeed the case for detailed problem analysis and assessment of response options makes very sound business sense. For instance, the School of Veterinary Medicine at Penn University in the US reports that an outbreak of avian influenza in 1997 took several months and cost the State of Pennsylvania $3.5 million to control, and this was before the University had developed a functioning GIS for animal disease control. In 2001, when the GIS was operational, researchers were able to identify the infected poultry flocks, identify surrounding flocks which were at risk by virtue of their location and plan for the transport and disposal of infected carcasses to minimise risk of further infection. The outbreak was controlled in less than a month and at a cost of $400,000.

From a geographical perspective, different kinds of emergencies have different characteristics, illustrated in figure 2 and table 2.

Type of Emergency	Example
A. Single Location	
Fixed site	Industrial plant, school, airport, train station, sports stadium or city centre
Corridor	Railway, motorway, air corridor or fuel pipeline
Unpredictable	Bomb, chemical tanker or random shooting
B. Multiple locations	
Multiple locations	Linked, possibly simultaneous or explosions at different sites
C. Wide area	
Large area	Toxic cloud, loss of electricity, gas, water, communications or flooding
Whole area	Severe weather, influenza pandemic or foot and mouth disease
D. Outside Area	
External emergency	Residents from one area involved in an emergency elsewhere e.g. coach or plane crash, passenger ship sinking or incident at football stadium
	Evacuees into one area from another UK area
	Refugees from an emergency overseas

Table 1: Emergencies classified by geographical extent
(Source: www.ukresilience.info)

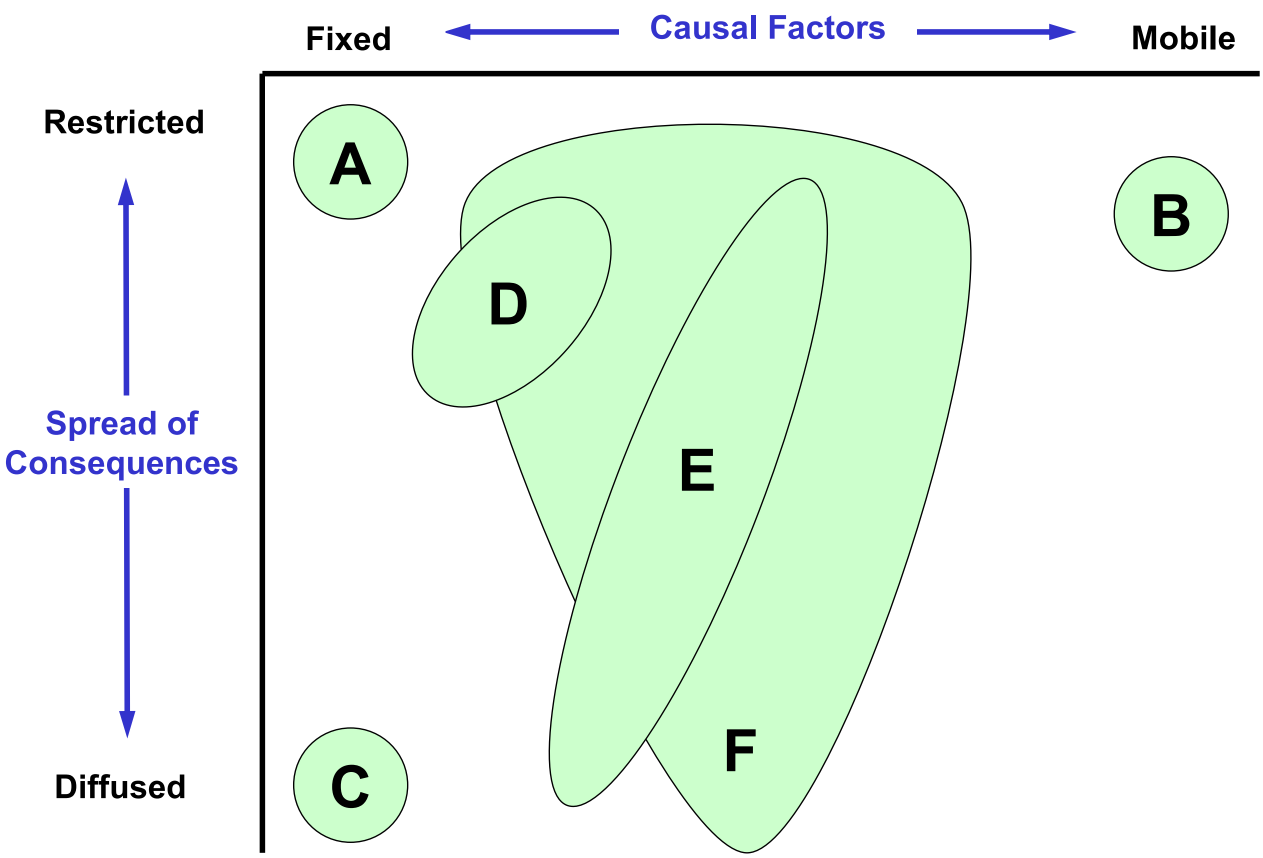


Figure 2: a typology of the geography of emergencies and disasters
(see table 2 for explanatory notes)

Region	Examples / Characteristics
A	The cause and direct consequences are focused on a small area. The sudden slump of a coal spoil heap onto a school in Aberfan, Wales in 1966 is an example of this. However, the human consequences of such a disaster can radiate through social networks over a wide area and be very long lasting.
B	An incident such as a multiple-pile up in fog on a motorway is one where some of the causal factors (cars) combines with a temporary fog bank to cause a locally serious emergency with loss of life, with some wider consequences due to road closures.
C	An incident such as the nuclear reactor fire at Chernobyl, Ukraine in 1986 is one where the causes of the incident are site-specific, but where the direct consequences (radiation fallout) were international in scale.
D	The 1953 floods on the East Coast of England were caused by a storm surge combining with high spring tides. Both of these were multiple, widespread causal factors and the consequences were spread from the Humber to the Thames with over 300 deaths.
E	The South Asian Tsunami of 26th December 2004 was initially caused by a sub-sea earthquake off the coast of Sumatra but the tsunami, itself the cause of the death and destruction of property, was both fast moving and international in scale.
F	Health emergencies can vary from the highly localised (e.g. Legionnaire's Disease outbreak from a single cooling system, affecting a local community), through to outbreaks of animal (e.g. Foot and Mouth) or human disease (e.g. SARS) which have the potential to spread between countries and continents.

Table 2: explanation of the regions identified in Figure 2

Resilience, as well as hazards and threats, is also geographically uneven. Figure 3 illustrates work done by the Met Office which identifies the relative severity of a gust of wind measuring 75mph across the UK as a whole. Severity is different to risk: risk is a function of likelihood and magnitude of impacts. Severity of impacts is related to resilience and resilience is to a large degree a function of experience. A gust of 75mph in North Wales and the West Coast of Scotland will, all other things being equal, be less severe in terms of its impacts as it is a more common occurrence (being rated as an approximately 1 in every 3 year event). As a consequence of this trees are more able to withstand the wind (or they have already been blown over), houses are constructed with this probability in mind and structures such as power lines are built and located to be resilient. In contrast, the metropolitan area of London can expect to experience gusts of this level approximately only once every 70 years; the 'abnormal' nature of the occurrence means that the impacts will be much greater, both in terms of people's expectations and the consequent physical disruption and damage.

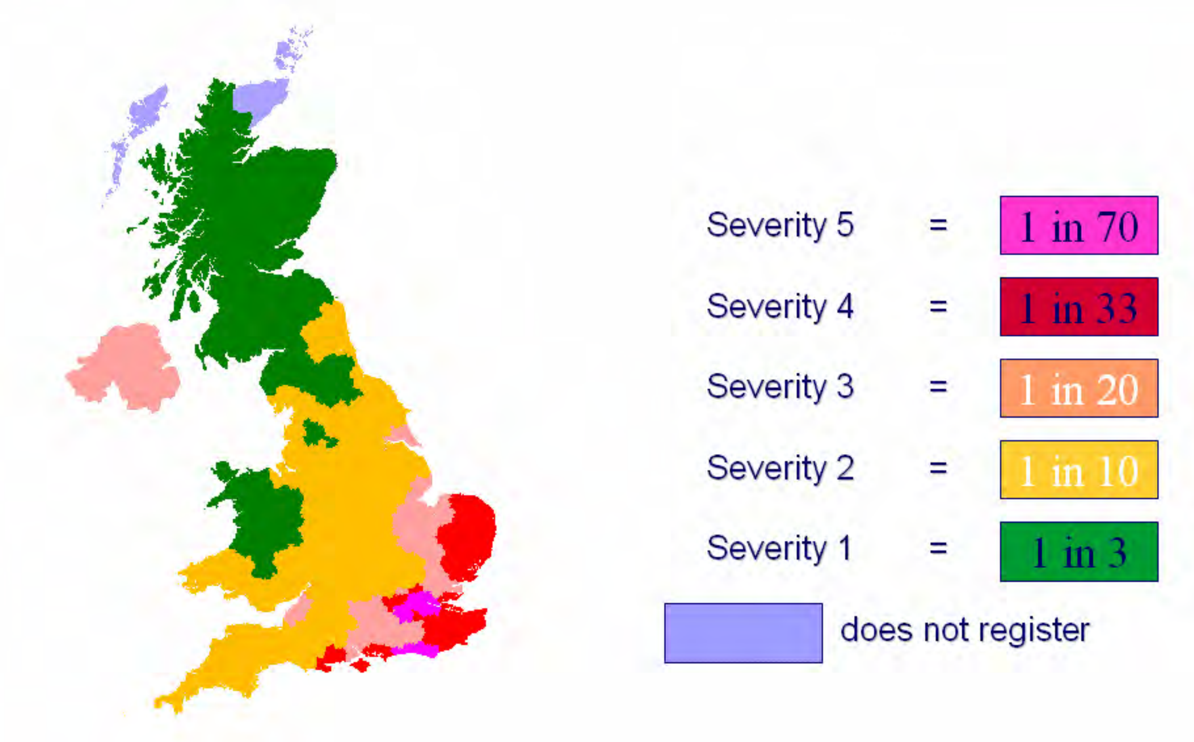


Figure 3: the relative severity of a gust of wind of 75mph across the UK as a whole (Courtesy of the Met Office)

By the same token the impact of given level of flooding in a densely populated urban area outweighs the impacts of a flood of equal magnitude in a sparsely populated rural area; this is effectively common sense, but we still need tools to identify hazards, assess risks and measure degrees of magnitude of impact, all of which have an explicitly geographical dimension.

So, different kinds of emergencies need to be prepared for and responded to in different ways and recovery from different types and levels of emergencies clearly poses different types and scales of requirements. The UK model of Integrated Emergency Management is intended to establish a framework to prepare for and have the capabilities to respond to and recover from such a range of potential emergencies.

Section Three

Integrated Emergency Management

Summary

This section provides an overview of the processes of Integrated Emergency Management (IEM) established in the Civil Contingencies Act 2004 and associated guidance. IEM is based around six processes - Anticipate, Assess, Prevent, Prepare, Respond and Recover – each of which is elaborated here.

3.1 Integrated Emergency Management

UK doctrine for IEM identifies six processes. Note that these are processes and activities as distinct from phases. They are:

1. **Anticipate:** knowing what might happen is important in being able to frame and scale an appropriate response. Emergencies arise from either hazards (non-malicious) which may be 'natural' (e.g. severe weather) or human (e.g. industrial accidents) or threats (malicious and deliberate) and their very nature is that they are more or less unpredictable in detail. However, 'horizon scanning' and effective anticipation of hazards and threats is essential.
2. **Assess:** appreciating the spread, severity and consequences of anticipated hazards and threats needs to be set within a risk assessment framework. Risk registers are developed and maintained at the local, regional and national level and it is important that they reflect the changing nature of hazards and threats and the nature of the population, environment and national security context in their makeup.
3. **Prevent:** it is intrinsically preferable to prevent an emergency than have to deal with its consequences. If an area that has suffered repeated flooding is assessed to be at high risk of flooding on an annual basis and bankside engineering and floodwater storage works have the potential to significantly reduce that risk, this is likely to result over time in both financial savings and reduced potential for loss of life and damage to quality of life.
4. **Prepare:** not all hazards and threats are foreseen and not all of those that are can be prevented. It is therefore critical to have structures, processes and resources in place to deal with emergencies and mitigate their effects. Central to this is emergency planning which falls into development (creating, implementing, reviewing and maintaining) and exercising and training processes.
5. **Respond:** emergencies are almost always responded to at the operational level by one or more of the 'blue light' emergency services. In the event of an incident that requires a co-ordinated multi-agency response, a specialized (e.g. CBRN) response or the rapid establishment of a higher level of command, procedures are established to escalate that response in a way that is appropriate. This response will draw heavily on established procedures, frameworks and resources that have been the subject of training and exercising prior to a 'real' incident.
6. **Recover:** although the involvement of the emergency services may be relatively limited in time, the process of recovering from an emergency can take months or years and there are effects, perhaps most notably those of personal loss and trauma, that extend over decades. There are medical, site clearance, decontamination, reconstruction, risk assessment, counseling and many other dimensions to recovery,

some of which will overlap with the emergency response phase, others of which succeed it over varying timescales.

These processes are underpinned by eight guiding principles for emergency response, which are:

1. DIRECTION – clarity of purpose is delivered through a strategic aim and supporting objectives that are agreed and understood by all involved to prioritise and focus the response.
2. INTEGRATION – effective co-ordination exists between and within organisations and tiers of response as well as timely access to appropriate guidance and support.
3. SUBSIDIARITY – co-ordination occurs at the lowest appropriate level; local responders are the building blocks of response on any scale.
4. PREPAREDNESS – all individuals and organisations that might have to respond to emergencies are prepared and clear about roles and responsibilities.
5. CONTINUITY – response to emergencies is grounded in the existing functions of organisations and familiar ways of working, though delivered at a greater tempo, on a larger scale and in more testing circumstances. Sustainability is a key issue.
6. COMMUNICATION – good two-way communication is critical to effective response. Reliable information is passed correctly and without delay between those who need to know, including the public.
7. CO-OPERATION – there is positive engagement based on mutual trust and understanding to facilitate information sharing and deliver effective solutions to issues as they arise.
8. ANTICIPATION – there is ongoing risk identification, analysis and mitigation so that potential direct and indirect developments are anticipated and managed flexibly.

Although these relate to IEM as a whole, these principles equally underpin the development and application of GIS within the context of IEM. The following presentation and discussion of GIS will identify a number of key themes, around anticipation, direction, preparation, integration, leadership, communication, continuity and co-operation – the principles are the same.

Section Four

The Civil Contingencies Act

Summary

This section provides an overview of the Civil Contingencies Act 2004, focusing specifically on issues around information sharing and co-ordinated working.

4.1 The Civil Contingencies Act

The Civil Contingencies Act (2004), referred hereafter as 'the Act', together with accompanying regulations and non-legislative measures, delivers a single framework for UK Civil Protection to meet the new challenges of the 21st Century. It is a wide-ranging piece of legislation and only the key elements are summarised here. For the act itself, the accompanying regulations, issues in relation to the devolved administrations and guidance consult www.ukresilience.info

Key to the Act is a definition of what constitutes an emergency:

- An event or situation which threatens serious damage to human welfare;
- An event or situation which threatens serious damage to the environment;
- War, or terrorism, which threatens serious damage to security.

It is important to note that the focus is on consequences rather than causes, so the Act applies equally to events or situations that originate outside of the UK as it does for those within UK boundaries.

Part 1 of the Act focuses on preparations by local responders for localised emergencies and Part 2 sets out the means to establish emergency powers for very serious emergencies which affect a larger geographical area. Part 1 of the Act divides local responders into two categories (1 and 2) and different duties apply to each. Category one responders include:

Local Authorities

- Local Authorities

Government agencies

- Environment Agency
- Scottish Environment Protection Agency
- Maritime and Coastguard Agency

Emergency Services

- Police Forces
- British Transport Police
- Police Service of Northern Ireland
- Fire Authorities
- Ambulance Services

NHS Bodies

- Primary Care Trusts
- Health Protection Agency
- NHS Acute Trusts (Hospitals)
- Foundation Trusts
- Local Health Boards (Wales)
- Welsh NHS Trusts providing public health services
- Health Boards (Scotland)
- Port Health Authorities

The following duties are placed upon Category 1 responders:

- Assess local risks and use this to inform emergency planning;
- Put in place emergency plans;
- Put in place Business Continuity Management (BCM) arrangements;

- Put in place arrangements to make information available to the public about civil protection matters and maintain arrangements to warn, inform and advise the public in the event of an emergency;
- Co-operation and information sharing;
- Provide advice and assistance to businesses and voluntary organisations about BCM (local authorities only).

It should be very clear that information and the effective and efficient flow of information is pivotal to almost all of these duties.

Category two organisations include:

Utilities

- Electricity
- Gas
- Water and Sewerage
- Public communications providers (landlines and mobiles)

Transport

- Network Rail
- Train Operating Companies (Passenger and Freight)
- Transport for London
- London Underground
- Airports
- Harbours and Ports
- Highways Agency

Government

- Health and Safety Executive

Health

- Common Health Services Agency (Scotland)

These Category 2 organisations are placed under the lesser duties of co-operating with Category 1 organisations and sharing relevant information.

The Act also establishes the means through which the activities of these responders are to be co-ordinated at local and regional levels. The key groups that have responsibility and authority to drive forward co-operation and information sharing in preparing for and responding to emergencies are as follows:

Local Resilience Forums (LRFs)

The LRF is a strategic co-ordinating group which matches, in the anticipation, prevention and planning phases, the strategic co-ordination group that is usually established by the police during the response and recovery phases of a major incident. It is a senior group, with a primary focus on co-operation and co-ordination. Outside of London, LRF areas equate with those of Police Force Areas.

Regional Resilience Teams (RRTs)

RRTs (and the National Assembly for Wales) are established to ensure effective two-way communication between local responders and central government. They ensure that planning is co-ordinated and that local responders have the support that they need to meet their responsibilities.

Regional Resilience Forums (RRFs)

The RRF is a mechanism for ensuring multi-agency co-operation at the regional level. It is a body for facilitating and supporting rather than directing co-operation and it does not have any statutory powers.

4.2 Information Sharing

Under the Act local responders have a **duty** to share information. This information will take may forms, for instance describing capabilities, resources, processes, contact details for key personnel. Only some of these will be spatial data and information, but these are critical in IEM.

> *Information is shared between Category one and two responders as they work together to perform their duties under the Act. Information sharing is a crucial element of civil protection work, underpinning all forms of co-operation* (Section 3.1).
>
> *The process of sharing information is crucial to … the duty* [for example] *sound risk assessment relies on obtaining accurate information about the nature of the hazard, the probability of a hazardous event occurring, and the potential effects and impact on the community if it does* (Section 3.3).
>
> *Information sharing is necessary so that Category one and two responders are able to make the right judgements. If Category one and two responders have access to all the information they need, they can make the right decisions about how to plan and what to plan for. If they do not have access to all information, their planning will be weakened* (Section 3.4)
>
> ***Emergency Preparedness* (2005)**[1]

In sharing information the Act states that the initial presumption should be that **all** information should be shared, although these are some exceptions to this. It is important that these are set out clearly as uncertainty about roles, rights and responsibilities in this regard is well known to be corrosive of attempts to foster information sharing for co-operative working. Sections 5, 8 and 9 elaborate on these issues, with 8.4.3 providing some detailed information on security, confidentiality and access to data and information.

[1] www.ukresilience.info

Section Five

Data, Information and Decision Making

Summary

GIS are computer-based tools for supporting decision making. For the use of GIS to be effective it has to be informed by an appreciation of issues around data availability and quality and the way in which information is used in decision-making, especially under the specific conditions of emergency situations. This section provides a relatively brief overview of issues which are critical to the efficient and effective application of GIS in different kinds of emergencies and at different levels of incident command. Fundamentally it is about informed decision making in an emergency context.

5.1 Introduction

In essence a GIS is a collection of tools that transform geographically-referenced data into information that is fit for purpose. However, without data that are suitable and sufficient to support the creation of the intended information, GIS can provide no effective part in the decision making process. This section starts with a discussion of what data and information are, how they are commonly used in policy, strategic and tactical decisions under different conditions, and introduces some key issues around data quality and security and access to data.

5.2 Data, Information and Communication

Data and information are different things. Data are results, observations, counts, measurements, locations, attributes and other basic descriptive characteristics of things and places in a fairly 'raw' format. Information is more processed, ordered, summarised, selective and 'user-friendly' with the intention of assisting correct interpretation. Typically data are high-volume (a lot of records) whereas information is more tightly geared to the requirements of a specific end-use. One of the key strengths of tools such as spreadsheets, databases and GIS is their ability to transform, if appropriately used, data into information that can be appreciated and acted on more readily. However, it is important to recognise that data are almost universally imperfect, therefore the decisions that are based on them may be misguided, and even when data and information are strong, decisions may still be misguided. Evidence is also widely used as a term and it is defined here as something that is created from information, through further sorting, selection, distillation or triangulation with other sources. In this respect it is similar to the term 'intelligence'; although specifically associated with the work of the security and intelligence services, the term is also widely used in contexts such as local government and regional development in a way that broadly equates with information and evidence.

Data do not just exist, they are created. They are usually created with specific purposes in mind, and for this reason they may be sub-optimal when evaluated for an unforeseen purpose. As emergency management is to a large degree the process of dealing with unforeseen incidents, this is especially pertinent in this context. Data created for the purposes of asset management, public health, community safety or education may be neither structured, appropriately detailed or attributed for the purposes of emergency managers, but the reality is that we have to work with the available data, while also ensuring that future data are more suited in quality, content, coverage and availability.

Evidence-based practice is central to public sector businesses, equally underpinning strategy and policy decisions and resource allocation and management decisions. In emergency planning and management, however, the preparation and response processes operate across very different time frames; if a suitably structured evidence base for response is not available and structured for rapid development and application at the time of an incident, the evidence base for operations will be partial and weak. For this reason, sections 9 and 10 of this document focuses on data and information sharing, a critical element of IEM, as it is important to be able to evaluate the validity, suitability and sufficiency of all data and information for specific purposes. This is in part a technical evaluation relating to what can be summarised as data quality (section 8.3) but it is more broadly about understanding what information are seen to be needed and how they are used in different kinds of settings.

There is a tendency to see digital data and information as preferable under any circumstances to paper-based or anecdotal sources. Data and information can be seen as being either relatively formal or informal. Formal data might be a local authority property database; it is digital, quality assured, from a public sector agency and widely accepted to be of high quality. An informal source might be verbally referred information about the contents of a specific building. Rapid decision making under pressure requires data and information of different types (or degrees of formality) to be evaluated, interpreted and acted upon. Where there is doubt about the validity of a certain source it may be discarded and for this reason informal data may take precedence over formal data. For instance, during a major fire at a chemical plant in the NE of England in 2001, the evacuation phase was understood to be complete until a local fire officer indicated that a single elderly person lived in an isolated house within the industrial area, something which was not recorded in the local authority address register that was available to the emergency services staff. There are circumstances under which a reliance on informal sources is justified, but the emphasis must be on ensuring that (a) the formal sources are valid, suitable and sufficient for all potential applications at different levels in the IEM command and control chain, as well as for agency-specific applications, and (b) that the potential need to use information in an emergency for a legitimate purpose, other than that for which it was originally obtained, is recognised and authorised.

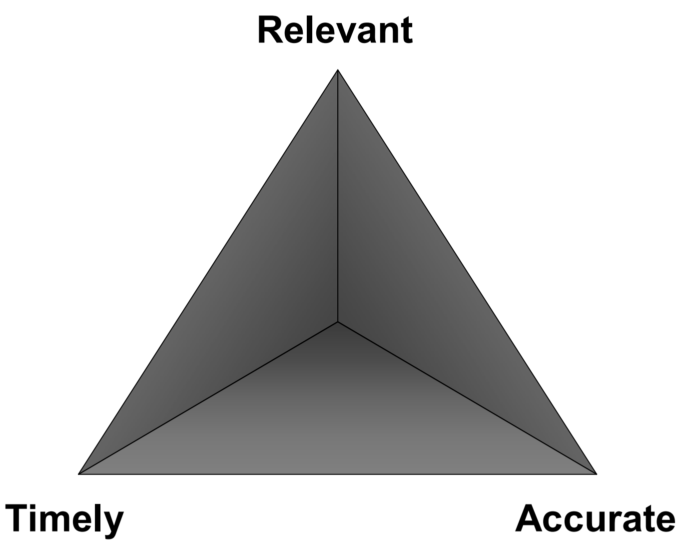


Figure 4: the three dimensions of good information

Figure 4 illustrates the three dimensions of good information. These are not, however, applicable equally to all those involved in managing an emergency. Information that is necessary and relevant to ‘front-line’ field responders would be ‘noise’ to higher level incident commanders and strategic issues that may be critical at the latter level could simply confuse those at lower levels of command. GIS and allied technology, including mobile data bearers such as the Airwave digital radio system, provide a framework for disseminating information in such a way that it is appropriately targeted to the requirements of different groups, and can support not just incident management and command information but also the 'back-flow' of situational information for tactical management and higher strategic decisions. Too much information can be a bad thing, and the emphasis must be on 'fitness for purpose', a theme that will come up again.

However, information does not just float between those who have it and those that need it, to be used the same way irrespective of recipient or context. A whole series of processes are involved in handling and communicating information, including:

- Providing
- Receiving
- Summarising
- Checking
- Collating
- Relaying
- Capturing
- Retrieving
- Prioritising
- Logging
- Distributing
- Responding
- Editing
- Filtering
- Recording

These are not of course specific to GIS, and the primary point is that the construction, transfer and application of information is far from simple.

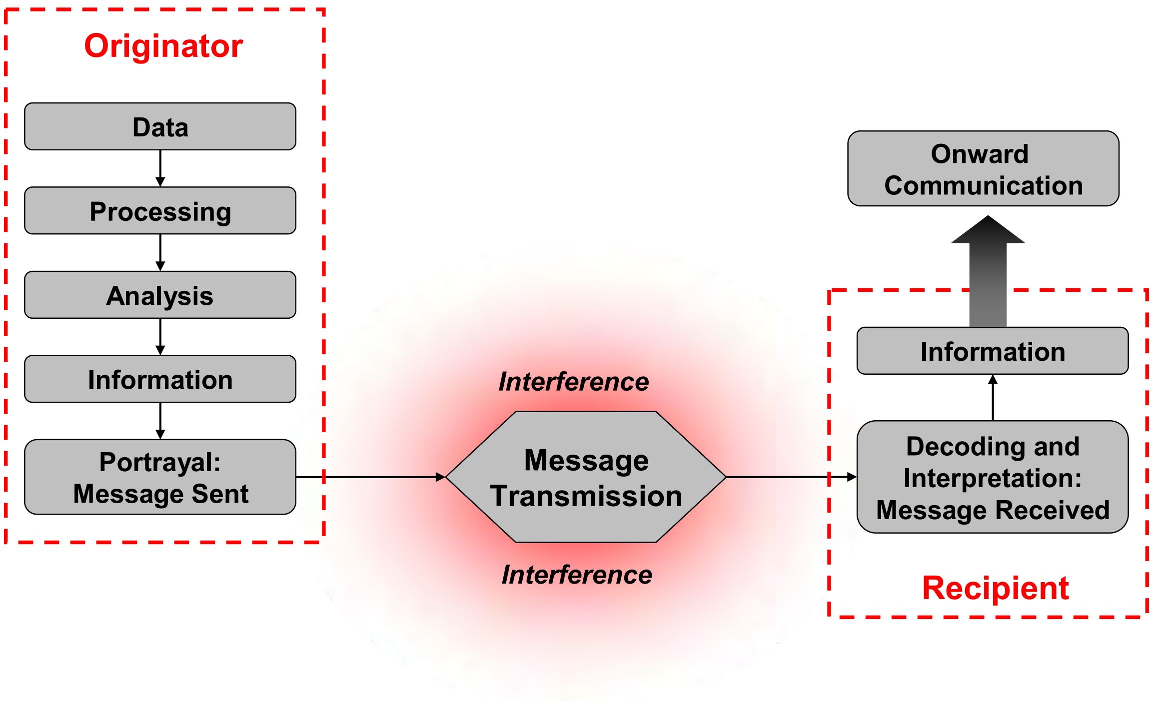


Figure 5: Data, Information, Interference and Interpretation in Communication

Figure 5 illustrates in simple schematic terms how information is developed by an originator and how interference (either 'environmental' or 'human') in transmission and personal interpretation can mean that the received message is different to the message that was (understood to be) sent. They key point here is that certain steps have to be taken to ensure clarity and unambiguity of message and purpose in all communications, including mapping. Messages must not only be received but also correctly understood.

In line with the argument through this document that GIS is a tool for managing Geographic Information (GI), which should be seen in the wider context of enriched Information (I) (see Box 1), all of these handling and communication processes and issues should be seen in the context of Knowledge Management (KM). Knowledge is often defined as something greater than information and evidence, which are in turn derived through the processing of data (Figure 6). Knowledge is acquired through a distillation of information, and it takes time to gain knowledge about a subject. It has been observed that information can exist independently but that knowledge is always associated with people. Knowledge is internally created from information as we digest and assimilate it, and the end result of this is a perspective on the situation in our own terms – communicating that so it is appreciated in terms another person can rapidly appreciate is difficult and complex (see Longley *et al*., 2005 in Appendix 2 for a more detailed discussion of GI Science and the context for GIS applications).

KM however is premised on the condition that much information, and the knowledge based on that information, is held (and often not very well organised) at the organisational as well as the personal level. To be semantically precise much of what is defined as KM is in fact focused on data, information and evidence, but as a set of organising principles for governing efficiency and equity of access to such resources, it is indisputably a good thing.

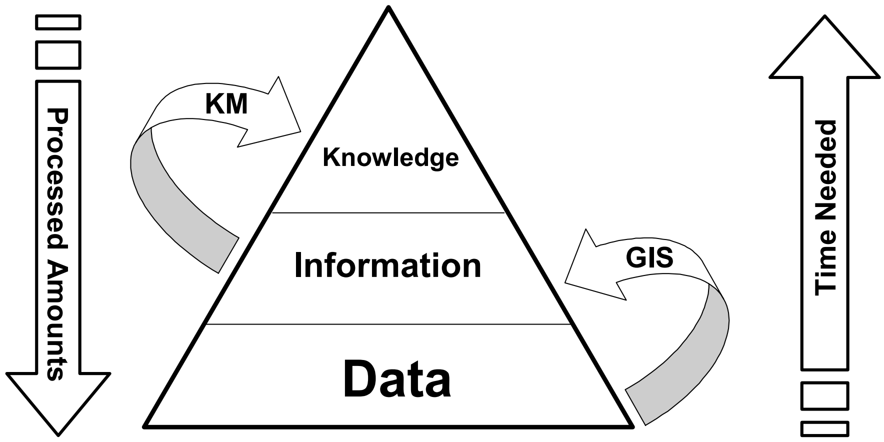


Figure 6: GIS and KM in the context of data, information and knowledge

Samuel Johnson (1709-84) observed that *'Knowledge is of two kinds. We know a subject ourselves, or we know where we can get information upon it'*. More recently the Improvement and Development Agency (IDeA) has defined KM as:

> *The creation and subsequent management of an environment that encourages knowledge to be created, shared, learnt, enhanced, organised and exploited for the benefit of the organisation and its customers.*

Effective emergency management is clearly something that requires not only the sharing of data and information, but also the ability to manage information of different types so that it can be accessed at the point of need. KM is about both people (ways of working and organisational cultures) and also about technology as an enabler to support people and organisations' requirements for information. In a GI context this embraces data and information that are held within organisations and in other organisations that should be working in partnership in an IEM context.

The key considerations are those of **awareness** (knowing what is available, what the quality and potential applications are, and how and where to access it), **capacity** (the skills base to source, analyse and disseminate data and information), **communication** (the technical and human channels to ensure that awareness is maintained, standards are observed and data and information can move freely as required) and **interoperability** (the ability of technical as well as human systems to work seamlessly together to provide information as, when and where required).

5.3 Models of Decision Making

IEM is to a large degree about decisions, which are in turn about making choices. Effective IEM is about making the right choices. Making the right choices is about (a) approach, (b) information and (c) ability and authority to pursue the determined course of action.

There is of course an almost impossible variety of decisions, but some of the key types are:

- Easy (routine) to Difficult (complex)
- Previously Experienced to Rehearsed to Unforeseen
- Inconsequential to Critical
- Single to Recurrent
- One-stage to Sequential and Contingent
- Single Objective to Multiple Objectives
- Individual to Group
- Structured to Unstructured
- Strategic to Tactical to Operational

It is clear that decisions relating to emergencies are of the more challenging type i.e. they are complex, contingent, relate to multiple objectives that are defined by a range of groups, they are commonly unstructured at the outset of an incident and a range of levels of Command and Control are involved.

Decision-making has been studied extensively and from a variety of different perspectives, including business management, informatics, sociology, economics and psychology. Early work established what is known as the rational model of decision making. In this model people are presented with a problem, they gather the relevant data to address it, analyse the data as appropriate to generate supporting information, evaluate the different options and then make what is the optimal decision under the circumstances. There are of course a number of assumptions underpinning this, namely that:

1. the problem is clearly defined;
2. the required data to understand the dimensions of the problem are available;
3. the tools to generate information on the problem are available and correctly applied;
4. the different options are accurately identified;
5. what constitutes the optimal decision is understood and agreed upon.

Subsequent work has studied the reality of decision-making in different contexts, and while the rational model remains attractive as the basis for making informed and considered decisions under ideal conditions, the specific circumstances surrounding an emergency are less than ideal and the assumptions outlined above may be invalid for the following reasons:

1. the problems may be multiple, developing rapidly and contingent on factors that are not yet fully appreciated;
2. the data requirements are not yet fully appreciated for the reasons above, and even core datasets may not be available to incident controllers due to inadequate preparation;
3. the tools to translate data into information may not be available or the available staff may not be sufficiently trained to make correct and effective use of them;
4. identifying options for tackling the incident is far more complex under pressure and where the contingencies are poorly understood;

5. achieving a common operational picture that is accessible and acceptable to different agencies and levels of operational control is hard to achieve and agreement on actions may be hindered by agency-specific cultures, interests or perspectives.

It is appropriate here to summarise what is understood to be characteristic of decision-making in an emergency context, as it has been observed that 'crises as well as civil turbulences or terrorist actions, can be characterised by "un-ness" – unexpected, unscheduled, unplanned, unprecedented, and definitely unpleasant'[2], characteristics which are distinctively different from other public-private sector decision contexts. These characteristics include:

- uncertainty
- complexity
- time pressure
- a dynamic event that is innately unpredictable
- information and communication problems (overload, paucity or ambiguity)
- heightened levels of stress for participants, coupled with potential personal danger.

Decision-making styles under these conditions vary between individuals and organisations, but a general distinction between an essentially intuitive approach and an analytical approach has been identified. The intuitive or 'naturalistic' approach is based on what 'feels right', based on previous experience, training and personal assessment of the observed circumstances and it supports rapid decision-making. The analytical approach is inherently slower, more intellectually and resource demanding, but it is permits a fuller consideration of the evolving situation, the resources available to address it and the risks associated with different paths of action. Different styles of decision-making 'fit' different processes of IEM and different roles and responsibilities. A major emphasis in IEM is on preparing adequately for a range of incidents that vary in their severity, location, contingencies, interdependencies, consequences and time-space overlap with other incidents. Preparation cannot reduce the complexity, time pressure or dynamic nature of emergencies, but it can permit controllers and responders to better appreciate what is happening, what might happen and be able to coordinate and communicate information flows that support effective decision making by all parties, at all levels of control and response. Figure 7 updates Figure 1 to illustrate how information needs to keep closer pace with the demand for information as both the intuitive and the analytical styles require information, although the latter is much more information-hungry.

[2] Crichton, M. (2003). *Decision Making in Emergencies*, Paper presented at NATO/RUSSIA ARW Forecasting and Preventing Catastrophes Conference, June 2003.

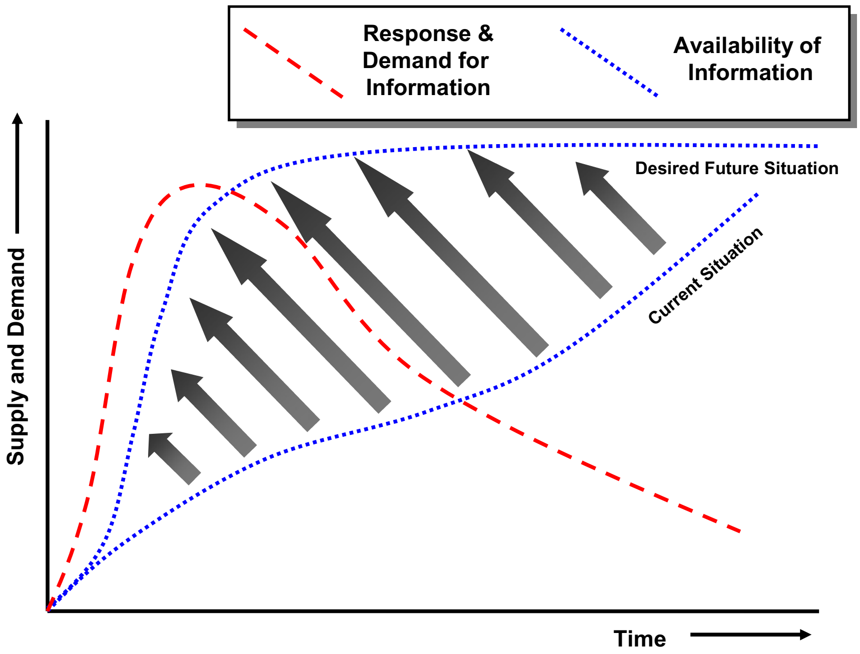


Figure 7: accelerating the provision of information to keep closer pace with demand

The AAPPRR processes of IEM do not all operate under the stress of emergency conditions and the emphasis in Anticipating, Assessing, Preventing, Preparing and Recovering must be on an analytical approach that is based upon data and information of the required breadth and depth and an appropriate level of quality. Indeed a critical element of preparation focuses on information as a resource that underpins effective response. In responding to an emergency different requirements are observed at different levels of incident control, and these are summarised in Table 3.

The picture is one where there are different kinds of requirements at different levels, but these requirements are more likely to be adequately met if preparation focuses on the core questions of:

- What might happen?
- What do we do if this happens?
- What do we need (to know) to frame and implement an appropriate and flexible response?

Imagination, anticipation and analysis are key to this, not just in horizon scanning or in contingency planning, but also in identifying what it is you need to know. At present information is dangerously underrated by many organisations in relation to emergencies, and this is something that has the potential to severely undermine their ability to conduct effective IEM.

Level	Nomenclature	Characteristics
Strategic	**Gold**	Gold command defines **'what to do'.** Gold has overall command and responsibility for an incident. In relatively minor incidents gold command may not be formally established, but is just nominally identified. Gold determines policy, overall strategy, resource deployment and the parameters within which lower levels of command will operate. This will include resources from multiple agencies if a single agency is identified as overall commander. This is most likely to be Police during a response, and local authority during recovery. A multi-agency Strategic Coordinating Group (SCG) may be established at Gold level if required and is intended to complement individual agencies' strategic management structures and procedures, not replace them. The SCG also has a communication and coordination function where an incident crosses boundaries and/or involves Government Offices, Lead Government Departments or Devolved Administrations. **Goals** at Gold level may be general, unclear, multiple and implicit. **Decision-making** should be analytical, in-depth and broadly-referenced, making use of specialist resources, and being able to develop and maintain a Common Operational Picture, identify and assess options and evaluate progress. **Information requirements** are broad and relatively unpredictable, but Gold commanders should avoid the 'long stick' intervention at lower levels of command that too much and too detailed information may encourage. **Information outputs** are varied, including tasking, situational awareness to Silver and meeting public, media and political interests.
Tactical	**Silver**	Silver command defines **'how to do it'.** Silver determines and directs the tactics of incident management within the strategy, parameters and with the resources defined at Gold level, which may include resources from multiple agencies. **Goals** at Silver level may be multiple and relatively general, although they should be clear and explicit. **Decision-making** needs to identify and evaluate options which necessitates an analytical approach, although pressure or rapidly changing circumstances may force an intuitive approach. **Information requirements** are more specific than those of Gold, focusing on hazards, vulnerabilities, risks and resources that shape the translation of policy and strategy into practice. **Information outputs** are task-specific to Bronze level, concerned with maintaining situational awareness at Silver and Bronze and the upward transfer of changing situational information that is of relevance to Gold.
Operational	**Bronze**	This level of command is concerned with **'doing it'.** Bronze commanders work within a functional and/or geographical area of responsibility to implement the tactical plan as defined by silver command. The Bronze commander must have a clear understanding of the tactical plan and have access to information that is critical to its execution on the ground, including the activities of other agencies that may be pertinent to their own goals and actions. **Goals** at Bronze level may be single or fewer in number, but should be specific, clear and explicit. **Decision-making** may be characterised by an intuitive approach, based on problem-recognition from previous experience, training and exercising. **Information requirements** are task-oriented. **Information outputs** are fed upwards to maintain an accurate and relevant Common Operational Picture.

Table 3: characteristics of civilian levels of civilian[3] command and control during an incident response

[3] Military terminology reverses Operational and Tactical in the hierarchy, so that Operational equates with Silver and Tactical with Bronze.

Section Six

GIS: an overview

Summary

This section provides an overview of GIS data models, tools and techniques. Related concepts such as scale, the integration of data using a 'spatial key' and effective communication with maps are covered. The emphasis in this section is on identifying and illustrating key functionalities of GIS but it is not intended to be a detailed training manual of how to implement such functions.

6.1 Introduction

As set out in the introduction, geography matters to IEM: hazards are spatially distributed, and generally very uneven in that distribution, vulnerable facilities are distributed and clustered in space, and resources may be sub-optimally located to deal with anticipated and actual emergencies. GIS are computer-based systems for the integration, storage, querying, analysis, modelling, reporting and mapping of geographically-referenced data.

The most commonly used conceptual model for a GIS is the overlay model (Figure 8). At its core, GIS stores 'layers' of data that share a common mode of geographical referencing, for instance the GB Ordnance Survey Grid or Latitude and Longitude. Because the layers of data have a common geography they can be superimposed upon one another. These layers are typically thematic, so one layer may be a terrain model, another may be hydrology, another 100 year flood plains, another all residential properties, another roads and so on. By holding each theme as a separate layer they can be analysed separately, and also in combination with each other.

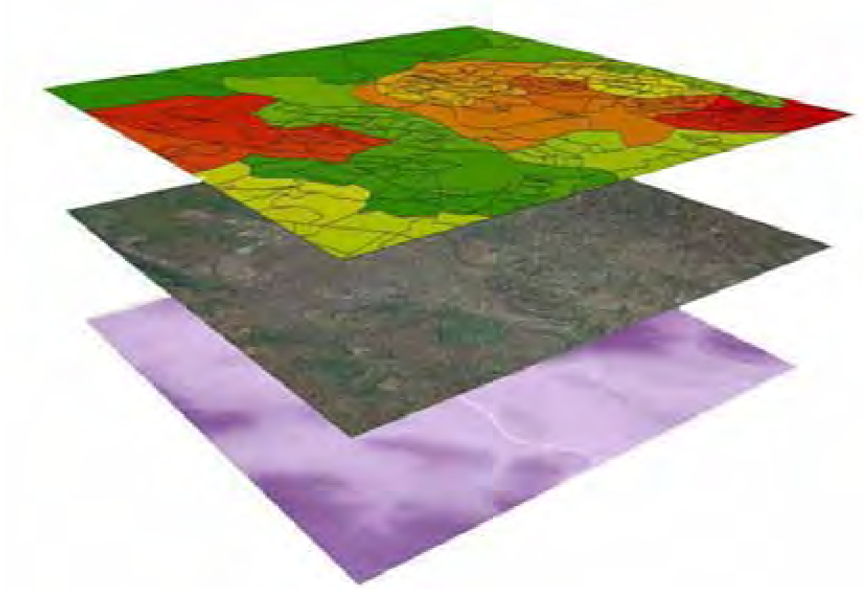


Figure 8: GIS depends upon 'layers' of data being accurately georeferenced relative to each other and an externally accepted standard framework such as the National Grid of Great Britain (Image Courtesy of Bristol City Council)

For instance, epidemiologists might be interested, as the first stage of an analysis, in the geographical distribution of patients with a specific disease. This might show a level of clustering that requires further investigation, and the second stage might be to superimpose other thematic layers which may have a causal association with the distribution of the disease.

The classic example of this is the work, 150 years ago, of Dr John Snow who identified cholera as being a water-borne illness. In September 1854, during the last great cholera epidemic in Great Britain, 500 people living in the Broad Street area of London died of the disease within a ten-day period.

Dr Snow established that cholera was a water-borne illness and he arrived at this conclusion by plotting the location of each of the deaths on a street map and then adding (as a separate thematic layer) the location of public water pumps. Dr Snow ordered the removal of the handle of a pump that was in the centre of the cluster of deaths, and thus ended the cholera epidemic.

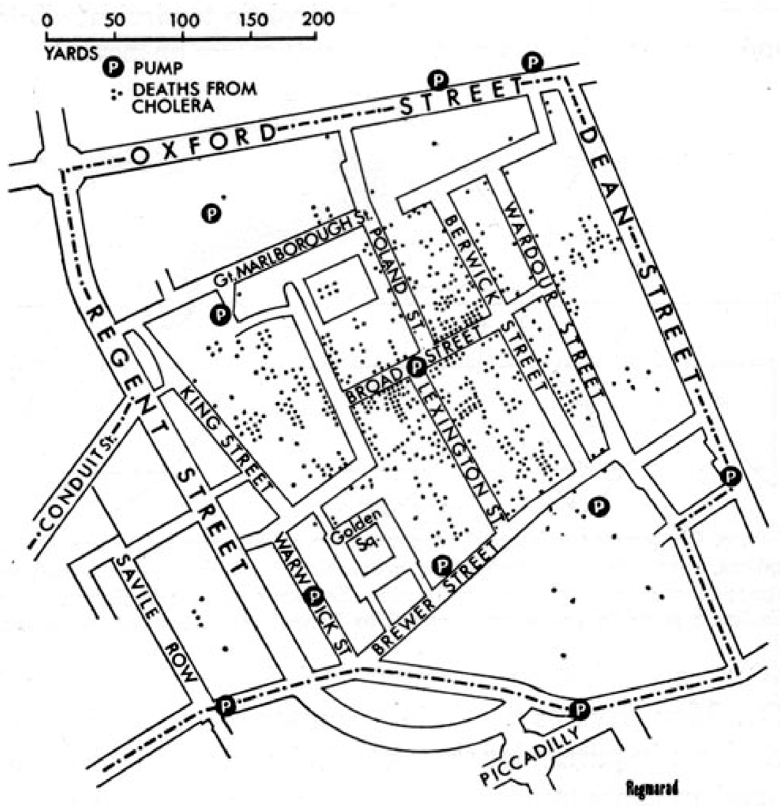


Figure 9: John Snow's Cholera maps of 1854 (redrafted) [4]

Figure 10: nature reserve boundaries superimposed on a 1:25,000 Scale OS Map Backdrop

'Backdrop mapping', typically supplied in the UK by the Ordnance Survey (OS), also utilises the same mode of geographical referencing, so thematic data layers may also be superimposed upon digital OS maps for location, orientation, interpretation and other purposes.

For instance, in figure 10 three Sites of Special Scientific Interest (nature reserves) are overlain on a 1:25,000 scale (see box 3) base map.

[4] http://www.ph.ucla.edu/epi/snow/mapsbroadstreet.html

Box 3: Map Scale

Map users are generally comfortable with the idea of scale. For example, a 1:50,000 scale map implies that 1 unit of distance on the map equates to 50,000 units of distance on the ground. It is also widely appreciated that paper maps which are produced at different scales contain more information at larger scales (note the terminology that 1:10,000 is a larger scale than 1:50,000, which means that maps of scales around 1:250,000 or 1:1 million are generally termed small scale maps, that is maps with relatively little detail).

There can however be a misconception relating to GIS that the ability to zoom in and out of digital maps has rendered the idea of scale somehow irrelevant. This is absolutely not the case, and a related concept is important, that of nominal scale.

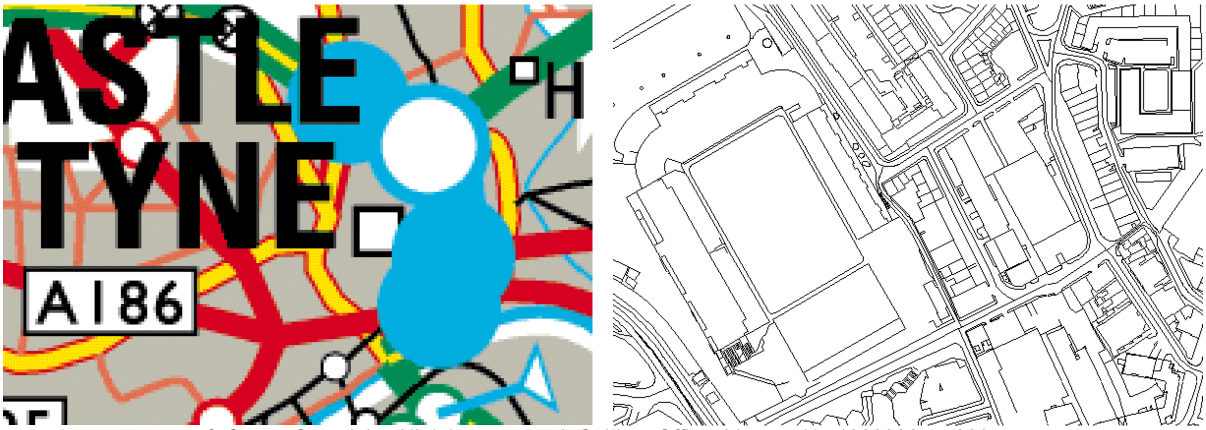


Figure 11: exactly the area in the centre of Newcastle upon Tyne, illustrated using 1:250,000 scale raster map and 1:1,250 Vector LandLine^{TM} data

Figure 11 illustrates a relatively small area of the centre of Newcastle upon Tyne, less than 1km from East to West. The image on the left is of 1:250,000 scale mapping. The image on the right is vastly more detailed, illustrating with much greater accuracy the location of buildings, football stadia, shopping centres, hospitals and roads. In the 1:250,000 map the Hospital (the collection of buildings upper right in the LandLine^{TM} map) has been generalised to a small white square and the letter H. Roads in contrast, have been magnified to many times their true size and consequently they have had to be relocated to fit them all in.

Nominal scale describes the scale at which a given mapping product was intended to be used. Clearly the road atlas style map with a nominal scale of 1:250,000 can be displayed at a scale of 1:2,500, but it yields very little of value and may in fact be misleading, yet the LandLine^{TM} data with a nominal scale of 1:1,250 would simply degenerate into an indistinguishable mass of lines at around 1:10,000, yet it retains a great deal of value at larger scales.

However, GIS can take us a long way past mapping and the visual analysis of spatial features. Three key attributes of any record within a GIS database are:

- **What** is it? This would be the defining and secondary attributes of the object or area. A defining attribute might be whether the object is a residential building, an industrial site or a nature reserve. Secondary attributes might then respectively be whether the building is a private dwelling or a care home, whether the industrial site is a COMAH site or whether the nature reserve is designated for its geological, flora or fauna interest.

- **When** do the records relate to? The temporal dimension of records can be highly variable. For instance, some records have a start and an end date/time, some will have a single date (e.g. date built or designated) and others may be cyclical or periodic, such as opening or operating times.
- **Where** are the objects on the ground? It has been estimated that approximately 85% of corporate datasets are geographically referenced in one way or another. For many organisations this is integral to their operations (for instance, in many utilities' asset management), whereas in others it is less direct or it may be incidental (for instance GP practices where patient records are referenced to their home address). However, even where the geographical location of individual records is not critical to the data originator, when used in another context (for instance during the targeted evacuation of those with specific health conditions) it becomes very significant.

  The geography of records is thus significant in two ways:

  - It is available to target individuals / properties / areas as required, even if such an application was not envisaged by the data originator;
  - Critically, a geographical location provides the means by which disparate datasets can be integrated (Box 4).

Box 4: Integrating disparate datasets using a 'spatial key'

It has been estimated that approximately 85% of all corporate information is spatially referenced in one way or another i.e. it is Geographical Information (GI – see Box 1). This does not mean that all organisations use GIS to access this proportion of their records, but that in the order of 85% of all records could potentially be mapped. To map a record in a dataset, some level of geographical reference must be included. This could be a grid reference, a full postal address, a postcode, the name of the Census Output Area it falls within or the name of the street or area it refers to. All of these could, albeit some with more processing than others, be used to map a record. It should also be noted that the level of geographical precision and accuracy that can be achieved with some geo-referencing frameworks are much better than with others. For instance, a full postcode can be shared by several residential properties and as such is less accurate than the full postal address, which is equivalent to a ten figure (to the nearest 10 metres) Ordnance Survey Grid Reference.

Different agencies and different applications within agencies have historically used different geo-referencing frameworks. For example, within a local authority, streetlights may be located using a very precise grid reference, schools and care homes may be associated with a full postal address, industrial units may be defined by a series of addresses, bridges may be associated with a street segment and flood plains will be represented by areas, as will demographic profiles, nature reserves, land use and planning zones. Linking records that use disparate geo-referencing frameworks within, and across agencies is not without its problems, but it can be done. Figure 12 illustrates the five generic geo-referencing frameworks that public and private sector agencies employ, and gives examples for each.

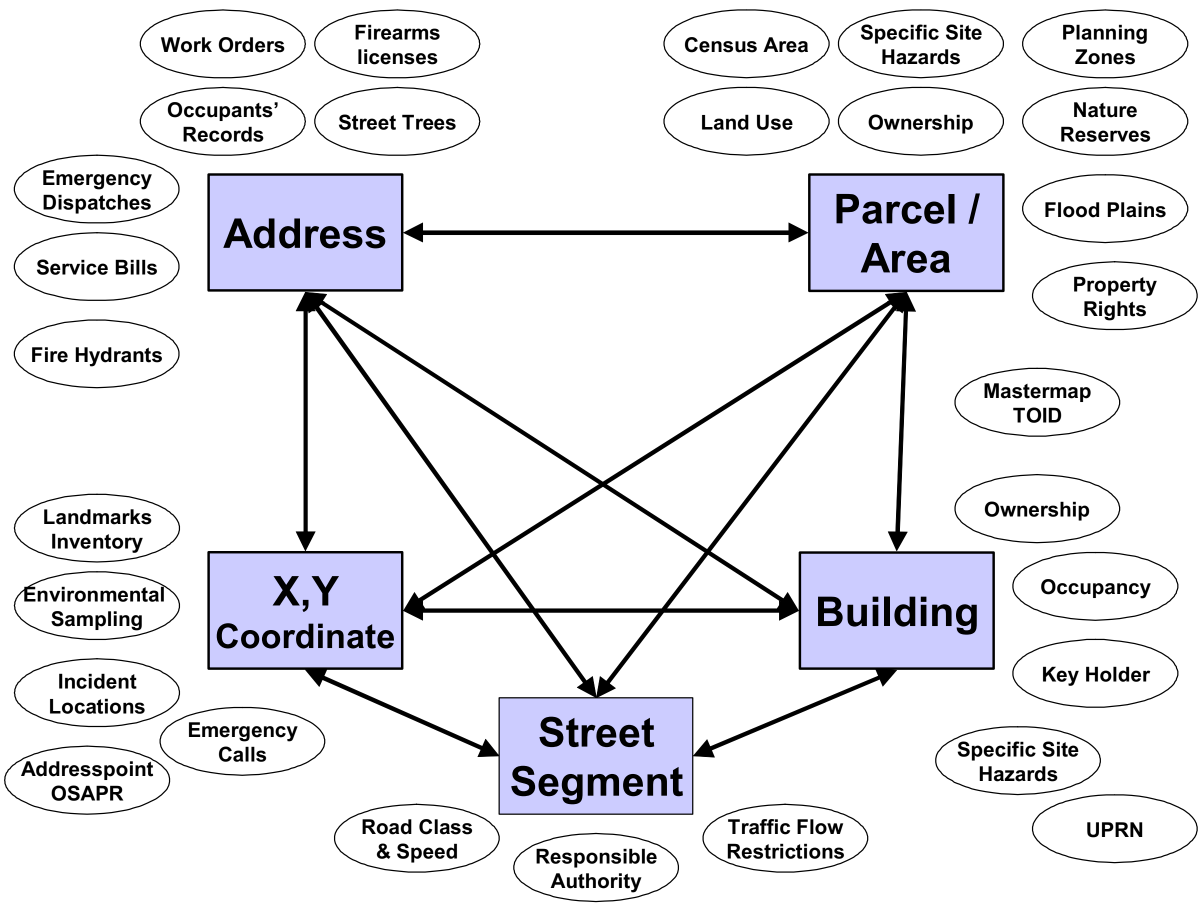


Figure 12: records integration using the 'spatial key'

Each mode of referencing a record's geography can be cross-referenced to the others. For instance, a full postal address can be given a grid reference, located with reference to the adjacent street, identified as a building or a property within a building (to which the local authority may have allocated a UPRN, or Unique Property Reference Number), it may also be registered as an address to which the Post Office delivers mail and as such it will have an OSAPR, or Ordnance Survey Address Point Reference, which in turn may be referenced against the Topographic Identifier (TOID) which is a unique reference for each object identified in Ordnance Survey's Mastermap dataset.

The details of how records utilising different geo-referencing frameworks can be integrated, and the consequences for data quality are beyond the scope of this document. The objective here has been to establish that such integration is possible, yet that it needs to be managed carefully.

6.2 The Key Functions of a GIS

This section outlines each of the key functions of a GIS, with examples. Further examples appear in Section 7, which illustrates GIS applications in the different processes of IEM.

6.2.1 Data Integration

Data that relate to defined geographical places or features (points, lines or areas in vector format data or grid-cells or pixels in raster format data – see Box 5) can be integrated within GIS, irrespective of their origin. This is of course a sweeping statement and a great deal depends on the format of those data, but as a general statement this is true; where records are geographically referenced to an accepted format they can be imported into GIS. It does not always have to be the case, however, that individual datasets have to have a spatial identifier themselves to be integrated into GIS. Figure 13 illustrates the way in which some datasets with no explicit spatial location (e.g. table in top left) can be integrated, on the basis of a common field, with others that have either a relatively inaccurate (e.g. postcode) or a highly accurate (e.g. Easting and Northing grid reference) location. This joining of tables is extremely significant in the context of a data creation and integration exercise.

ID	Parcel	Checked
1	111-000-101	Yes
2	111-000-102	Yes
3	111-000-103	No
4	111-000-104	Yes
5	111-000-105	Yes

Address	Postcode	Easting	Northing
1 High Street	AZ1 1QT	869123	253476
3 High Street	AZ1 1QT	869133	253478
5 High Street	AZ1 1QT	869143	253480
7 High Street	AZ1 1QV	869152	253482
9 High Street	AZ1 1QV	869164	253483

ID	Parcel	Type	Address	Postcode
1	111-000-101	Residential	1 High Street	AZ1 1QT
2	111-000-102	Residential	3 High Street	AZ1 1QT
3	111-000-103	Retail	5 High Street	AZ1 1QT
4	111-000-104	Residential	7 High Street	AZ1 1QV
5	111-000-105	Retail	9 High Street	AZ1 1QV

Postcode	Geodemographic
AZ1 1QT	C15
AZ1 1QT	C17
AZ1 1QT	C17
AZ1 1QV	D21
AZ1 1QV	C15

Figure 13: integrating non-spatial data with spatially-referenced data on the basis of common fields

Table 4 illustrates a range of relevant thematic datasets (i.e. data about specific things rather than general backdrop mapping). It is not exhaustive of the data that could be of relevance IEM, and it is also relatively 'high-level', so telecommunications as a heading would incorporate infrastructure relating to landlines, commercial mobile telecommunications, fibre optic cables, internet exchanges, government digital communications and analogue radio communications, each of which is an extensive and complex dataset in itself. As all of the elements that comprise the table are located at specific places or have other geographical dimensions (e.g. height, depth, area and route or pathway) they can be (and mostly are) recorded, managed and analysed using GIS. However, the datasets listed or encompassed in table 4 are owned and maintained by a wide range of bodies including, but not limited to:

- Central Government Departments
- Government Offices for the Regions
- Local Authorities
- Highways Agency
- Environment Agency
- Natural England
- Health Authorities
- Primary Care Trusts
- Emergency Services
- Ministry of Defence
- Private Sector Companies
- Regional Development Agencies

Data and information sharing is critical to the effective application of GIS to IEM. GIS depends on data, and data that are fit for use. Sharing data is therefore pivotal to the long-term development of GIS in this field and much else besides (see sections 9 and 10).

The concept of a **Common Operational Picture** (COP) is significant. For agencies to work effectively together as part of a multi-agency response to emergencies, each agency has got to be appraised of the 'bigger picture'. This is significant as (a) the perception of a specific .

Hazards	Community and Demographics	Built Environment and Economy	Natural Environment	Infrastructure	Resources
River Flood Plains	Government Agency Boundaries	Land Use Density	Terrain	Energy Generation and Distribution	Emergency Services resource sites, service boundaries and control rooms
Coastal flood hazards	Total population and demographic breakdown	Vertical Structures	Geology	Telecommunications	Hospitals
Storm tides	Census data	Centres of Employment	Groundwater	Transportation (incl. routes, depots, ports, bridges, etc)	Suitable buildings (e.g. leisure centres or warehouses)
COMAH sites	Deprivation data	Retail Units	Nature Reserves	Financial Services	
REPIR sites	Vulnerable Individuals (e.g. physical & mental health or mobility)	Service Units	National Parks	Food supply system	
Pipelines	Schools & Colleges	Industrial Units	Cultural & Historical Sites	Water supply system	
Specific building hazards	Care Centres	Hotels	Country Parks		
Slope instability	Other communal establishments associated with high density occupancy		Recreation Sites		
Fire hazards			Farmland		
Transport-related hazards			Woodland		
			Water & Rivers		

Table 4: examples of thematic data sources relevant to emergency planning and management, illustrating the need to develop multi-agency databases (Note: the categories are not of course entirely mutually exclusive, and are used indicatively here)

incident will differ, both in control and on the ground, between agencies, and (b) because the resources of those individual agencies are themselves part of the bigger picture.

Box 5: Raster and Vector data

Vector data are those which are stored as points, lines and areas (below right). Raster data are those which are stored in a regular gird, or matrix of cells (below left in which U = urban, F = forest, A = Arable and W = water).

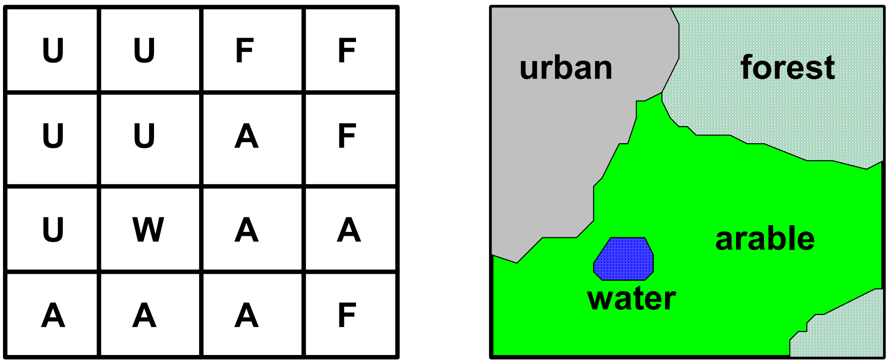


Figure 14: Raster and Vector data structures compared

Vector data have the advantage of being able to represent real world features such as rivers, roads and buildings more accurately, as the exact location, path or boundaries of features can be reproduced (see Figure 16). In vector format each feature (for instance a water body, a building or a bridge) is allocated a unique identifier in the associated database. A large number of attributes can then be associated with this identifier. For instance, each of three bridges could have a series of attributes, such as those illustrated below, associated with them.

Bridge ID	Built	Type	Lanes	Traffic Control	Traffic Flow (veh/hour)	Maintained By
BG0001	1901	Arch	1	Lights	50	County Council
BG0002	1959	Suspension	4	Toll Booths	25,000	Bridges Inc
BG0003	2001	Beam	2	None	5,000	County Council

The raster data format is now most commonly used for remotely sensed data, that is satellite images or aerial photographs. Figure 15 illustrates a false colour (red shows vegetation, light blue or blue/grey shows sealed surfaces such as buildings and roads and very dark blue is water, with the North Sea visible in the upper right) SPOT satellite image. These data are measured solar radiation that is being given off by the earth's surface, and the data are collected in raster format, with one value for each cell (or pixel) of 20m x 20m resolution. The pixel-based nature of the data is clear when you zoom into a small area, also illustrated in Figure 15.

The raster format is also commonly used in modelling data, where the grid is used to identify, for example, the predicted value of an atmospherically pollutant. Figure 27 (radioactivity atmospheric dispersal modelling by the Met Office) clearly illustrates the grid based nature of such model output.

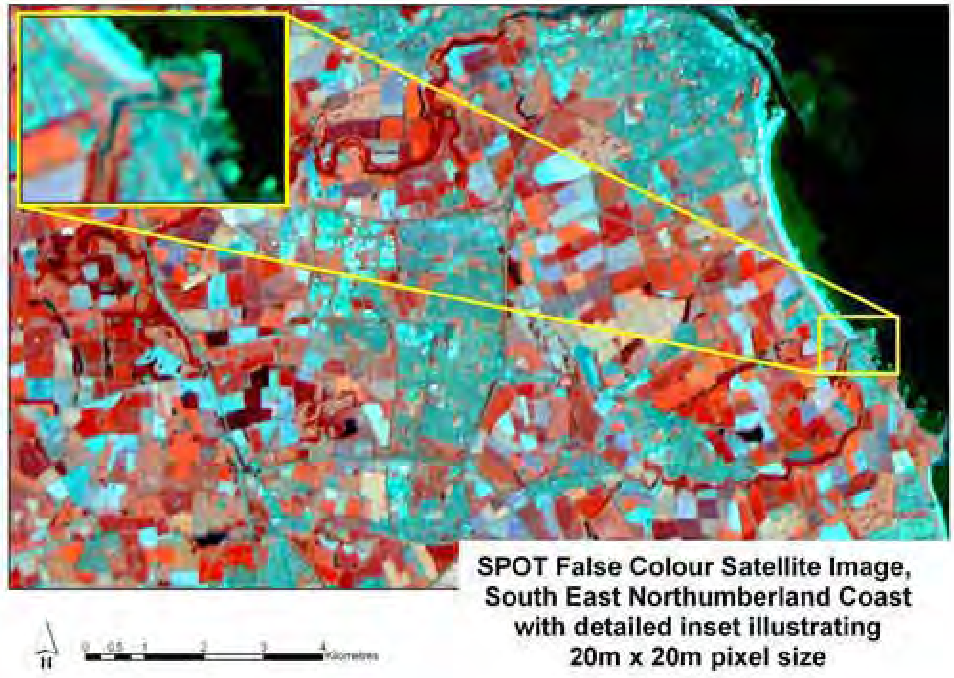


Figure 15: Satellite image illustrating pixel-based nature of raster data

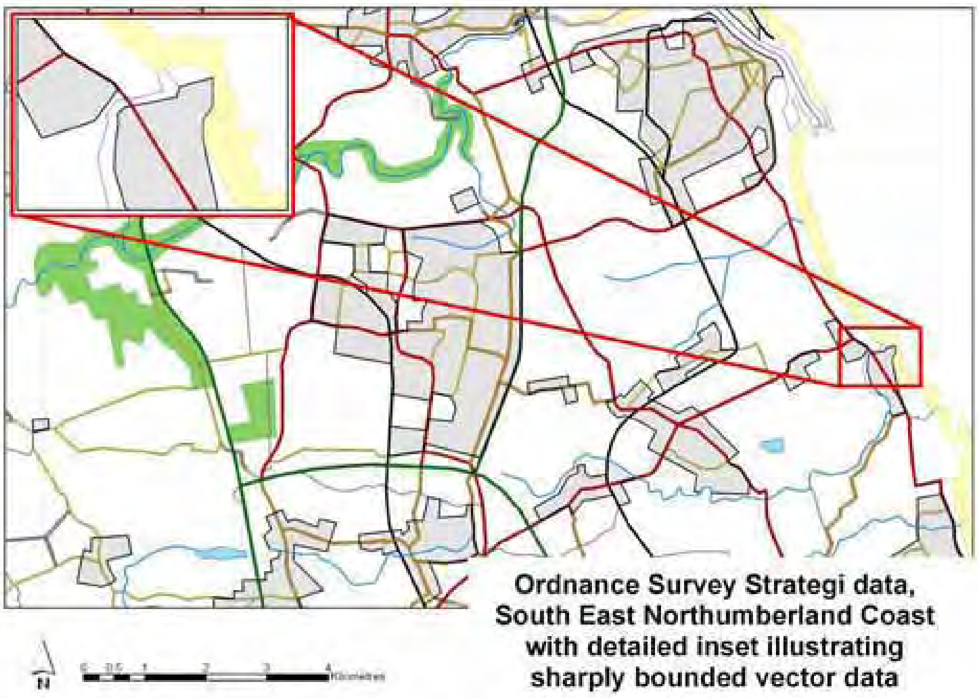


Figure 16: OS Strategi™ data illustrating geographically precise nature of vector data

The spatial resolution (pixel size) of aerial photographs is much small than most satellite data (1m x 1m or rather less is typical) although the resolution of satellite data varies dramatically between sensors (the equipment mounted on the satellite which gathers the data) as weather satellites have very different applications to modern systems such as IKONOS (see section 11) which can produce data that are comparable with aerial photographs.

In the New York City Emergency Operations Center (NYC EOC), in common with many in the UK, including the Lothian and Borders Police Joint Agencies Control Centre (JACC) in Edinburgh, a series of agencies with responsibility for emergency response are brought together and a GIS capacity has been established. In the JACC information from the GIS can be displayed on large wall displays. However, in the NYC EOC representatives from each agency sit at a designated PC which provides access to an Intranet GIS. This GIS is constantly maintained by EOC staff during an incident so that all agencies have access to precisely the same information about the incident, its implications, the response and associated issues. Although neither the EOC nor the JACC have access to real time data from all relevant agencies (but see section 7.4.6 on Automatic Vehicle Location Systems), the benefits from all agencies facing the same information, the Common Operational Picture (COP), is widely accepted.

There are technical issues to be addressed to achieve a COP, but more complex are the cultural and organisational issues which hamper effective inter-agency communication and working at all levels of operations and command.

6.2.2 Data Analysis (i): Querying

Data analysis is the process of generating added value from a dataset or a number of datasets, and beginning to get to grips with details and causes. For instance, analysing the relationship between hoax 999 calls, the demographics of an area and the distribution of prolific youth offenders is an approach that can target school-based educational work by fire prevention officers. Also taking risk as its focus, an analysis of the spatial distribution of accidents over time, in relation to the spatial distribution of police, fire and ambulance stations and travel time zones around those locations, is a technique to analyse the efficiency and effectiveness of service provision and plan for the optimal re-location of emergency service locations. See the case studies in section 7 for further details.

Data can be queried in two main ways in a GIS:

a) On the basis of location: records can be selected on the basis of where they are, and this is unique to GIS. For example, Figure 17 illustrates a map of total hazard score for an area in the Eastern United States. Overlain on the hazard map are the 'footprints' of all buildings in that area. Selecting those buildings that fall within the highest hazard score zones and then accessing a table of their attributes is a simple operation in GIS. As set out in Box 4 these records could then be integrated with a range of other attributes such as occupancy details, telephone numbers and details of any vulnerable individuals or groups located in them. This is returned to in section 7.

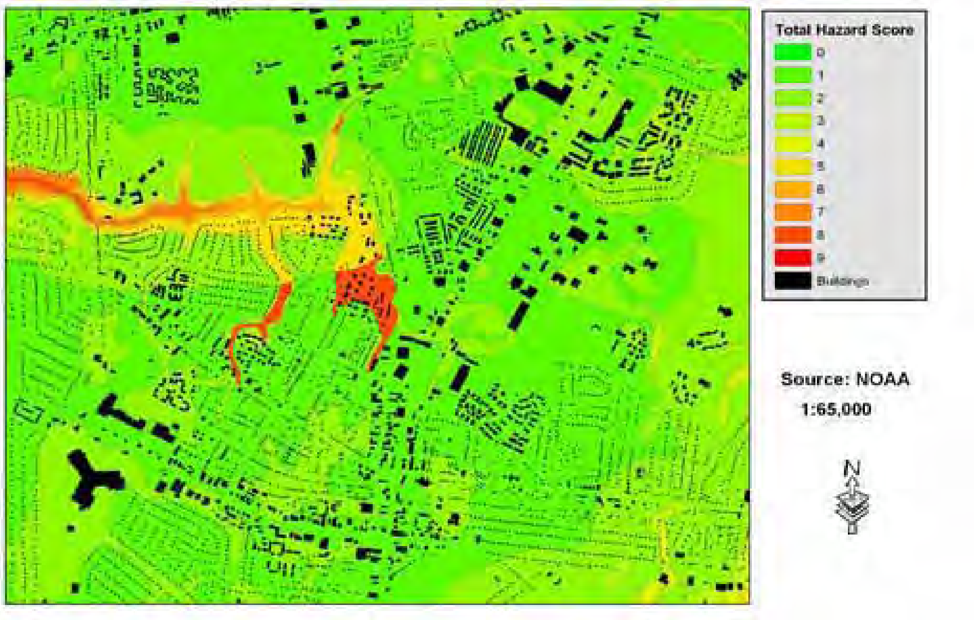


Figure 17: identifying properties that fall within hazardous areas

b) On the basis of attribute: in common with any other database management system, structured queries can be applied to a dataset to extract records on the basis of their characteristics, irrespective of their location. For example, in the immediate aftermath of the September 11th 2001 terrorist attacks on New York City, GIS was used to identify all the concrete slab buildings in Lower Manhattan that had at least 10,000 square feet of clear space, for use as temporary mortuaries.

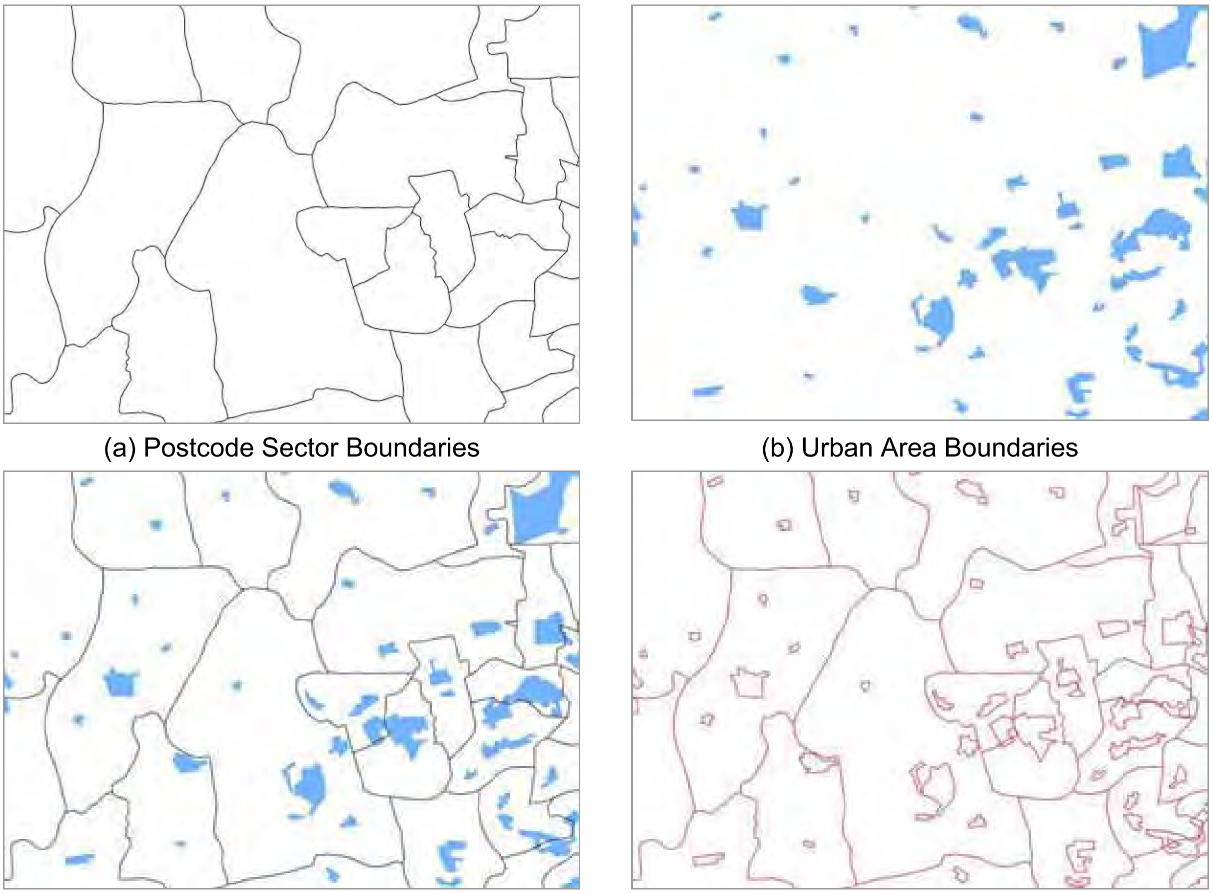
6.2.3 Data Analysis (ii): Spatial Analysis

Spatial analysis is concerned with the patterns and associations that exist within and between 'layers' of spatial data, patterns and associations that might go unnoticed unless an explicitly geographical perspective is taken. This is an extensive field and reference to a specialist text book is recommended for further details (see Appendix 2), but the key operations are set out here.

(a) Overlay analysis

As the name suggests this is the process of superimposing one or more thematic layers upon another. At its simplest level this can be a visual process, to see how the distribution of one set of features relates to another. GIS also supports the combination and subsequent analysis of layers of datasets. For instance, points can be appended with the unique identifier of each polygon that they fall within. From this the number of points per polygon can be calculated, and if each polygon is associated with a population figure, the rate per 1000 can also be calculated.

Polygon layers can also be combined, and a series of different operations are possible, including spatial union (see Fig 18) and a 'cookie-cutter' approach (see Fig 19).



(a) Postcode Sector Boundaries

(b) Urban Area Boundaries

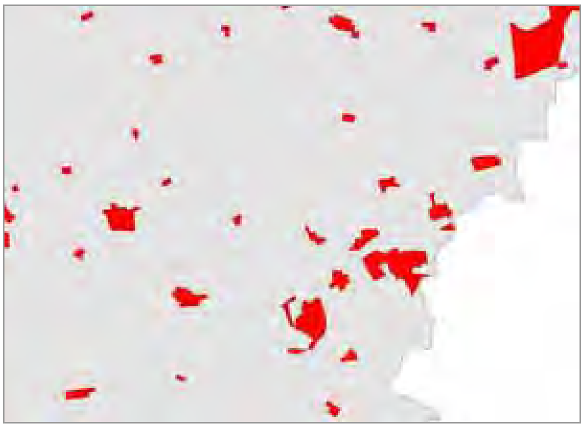
(c) Postcode Sectors and Urban Areas overlain as separate thematic layers

(d) Postcode Sectors and Urban Areas combined to form a single thematic layer

Figure 18: Spatial Combination, or Union, of Separate Thematic Layers

In the operation illustrated in Figure 18 each polygon created in (d), through the spatial combination of postcode sectors and urban areas, has the attributes of both layers appended to it. This would then support queries to identify urban areas that are also in a defined postcode sector. In this particular case a level of caution is required as some attributes, for instance population associated with urban areas, will no longer be accurate where the original polygon (for which the population data *was* accurate) has been divided into one or more separate polygons, each of which will be attributed with all fields from both the urban areas and the postcode sector layers. It is important to remember that GIS is a tool and that user discretion is a critical aspect of proper and appropriate use.

County Boundary overlain with Urban Areas



Urban Areas falling within County clipped out as new thematic layer

Figure 19: Using one thematic layer as a 'cookie cutter' to clip out only those features of another layer which fall within its spatial extent

(b) *Boolean analysis*

As has been identified, much of the power of GIS derives from its ability to combine spatial and attribute queries. In a conventional database management system queries are usually structured to identify records that meet defined criteria. A simple query might be to select all records where Type = B or where Quality is > 27. More complex queries use what are termed Boolean operators such as AND, OR and EXCLUDING. Simple set theory can be used to illustrate the point.

A series of sets can be identified in the Venn diagram illustrated right:

- The area covered by A
- The area covered by B
- The area covered by A but NOT covered by B
- The area covered by B but NOT covered by A
- The area covered by A AND covered by B

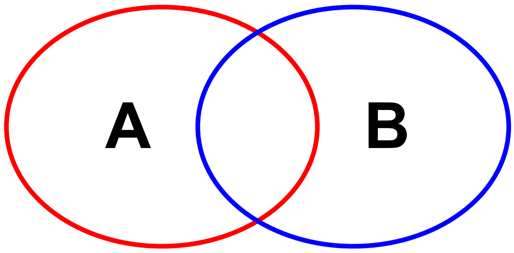


Figure 20: the principle of Boolean analysis is that of a Venn Diagram

Additional operators could be employed to identify further sets, but the point is that queries can be defined to identify areas that meet certain criteria defined by the relative spatial extent and attributes of two (or indeed many more) thematic layers within a GIS.

A combined approach can also be applied to identify records that both meet certain attribute criteria as well as defined spatial criteria (e.g. identify all the schools with grounds large enough to land a heavy helicopter **and** sufficient indoor space to act as a major casualty clearing station that are **also** within 5km of the crash site but **not** within the probable contaminated area). These kinds of queries could be answered without GIS, but this would take time and resources that incident responders are unlikely to have. Time and resources need to be allocated to develop GIS in advance of an incident to support a more efficient, better informed and more effective response when it matters.

(c) Buffering

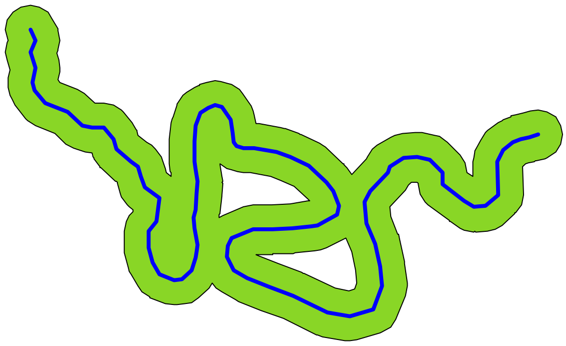
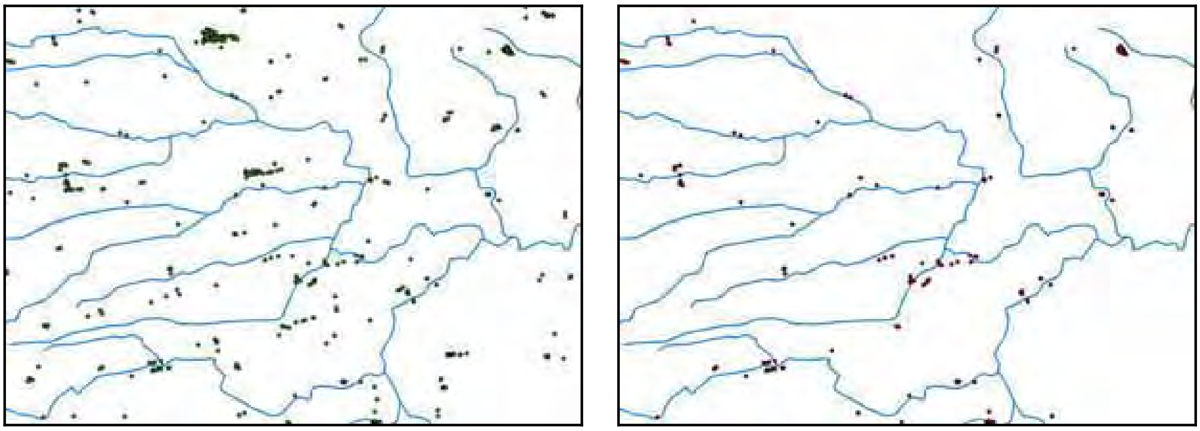


Figure 21: Buffer around a linear feature

Buffering is the process of creating a new polygon feature around an existing feature, or set of features. Buffers can be generated around points, lines or areas and for areas they may be either within the polygon, outside the polygon, or both. Once created, buffers or a defined extent (e.g. 200m or 4km) can be used in any of the other operations described here, for example in selecting features that fall within the buffered polygon such as key holders within an affected area.

(d) Neighbourhood analysis

The spatial relationship between datasets can be analysed through overlay analysis as identified above, but neighbourhood analysis permits a more interactive approach to define features by their spatial relationship to other features. For instance, in Figure 22 all properties falling within 200m of a river have been selected. Alternative approaches may define all features that fall entirely, or partly within other features, or be within given distances of other features.



Rivers and all Properties   Properties within 200m of Rivers

Figure 22: Spatial Selection of Buildings located within 200m of a River

(e) Surface modelling

In many applications that deal with point data, there is an emphasis on understanding the density or level of concentration of points over space. In many cases simple visual analysis will be unreliable, as many points may be so closely clustered as to be indistinguishable, or may be even be superimposed. Under such circumstances using analytical techniques to convert the point layer into a grid-based (raster) layer (see Box 3) that illustrates density of points per unit area gives a much more effective picture of the actual distribution, and clustering, of the dataset.

Figures 23 and 24 illustrate this with an example of child pedestrian road traffic accidents (RTAs) in a UK city. Each point in Figure 23 represents a single RTA involving a child pedestrian over a ten year period. The overall pattern is relatively clear and the areas of particular concentration can be relatively well discerned. Which areas are the worst, the real blackspots, is not however very clear.

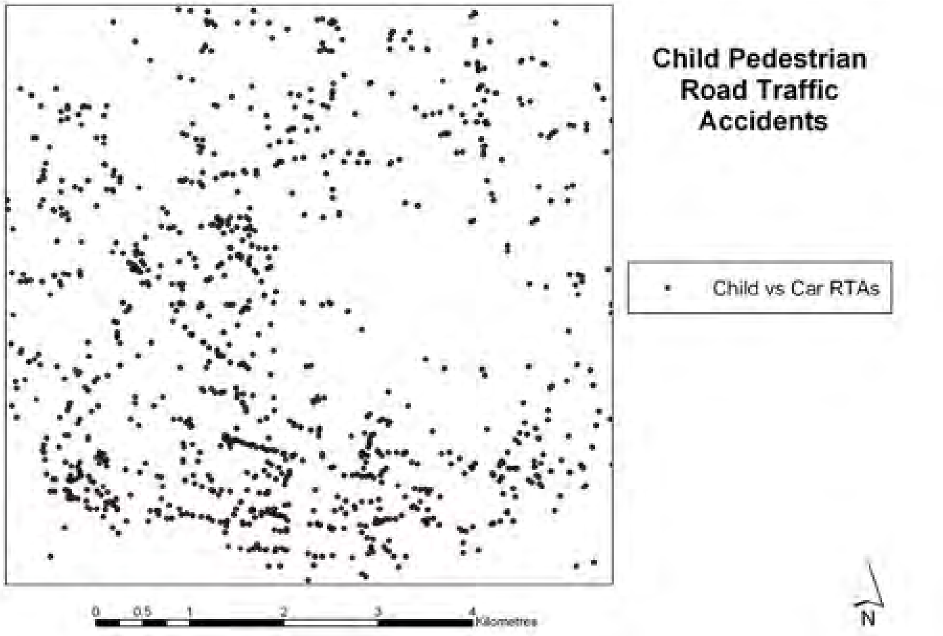


Figure 23: the point location of Child Pedestrian RTAs

Converting the point data into a density surface, illustrated in Figure 24, is much clearer and of more immediate and effective use to decision makers.

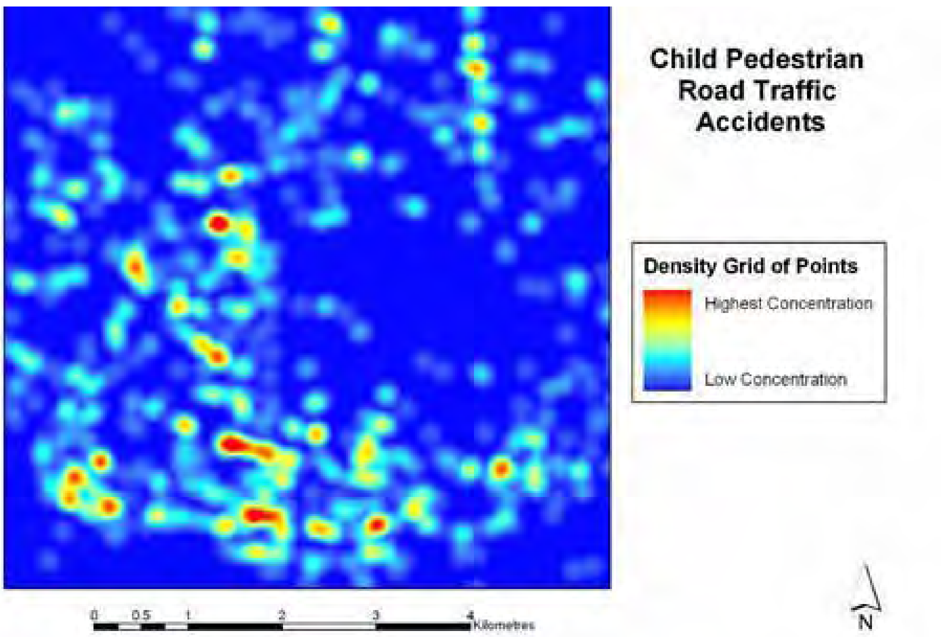


Figure 24: point locations of Child Pedestrian RTAs converted into a density surface

(f) Spatial Statistics

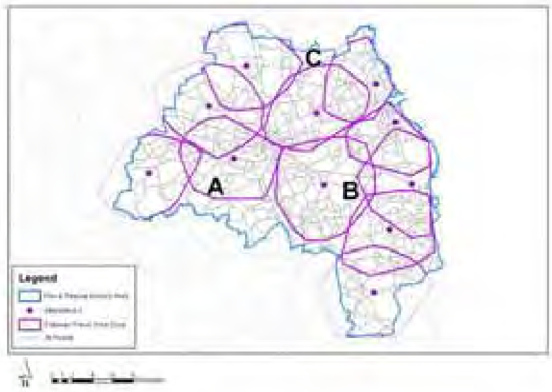
In the example of child pedestrian RTAs above, spatial statistics could be used to identify both the most highly statistically significant clusters of incidents, and also test for the strength of association with other variables such as demographic profiles and census data. This is a complex area and reference to a specialist textbook is recommended for further details (see Appendix 2).

(g) Network analysis

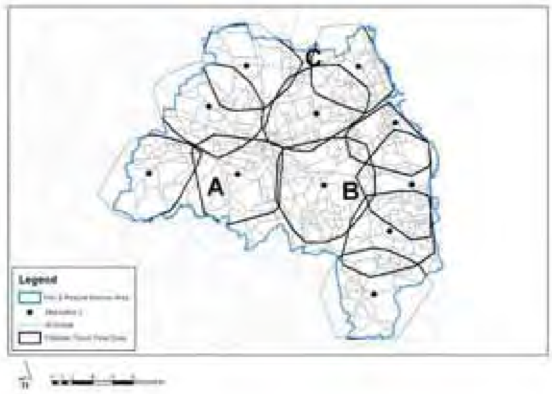
Network analysis focuses on the movement of objects (usually, but not always vehicles) along an interlinked network of, routes or pathways (usually but not always, roads). The analysis includes a number of parameters, including:

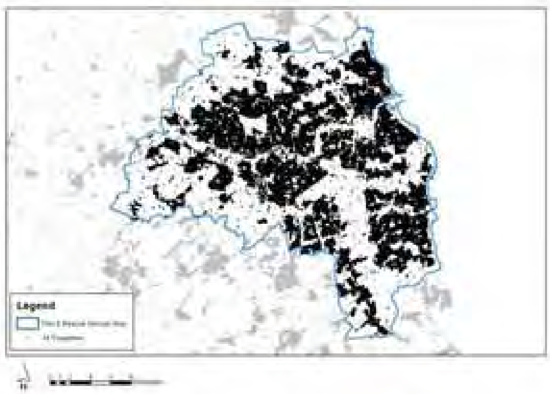
- *Connectivity:* network analysis can only work for a network of roads that has been correctly linked together. For instance, even the smallest error in data creation that leaves one section un-linked to another will lead to the software assuming they are not meant to be linked – computers do not compensate for human failures. The network also needs to be structured in such a way that features such as overpasses, bridges and underpasses are correctly interpreted by the software so that drivers are not erroneously instructed to leap off a bridge onto the road below!
- *Speed:* travel time along a network is calculated as a simple function of distance and speed. Therefore speed must be included as an attribute of each section of the road network. Usually it is the speed limit that is recorded, although this can lead to dangerously optimistic results for many applications – bear in mind that fire engines responding to a 999 call in urban areas usually travel at an *average* speed of less than 20mph. For most of the roads in an urban area the speed limit is 30 or 40mph, and even then average actual speeds take no account of variations over the course of a day, such as rush hour. Many data re-sellers enhance road networks to include attributes such as likely travel speed at different times of the day.
- *Direction:* most road networks are two-way but some streets are one way systems and these need to be represented as such in a road network that is intended to support network analysis, for obvious reasons.

Different software packages operate in slightly different ways in respect of how they report results of analysis, but typically areas that can be reached within a given time (e.g. <5 minutes) can be identified and isochrones (contour type lines of equal travel time) can be identified.



Network analysis permits scenarios to be analysed, for instance in assessing the relative coverage of an area with different permutations of service provision, such as fire stations. In this hypothetical example the service shortfalls identified above at A, B and C are addressed to differing degrees in the three alternative scenarios identified above and to the right.





Simple geographical coverage however is only part of the picture, and GIS permits other variables to be considered, for instance the actual distribution of properties *within* the urban area (illustrated left) as well as, for instance, the distribution of residential properties, schools, hospitals, care homes, recreation complexes, hazardous installations and road accident blackspots.

Analysis to underpin major decisions such as the relocation of emergency service stations needs to be rigorous, taking into account possible future trends as well as factors that can explain the current level of problems experienced. For instance, patterns of deprivation (illustrated here using the ODPM Index of Multiple Deprivation scores) are closely associated with crime and disorder, including arson.

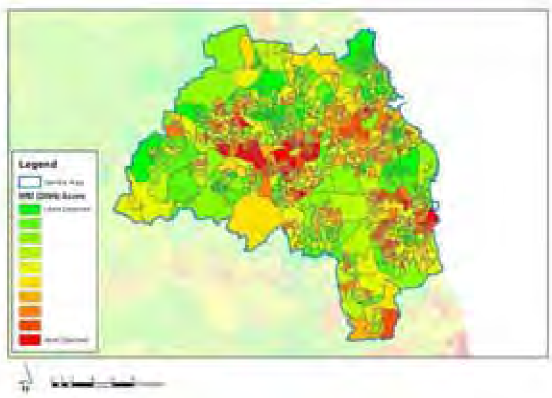


Figure 25: Network Analysis Application

Although GIS is a set of tools which can be applied individually, the greatest leverage of information is often achieved by using a range of such tools within an overall project to analyse different dimensions of a given problem.

6.2.4 Data Modelling

Modelling is the process of generating additional elements from existing datasets. For example a model of atmospheric pollution dispersion from a point source takes a number of known or estimated facts, such as the location of release, the characteristics of the compound, wind strength and direction and terrain characteristics to predict the likely dispersion of the compound over space and time.

Figure 26: map of the immediate ‘Area-at-Risk’ for a fictitious radioactive release pollution incident in Hartlepool (Courtesy of the Met Office)

As an example of this, Figure 26 was produced by the Met Office Environment Monitoring and Response Centre to map the immediate ‘Area-at-Risk’ for a fictitious radioactive release pollution incident in Hartlepool, and Figure 27 illustrates the modelled the longer term spread of Caesium-137 across the British Isles and Northern Europe.

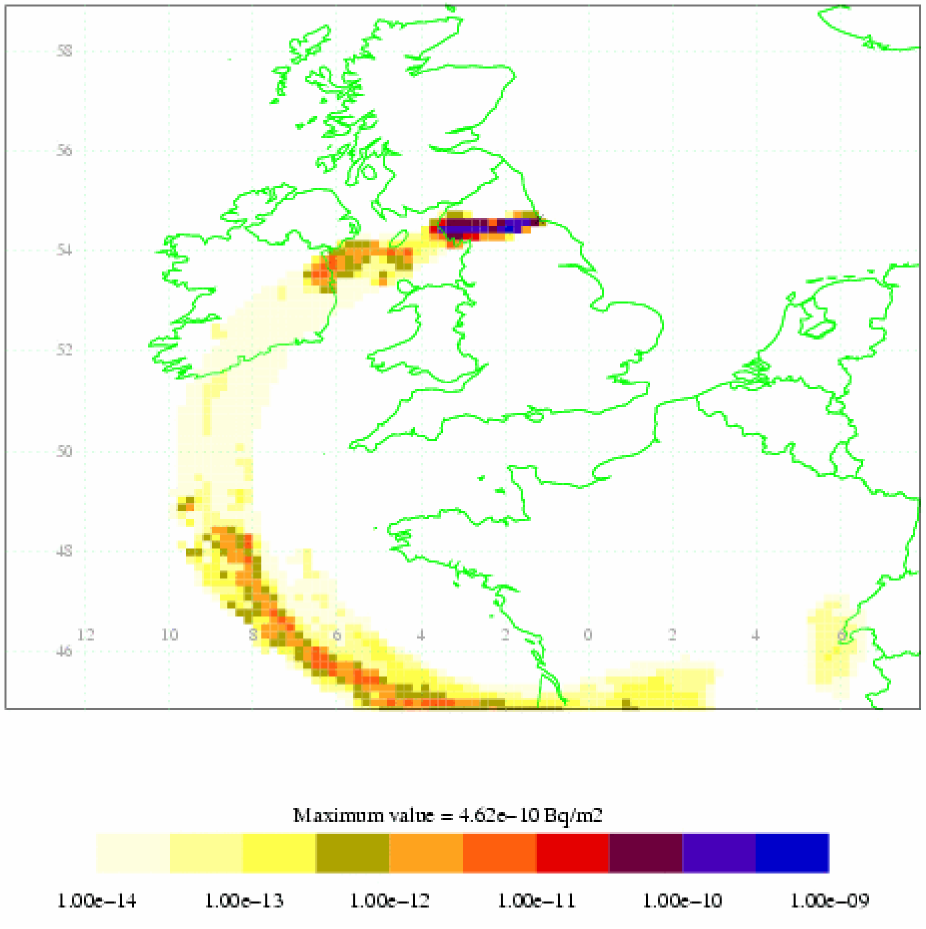


Figure 27: the modelled the longer term spread of Caesium-137 following the hypothetical incident established in Figure 26 (Courtesy of the Met Office)

This ability to run different scenarios and assess their likely implications is pivotal to activities associated with preparing for emergencies, but it is also significant in an emergency context during which the implications of a shift in wind direction could be estimated and worked through.

Models are based on assumptions and data that *may* be flawed, so their outputs should be treated with a degree of caution, but if the data and the models are robust then the output is of potentially great value to emergency managers. See the case studies in section 7 for further details.

6.2.5 Data Mining

Although data mining is a highly advanced set of techniques for identifying anomalies in extensive digital datasets, at a basic level it is a process of applying a set of queries to a dataset, except it is done automatically and with specific purposes in mind. For example, an increasing number of Police Forces in the UK use Automatic Number Plate Recognition (ANPR), and once read each number plate can be compared with a set of records. These records may, for example, be whether the car is associated with a wanted person or whether it is untaxed. Boolean queries that include a spatial element can also be associated with this, for example to narrow the query to be whether a set of number plates associated with wanted people appear in a given area.

6.2.6 Terrain Analysis

Terrain analysis is a specific set of techniques which analyse the surface of the earth. The purposes of such analysis might be to identify slope angle or aspect (both of which are relevant to slope stability and hydrological modelling) or carry out what is termed intervisibility analysis.

Terrain analyses are typically carried out on a Digital Elevation Model (DEM), which is a raster data layer in which each individual cell is allocated a value which is the average altitude of the land represented by that pixel (Figure 28).

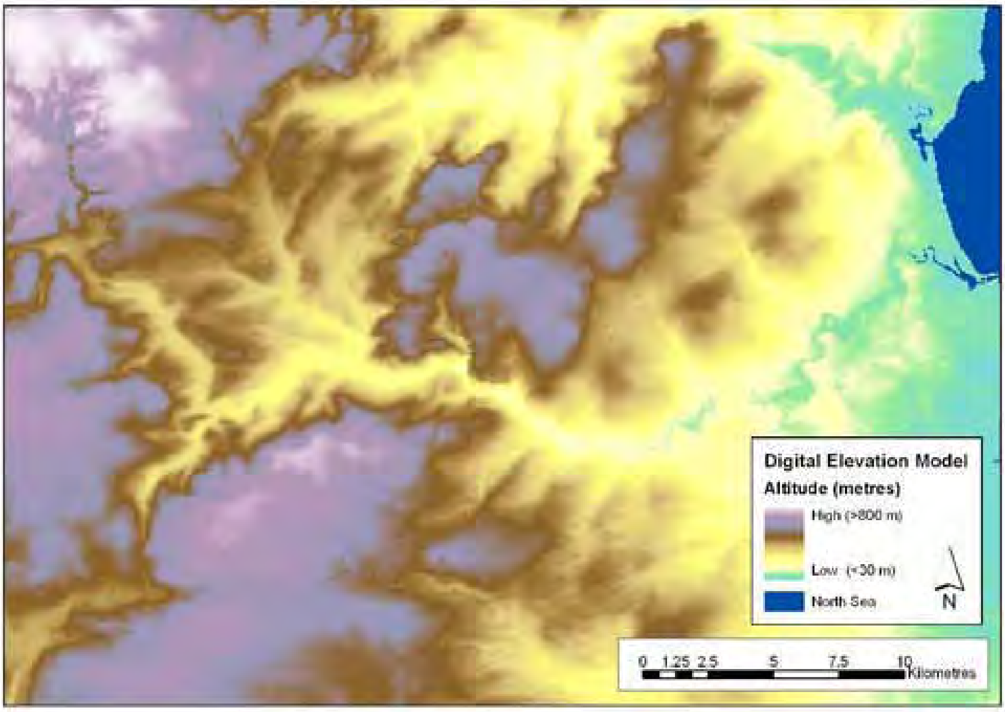


Figure 28: a Digital Elevation Model of the Northumberland Coast and Hills

Intervisibility analysis can calculate whether one point on a DEM is visible from another and also carry out more sophisticated viewshed analysis, heavily used in environmental assessments of new developments such as windfarms, which can calculate the cumulative visibility of a feature from the surrounding landscape. Precisely the same technique is also widely used in communications planning, where analogue radios in particular depend upon line of sight between transmitter and receiver, and mobile phone companies use this technique for service assessment and planning.

Figure 29: 3D Rendered Digital Elevation Model (Courtesy of the Humanitarian Crisis Information Centre, Pristina, Kosovo)

Having the ability to store altitude, the third dimension of the land surface, in GIS also has implications for visualising data and information. Figure 29, for example, was produced by the Humanitarian Crisis Information Centre in Pristina, Kosovo. The purpose of the map was to familiarise international aircrews who were flying relief missions into Kosovo with the landscape of the country as a whole. Thematic layers and images such as aerial photographs and satellite images can also be 'draped' on top of such 3D visualisations, illustrated in Figure 30 for the area around the Clifton Suspension Bridge in Bristol.

Figure 30: Layering infrastructure data and draping aerial photography over a DEM (Image Courtesy of Bristol City Council and Cities Revealed Aerial Photography © The GeoInformation Group[5])

6.2.7 Information Outputs and Cartographic Standards

Maps are the primary output from GIS. However, GIS also support a range of other forms of output, including:

[5] www.CitiesRevealed.com

- Charts, graphs and histograms
- Tables
- Animations
- 3D graphics.

The emphasis is on graphical communication, and the adage that ‘a picture is worth a thousand words’ is worth bearing in mind. Visual images can interest and engage people and also help them to understand relatively complex issues in terms that are accessible to them. Some of the advantages of using images, including maps are that they:

- are easy to remember
- form a visual basis for an accompanying narrative and discussion
- can reinforce potential changes – ‘seeing is believing’
- can effectively condense extensive and complex information
- are accessible to many people
- can be appraised in a short period of time
- fit within an increasingly image-laden culture within which people have accelerating expectations of the way in which information is served.

Figure 31: simulated flood over Great Yarmouth (Source: www.nrsc.co.uk)

In this example, the modelled results of a flooding scenario for Great Yarmouth as illustrated.

What makes this a particularly effective map is the way in which the affected area is shown ‘underneath’ a watery blue semi-transparent overlay. This has greater visual impact than a simple boundary.

The use of aerial photography rather than an OS map increases the impact as photos are perceived (and in many respects are) more ‘real’.

However, a picture that makes no sense, is impenetrably complex or otherwise fails to engage the end-user has failed to do its job and the information it is intended to convey will go unheeded.

A range of ‘wizards’ are available in most modern software to guide the user through the process of designing and creating such outputs, but some general principles should be borne in mind:

- map design (including animations and 3D graphics) is a complex field where a huge range of decisions about the look, feel and accessibility of the map have been automated. Making a map that has the desired effect, which should be a rapid and accurate appreciation of the key information, cannot just be assumed. Standard templates using universally accepted norms and standards should be developed and adhered to. Although this is increasingly the case in some fields, notably the military, this is something that still requires work in the UK and internationally.

- Know your audience: just as a comic will fall flat if s/he misjudges the audience, a map that is appreciated and understood amongst a technical group, may be impenetrable, even misleading, to a more generalist group. Figures 32 to 34 illustrate some basic map design issues, but this is the tip of a sizeable iceberg and reference to Appendix 2 for further material is recommended.

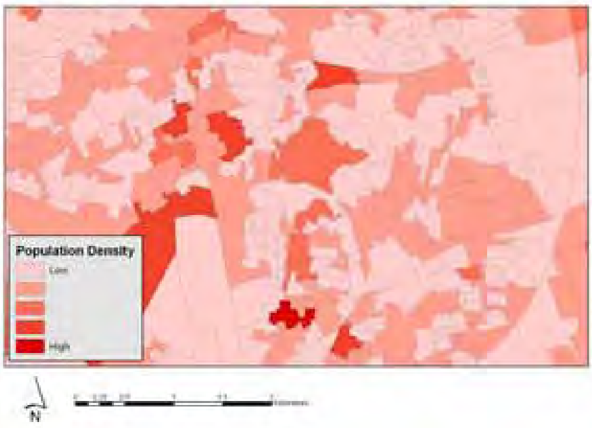


Figure 32

Figure 33

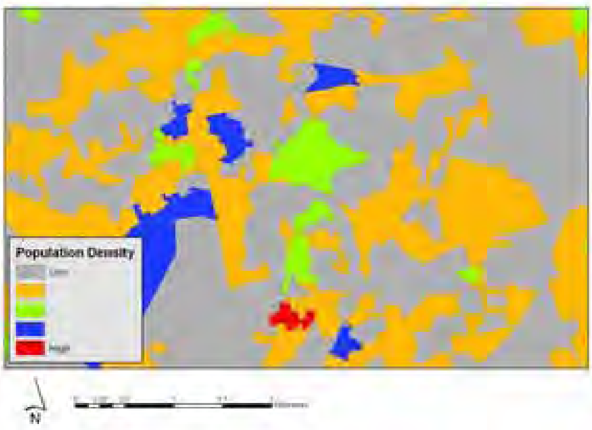


Figure 34

Figure 32 is a simple map but one where the key message of population density is rapidly appreciable using an intuitive low to high, light to dark colour scheme.

Figure 33 uses the same basic scheme, but there are fewer categories which means that some of the detail is lost. This may be an advantage in making impressionistic interpretation easier, but a disadvantage if important distinctions are lost.

Figure 34 is a map of exactly the same dataset, but it is not at all intuitive: if a reader has to pay very close and repeated attention to a key then much of the impact of the map has immediately been lost. By failing to use a scaled approach, in favour of a categorical classification, the map fails to be readily accessible.

IEM demands that agencies cooperate in preparing for, responding to and recovering from emergencies, which means that data and information must be able to pass between agencies in a way that they can effectively support joint-working. Section 10 provides an overview of the issues around interoperability which is a multi-dimensional pre-requisite to be addressed over the coming years to realise and manage the level of data and information mobility that is required. One dimension of this is what has been termed ‘soft interoperability’ or the ability of organisations to work together towards a common goal. Another dimension is that of ‘semantics’, or what data and information mean, as these may vary widely between organisations. Differences in terminology, map design and expectations of these have the potential to cause serious inefficiencies, or worse, on decision making.

In the UK there are no agreed principles or details for map design in an emergency planning context; it is a case of locally or internal agency-agreed (or often not-agreed) colours, shadesets, and symbols being unilaterally adopted. As one of the most basic principles of map design is that the basic message should be understandable with only limited reference to the legend, this clearly cannot be the case where expectations from within one agency may not match with those from others.

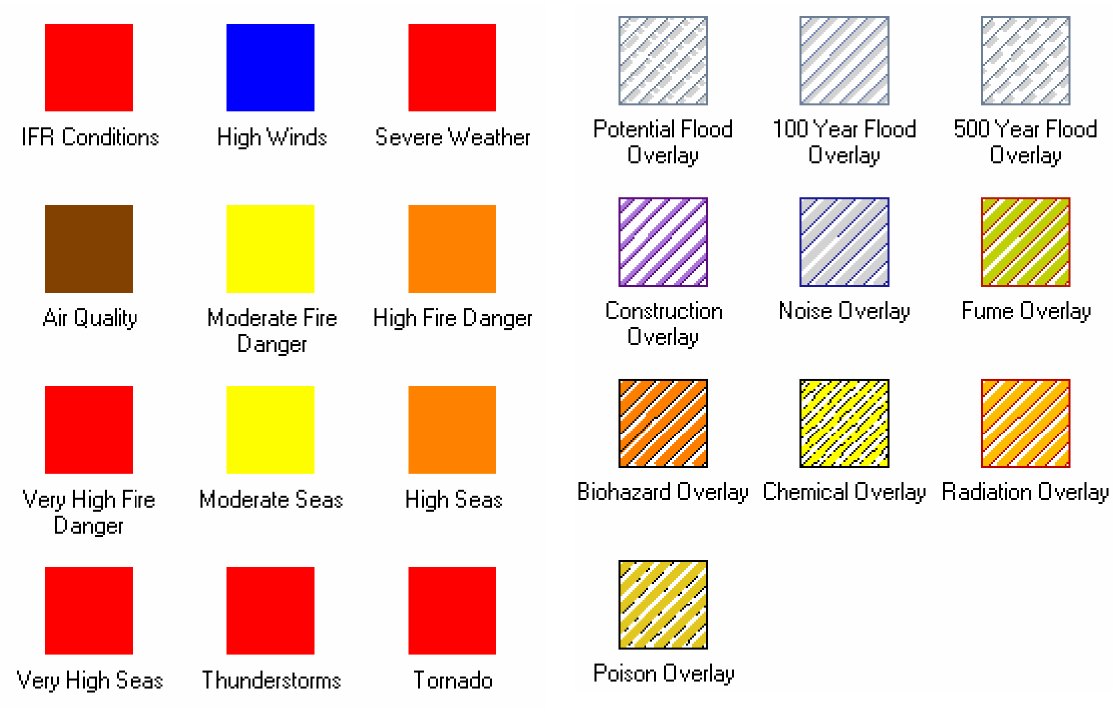


Figure 35: Pre-defined symbolisation for areas within a desktop GIS (ESRI, 2004)

Figure 35 illustrates some symbols for colouring areas that are available within a widely used desktop GIS, but these are part of a commercial product rather than a common position within the UK. Two instances where common symbolisation has been agreed are in UK nature conservation and the military. Templates for colouring land cover and vegetation classifications are promoted by government agencies such as Natural England and accepted by professionals in the field; although many of these colours are not intuitive or 'realistic' they have been widely adopted and are appreciated by relevant staff. The military imperatives (and indeed the consequences of failure) to arrive at a common symbolisation for mapping are self-evident and these have now been implemented at a NATO level to ensure communication between international forces, although the antecedents of common graphical symbolisation in a military context goes back two millennia to the Roman army.

Work in progress in the United States by the Federal Geographic Data Committee Homeland Security Working Group is developing a common symbol set for GIS applications in emergency management (see Figure 36). Although there is currently no equivalent in the UK it is essential that common symbolisation is developed and that it is done through consultation and reference to both international experience and standards and also local circumstances. This is a critical issue where agencies work together and it becomes especially acute in wide area emergencies and cross-border and well as inter-agency operations.

Figure 36: proposed emergency map symbols for the United States
(Source: http://www.fgdc.gov/HSWG/index.html)

Section Seven

GIS Applications in Integrated Emergency Management

Summary

The basic capabilities of GIS have been identified in the previous section. This section develops and illustrates these capabilities in the context of the IEM model, broken down by processes. The emphasis throughout is on the capabilities of GIS as a tool.

7.1 Anticipating and Assessing Risks

Although the anticipation and assessment processes are separate, they have a common focus on hazards, threats, vulnerabilities, risks and interdependencies. GIS applications primarily fall within the assessment process, in which identified hazards and threats are analysed in their spatial context, which supports vulnerability and risk assessments. For instance, Figure 37 illustrates different aspects of the demography of an urban area. The four maps illustrate (a) the total population (which says relatively little about daytime population or vulnerability), (b) the population over 65 years of age (which, all other things being equal, are more likely than other groups to be at home Monday to Friday 9 to 5), (c) the proportion of the population that is linguistically isolated (so may be unable to appreciate aural warnings given in English) and (d) the proportion of people with mobility impairments (who would need assistance in an evacuation scenario). Such information is extremely valuable in the process of anticipating and assessing risks from various scenarios.

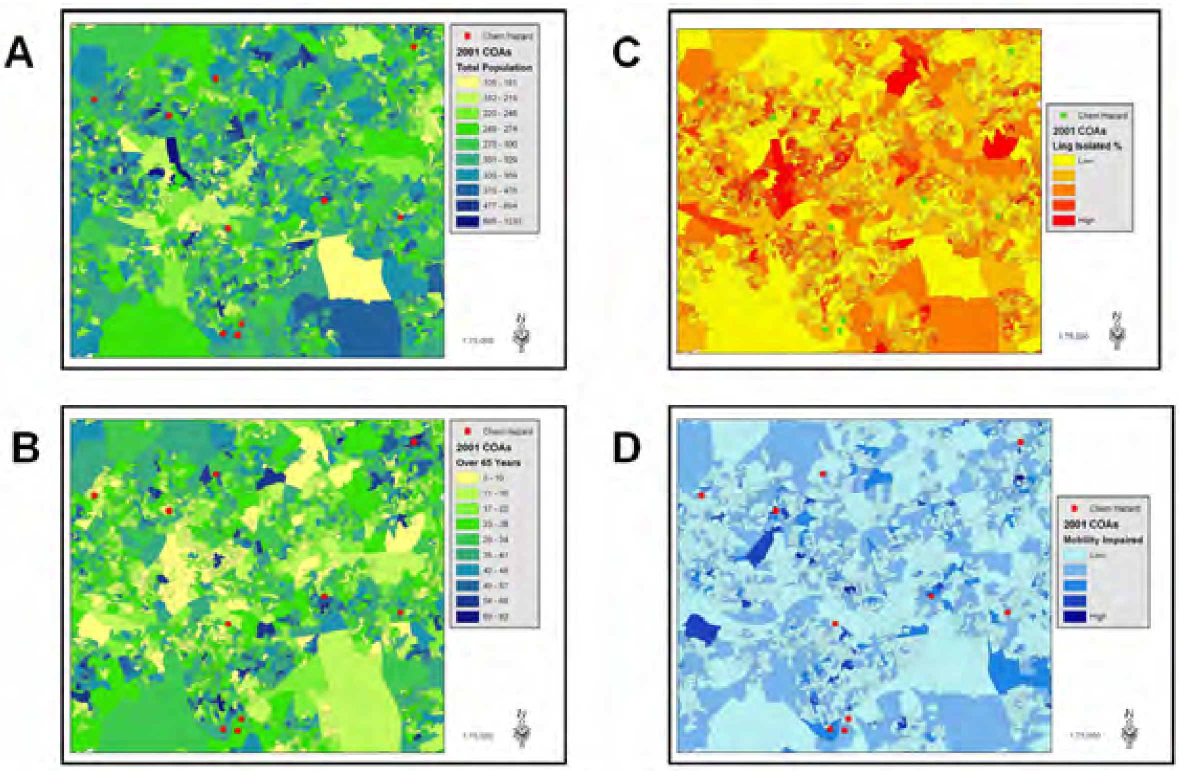


Figure 37: profiling an urban area for risk and vulnerability assessment

7.1.1 Case Study: Risk Assessment in the Insurance Industry

Assessing hazards is not just restricted to emergency planners; it is something that the public and private sectors alike need to consider, and public-facing systems such as the Environment Agency's *Floodline* system (see Figure 41) enables individual businesses and householders to identify the hazards and assess the risks to which they may be exposed. One example of a private sector initiative to assess risk comes from the insurer Norwich Union. Their business interests make it essential that they charge insurance rates which are proportionate to risk, and losses from flooding represent a major business concern for the insurance industry as a whole. However, flood modelling for the UK has previously been hampered by terrain data that are insufficiently detailed to discriminate between properties. As a consequence of this, many homes and businesses which are at low risk of flooding may previously have been refused cover or charged excessive premiums. Norwich Union commissioned a digital map to help pinpoint and understand exactly which areas of the country are at risk from river flooding.

Box 6: spatial interdependencies

IEM has to be concerned with interdependencies. One event may be caused by others, and the severity of consequences may depend upon a series of other factors such as nature and time of incident and proximity to vulnerable facilities. The nature of financial, industrial, social, transportation, communications and other systems is that failures or emergencies in one part of intermeshed systems has widespread implications elsewhere, and in ways that may not have been precisely foreseen. The seriousness of the fuel protests of 2000 was not in proportion to the numbers taking direct action against fuel supplies. In the same year the Food and Mouth Disease epidemic caused serious financial loss for many farm businesses, including those that were not directly affected. However, what was the effective 'closure' of public access to much of the UK countryside also had very serious implications for rural tourism and leisure businesses – these are interdependencies.

Many of these interdependencies are spatial in nature. For instance, in July 2001 in the US a train carrying chemicals and paper products derailed in a tunnel in central Baltimore, caught fire and, in the ensuing five days, caused a series of infrastructure failures and public safety problems. The train leaked several thousand gallons of hydrochloric acid into the tunnel, and the fire caused a water main to burst. More than 70 million gallons of water spread over the downtown area, flooding buildings and streets and leaving businesses without water. The fire also burned through fibre-optic cables, causing widespread telecommunication problems. The fire and burst water main damaged power cables and left 1,200 Baltimore buildings without electricity[6]. This is a very clear example of interdependencies that are physical, geographical and information-related (the loss of fibre-optic cables).

GIS can help, in both planning and response, to analyse and visualise such potential interdependencies that might not be identified with a solely non-spatial view.

Commercially available terrain data that Norwich Union were using to model flood risk prior to this project had an error estimate of +/- 5 metres. Clearly, this is the difference between no flooding and complete inundation of a 2 story building. Data were collected by an airborne radar system which was used to produce a Digital Elevation Model, which shows the height of the ground above sea level. This was then combined with a flood software model to produce information on where floods are likely to occur and how far they might extend. The

[6] Peerenboorn, J.P., Fisher, R.E., Rinaldi, S.M. and Kelly, T.K. (2002). Studying the chain reaction, *Electric Perspectives*, January/February 2002.

new terrain data has an error estimate of +/- 0.5 metres, or 10% of the previous level, illustrated in Figure 38.

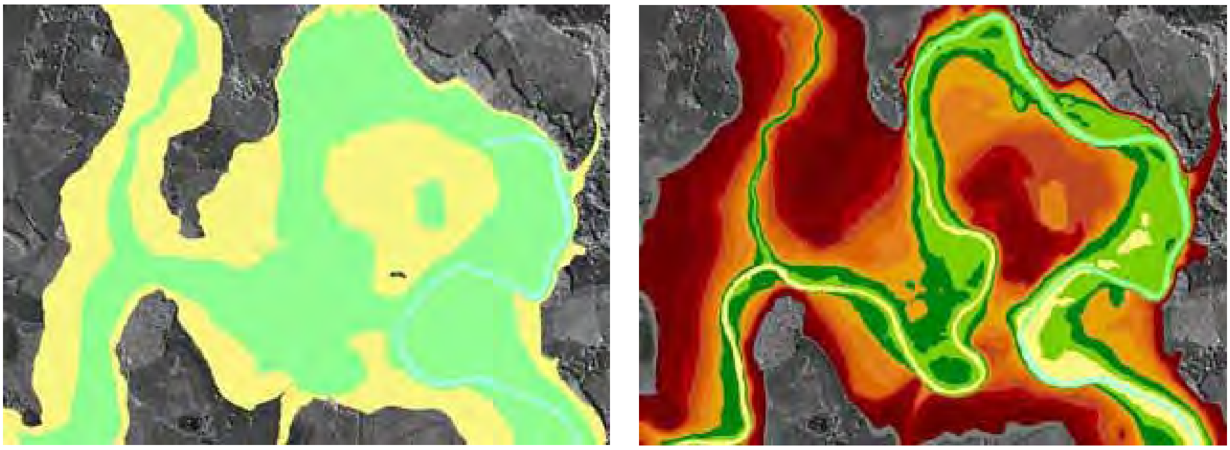


Figure 38: an area near Shrewsbury mapped using the commercially available 5m contours (left) and the new 1m contour data (right) derived from airborne survey (courtesy of Norwich Union)

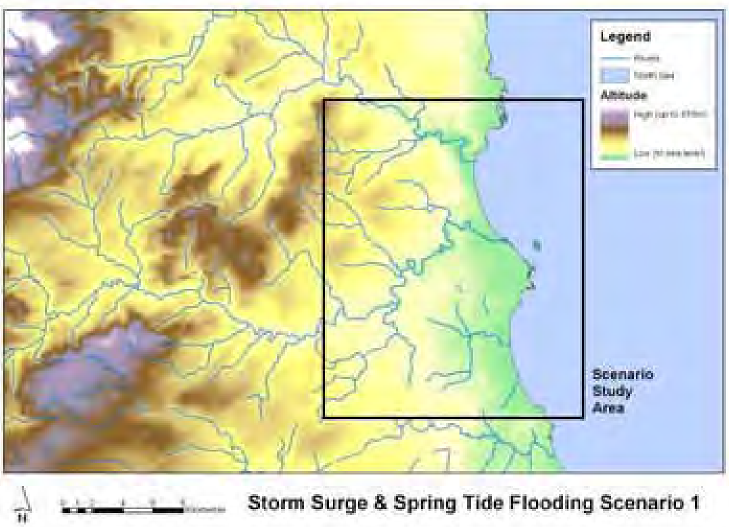
By investing in consistently accurate information on the height of land surrounding rivers Norwich Union have the best available information about the risk of flood for insurance purposes, which enables them to better understand whether a customer has been a victim of a one-off occurrence or is at risk from potentially frequent flooding.

7.1.2 Case Study: River Flooding and Storm Surge

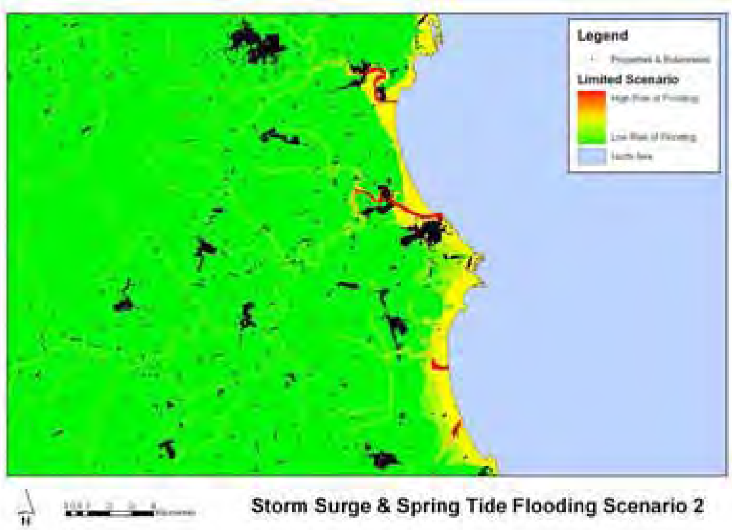
To develop contingency plans, prepare emergency responses and identify areas and groups at risk of flooding this case study is intended to illustrate the way in which the implications of different severities of flooding can be identified, prepared for and publicised. In this scenario extremely high tides and rising temperatures have combined with forecast high rain, following a period of heavy snowfall to threaten an area with severe flooding.

This illustrates the study area for this scenario (the coastal area within the box). Two rivers run, over a relatively short distance, from the coast up to high ground, thereby establishing a clear hazard from rapid snow melt.

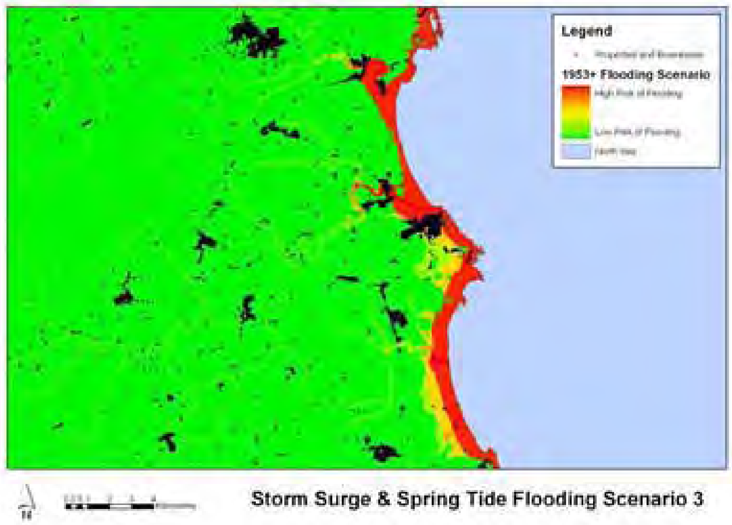
Much of the coastal area is relatively low lying and therefore at risk from coastal flooding.



This illustrates a limited scenario of significantly heightened stream flow resulting from snow melt and rainfall and high tides, and a flood model which incorporates a digital elevation model of the terrain, projected stream flows and tidal pressure to predict the areas at greatest risk of flooding. Using an accessible colour scheme (green for low risk to red for high risk) the areas and properties at risk are identified.



In this scenario the assumptions have been changed to exceed the severity of the 1953 coastal floods along Eastern England as part of a future sea level change risk assessment.



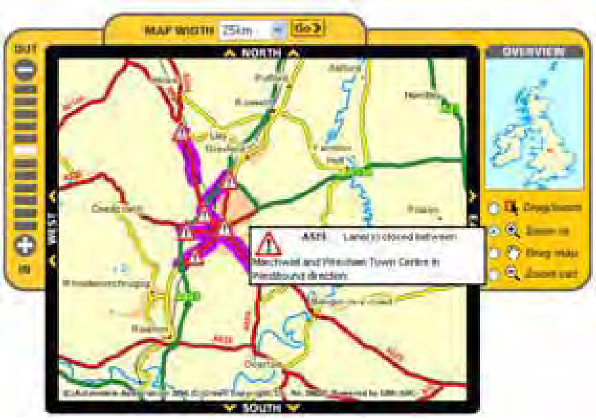
Such scenarios are extremely helpful in contingency planning, and the private sector, most notably insurers, have invested a great deal in this so that premiums reflect the spatial distribution of risk, balanced against the probability of different levels of flooding occurring.

7.1.3 The Role of Public Facing Systems

Over the past decade on-line mapping applications have been developed in internet, extranet and intranet sites for a wide range of agencies and across a diverse set of application areas. They have proven to be effective as one way of communicating information within organisations, between organisations and to the general public. Many on-line, or web-based mapping applications portray spatial information that is relatively static, or is changeable only over relatively long periods of time. For example, electoral representation, landscape character and the location of bus stops are all on-line in many UK Local Authorities' publicly accessible web-mapping applications.

Such applications can also deal with more dynamic situations and one heavily used example of this is the Automobile Association's Travel Watch Service, which provides an up-to-date view of roadworks and delays on the road network in both map and textual form (Figure 39).

The Highways Agency and the RAC also offer similar services, and the Highways Agency have extended this to include details of scheduled future works on the major routes[7].



Last Updated: 21/04/2005 09:40

Road	Incident
A5152	Slow traffic between Wrexham Bypass (North) and Wrexham in Southbound direction.
A541	Heavy traffic between Wrexham Bypass and Wrexham Football Ground in Southbound direction.
A525	Lane(s) closed between Marchwiel and Wrexham Town Centre in Westbound direction.
A525	Lane(s) closed between Wrexham Bypass and Wrexham Town Centre in Eastbound direction.
A541	Lane(s) closed between Wrexham Town Centre and Wrexham Football Ground in Northbound direction.
A541	Lane(s) closed between Cefn-y-bedd and Gwersyllt in Southbound direction.
A5152	Slow traffic between Rhostyllen and Wrexham in Northbound direction.

Figure 39: the AA's Travel Watch Internet Mapping service, through which individual delays can be interrogated to give further details (www.theaa.com)

In recent years a growing number of authorities have started to develop web-mapping applications in areas of direct relevance to IEM. For example, the Centre for Environment Fisheries and Aquaculture Science (CEFAS), website provides a mapping application that permits access to multiple layers of marine environmental data that are of clear relevance to coastal emergency planning, for instance in respect of assessing the risk of pollution incidents[8] (Figure 40).

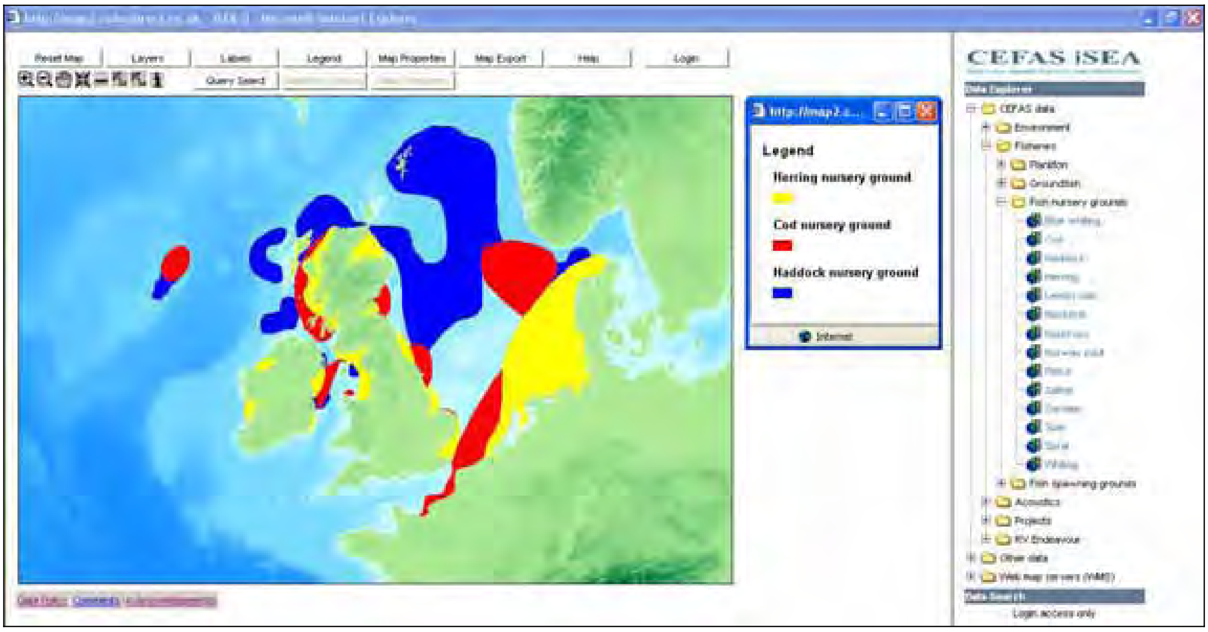


Figure 40: the CEFAS marine environmental data web-mapping application

Public Facing Systems are not of course the same thing as GIS and the wider work of the National Steering Committee on Warning and Informing the Public (NSCWIP) embraces many areas of work[9]. However, given the impact and accessibility of (well designed) maps, they deserve attention in this context. Note that at the height of the Foot and Mouth Disease

7 http://www.highways.gov.uk/
8 http://www.cefas.co.uk/
9 http://www.nscwip.info/

epidemic of 2001, the DEFRA website that provided public access to maps of affected areas was receiving up to 600,000 hits a day.

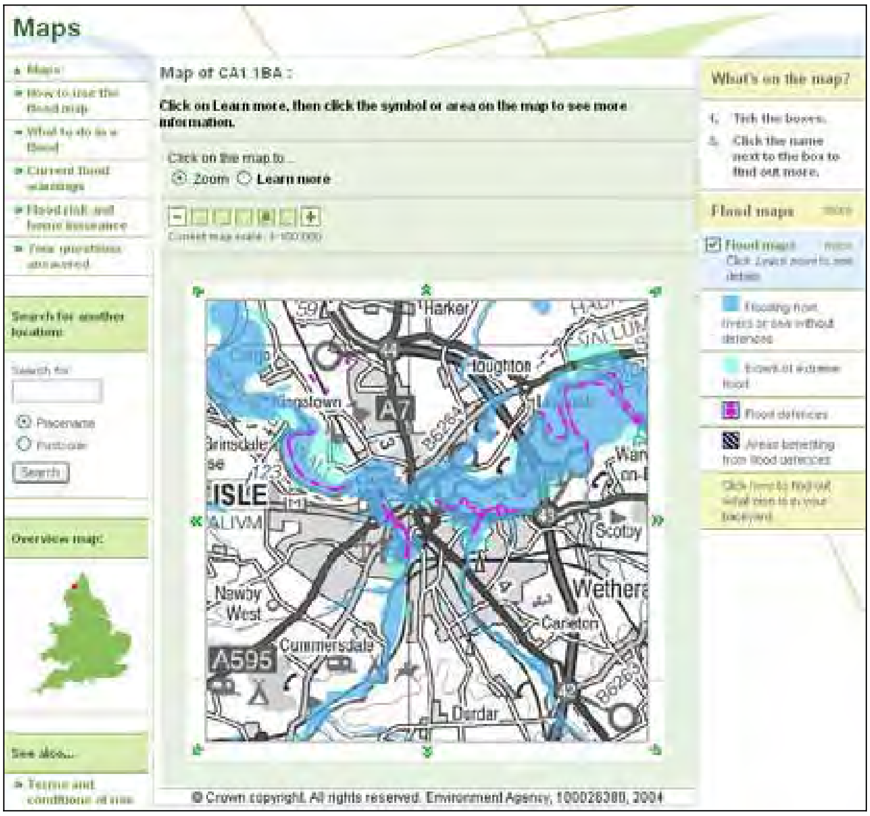


Figure 41: EA's web flood mapping

The Environment Agency website[10] provides a mapping service for members of the general public to identify both current flood warnings and also the likely extent of different severities of flooding.

While this is unwelcome news for those who live or work in the identified areas, it is a necessary element of preparing for flooding emergencies.

7.1.4 Case study: Surrey Alert

Surrey County Council, working in partnership with the Surrey Emergency Services Major Incident Committee (SESMIC), has pioneered the use of web-based GIS as an element of the Surrey Alert system. Surrey Alert is intended to provide spatially related information for use in planning, training and responding to incidents. Designed to be used in conjunction with existing emergency planning procedures, Surrey Alert is intended to be the definitive source of spatial information during an incident, so that all responders can trust that the information they are using is the most up to date, and accurate.

There are four main elements to Surrey Alert:

i) An Emergency Contacts Database that is universally accessible and always up to date
ii) An Incident Management System that provides an audit trail of communications and decisions over the course of an incident
iii) A Public Website that is intended for the general public and media organisations to use as an information point during a major incident
iv) An Extranet site that is intended to be used by the SESMIC organisations who would respond during an emergency (emergency services, local authorities,

[10] http://www.environment-agency.gov.uk/

military, Environment Agency, Highways Agency, Government Office South East and the NHS).

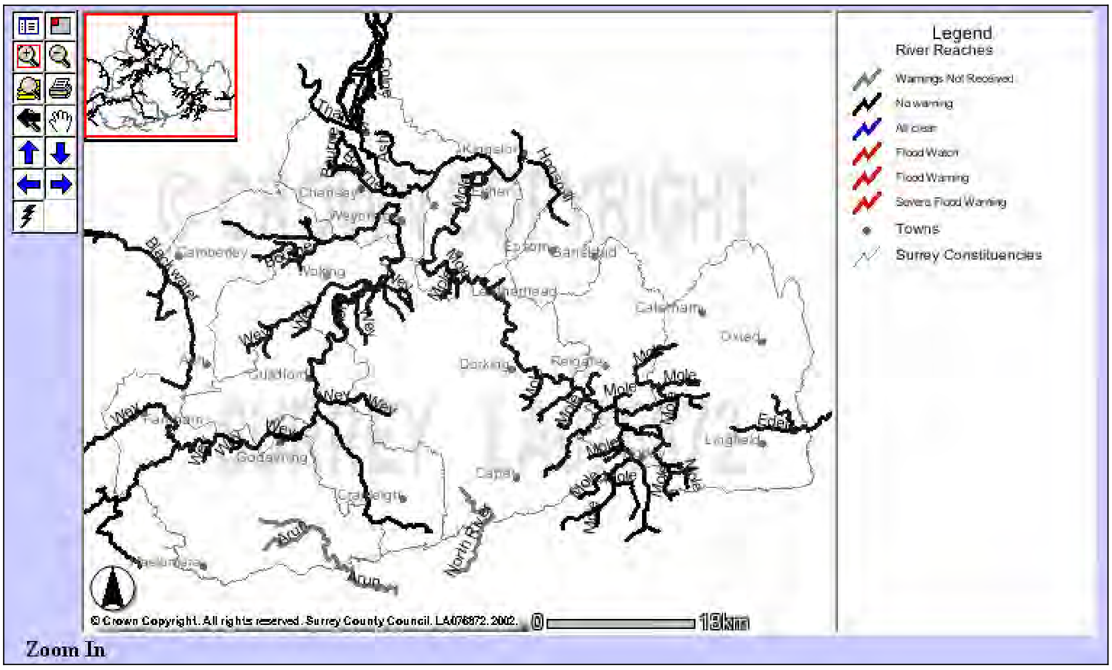


Figure 42: The Surrey Alert Public-Facing Flooding GIS

Datasets that are available on the extranet-based mapping application include:

- Emergency Services bases & boundaries
- PCT boundaries and head offices
- Pipelines
- COMAH sites
- Voluntary services
- Emergency Rest Centres
- Environmentally sensitive areas
- Hospitals, GP surgeries, pharmacists
- Utility boundaries
- Ordnance Survey Address Point data
- Petrol stations
- Schools

Figure 42 illustrates the publicly accessible flood-warning application for the whole of the County and Figure 43 illustrates much more detailed, large-scale mapping, for a much smaller area. The intention is to develop the GIS to become the basis of a Community Risk Register as required under the Civil Contingencies Act.

It should be noted that web-mapping applications are not the same thing, in respect of functionality, as desktop GIS. Specifically, the analytical capabilities of such systems (this relates to currently available Commercial Off The Shelf Software - COTS - systems) are weak and their main use is restricted to displaying and querying spatial information. Many organisations have recognised that this 'lightweight' characteristic of such applications is in fact an advantage in certain contexts, and cost savings have been realised by replacing desktop GIS with web applications for casual users (see Section 9 and Box 11). The organisation benefits from reduced costs and the user benefits from a system that is usually less complex to use and where there is no risk of over-writing or otherwise corrupting core datasets, as access is usually read-only. A further gain is that versions of datasets can be controlled more tightly in web-applications and users' access to current (or approved) datasets can be more easily facilitated and managed.

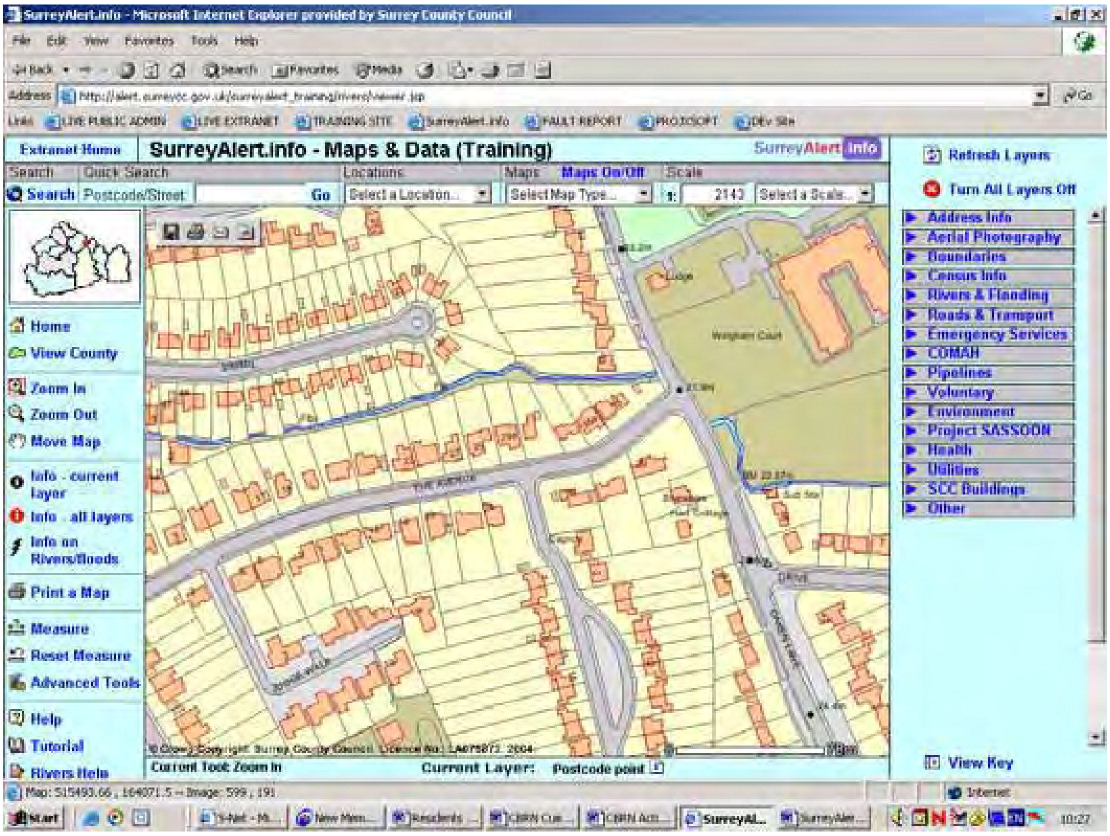


Figure 43: The Extranet GIS for Incident Management

For more advanced GIS users (sometimes known as 'power-users') web-applications are currently very unlikely to meet their data management, manipulation and analysis requirements, but as datasets are readily interchangeable between desktop GIS and web-mapping applications, the results of desktop analysis can rapidly be posted to a web-mapping application for much wider access. The New York City Emergency Operations Centre (EOC) uses exactly this approach, analysing incidents, changes, trends, etc on desktop GIS, and then enabling access to this information by every agency in the EOC using a web-mapping application. In this way a Common Operational Picture is maintained.

7.2 Preventing Emergencies

As introduced above, risk assessment is an essential prerequisite to effective risk mitigation, itself a critical component of the overall approach to build and foster resilience. GIS in itself cannot prevent emergencies but it can inform policies, plans and practices that can help to more effectively manage risks.

7.2.1 Case study: Integrated Risk Management Planning in Surrey Fire and Rescue Service

GIS was adopted by Surrey Fire & Rescue Service to analyse the implications for service delivery of changing crewing patterns at their fire stations. The question was whether savings could be made without increasing the risk to people, properties and businesses within the fire service area. Underlying this was the need to identify fire stations that could change the role of their personnel from being dedicated to crewing a fire engine, to being able to carry out more flexible roles. To achieve this way of working, it would need to shown that effective operational cover could still be provided, even if the change in working took place. The ability of GIS to plot isochrones, lines of equal travel time, and then to validate these models with data of real times taken to reach certain geographical areas proved an objective means of proving this risk management approach.

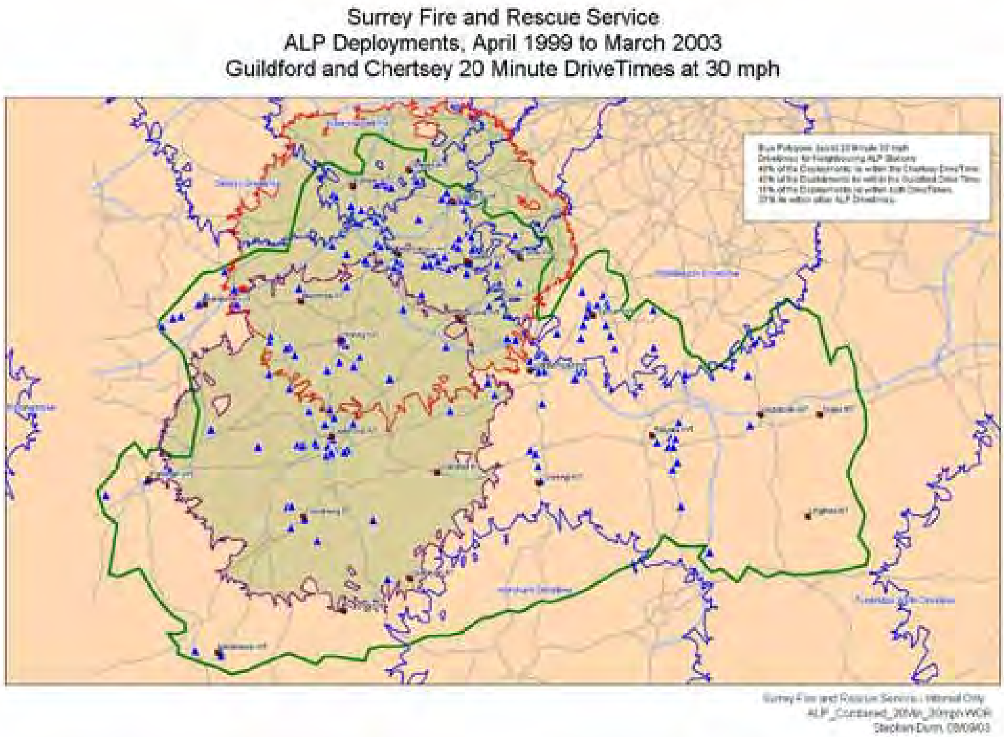


Figure 44: drive-time analysis to inform the deployment of specialist vehicles within the SFRS

Although GIS has been used for some time within the organisation for route finding and hazard identification by both control and operational staff, at the beginning of the integrated risk planning process, GIS analysis was limited within the organisation. Therefore, a consultant was employed to develop GIS solutions specifically for IRMP. Following the period of consultancy work, a risk information unit of two analysts and a team manager was established.

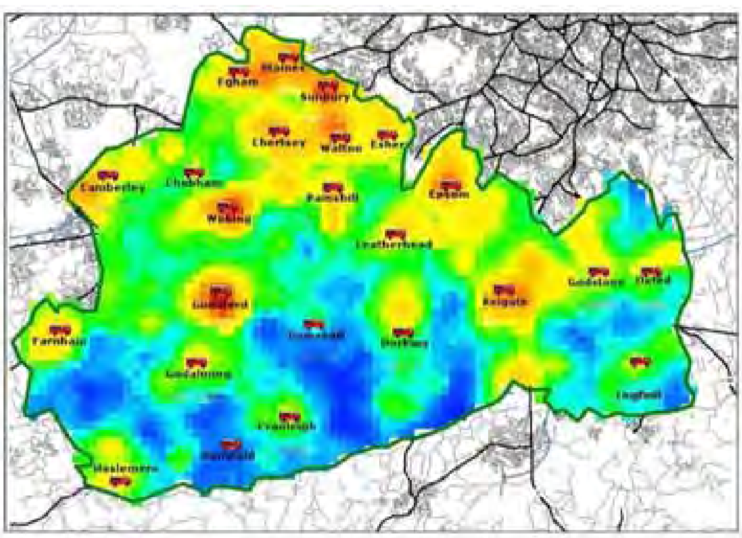


Figure 45: historical incident data illustrated as a ‘hotspot’ map where red shows high operational activity, blue shows low operational activity and fire engine icons show the locations of fire stations

The data used for the IRMP process was already available in the organisation within an operational database, which held details of all incidents attended by the organisation. A degree of data cleansing was required, but as it was used for performance indicator returns data quality was almost all fit for purpose.

The use of GIS within the IRMP process has been successful, and different crewing patterns at certain fire stations within the organisation have now been implemented, leading to efficiency gains across the service. Building on this experience SFRS plan to extends the use of GIS initially for enhancing existing risk profiling within the county through integrating various data sets including census data and incident data. IRMP has also strengthened partnership and inter-agency working, particularly with the police and community safety partnerships, to direct activities such as home fire risk assessments and smoke alarm fitting (integral to emergency prevention), and also crime and disorder reduction initiatives in the county.

Although this case study relates to Fire and Rescue, the principles of data analysis for risk assessment and service assessment are highly transferable, and have been adopted by other emergency services. In the ambulance service in particular, it is well established that response time is crucial to the survival of trauma victims, and analysis of frequently occurring traumas such as those associated with road traffic collisions has been influential in guiding the spatial distribution of emergency services, at particular times of day, week and year. The principle is the same: data analysis informs risk assessment which drives service planning to meet defined criteria and standards.

7.3 Preparing for Emergencies

Emergencies will happen and preparing for them is critical. The nature of emergencies is that there are a range of unknowns involved (location, cause, magnitude, severity of consequences, etc) and so the emphasis must be on building capabilities that are suitable, sufficient and also flexible. The emphasis is therefore on planning for a flexible response.

Planning is core to preparing for emergencies, and there are three basic types of plan: (a) generic (including generic capability or procedure), (b) hazard or contingency-specific and (c) site or location-specific. These are detailed below.

a) *Generic Plans:* these plans define how an organisation should respond to any emergency. They are not specific in respect of location, nature and severity, but they are premised on the understanding that responding to many emergencies will require the same initial steps to be taken in terms of staff alerting, resource deployment, media relations and warning and informing the public. The role of GIS in generic plans is relatively limited, but generic plans should offer guidance on how GIS should be deployed in the event of an emergency.

b) *Hazard or Contingency-Specific Plans:* many events such as festivals, sporting occasions or conferences give rise to a set of conditions that require specific plans to be set in place. The combination of large numbers of people, a high level of concentration, overloaded services and security considerations make it very likely that any incident would be resource-demanding and complex to respond to. Although planning is, by its very nature, based on assessments and assumptions, GIS has a range of applications in risk assessment, service analysis and response if an emergency such as a bomb threat, building collapse or disease outbreak was to occur during the event.

Specific contingencies such as major transport emergencies (e.g. aircraft or rail crash) or terrorist attacks also need to be planned for. With such hazards and threats risk assessments and intelligence reports may enable planners to be *relatively* specific about the potential location and severity of such emergencies. However, the planning emphasis must be on flexibility and the ability to generate an appropriately scaled and resourced response within a framework and processes that can translate the principles into geographically-specific actions. The role of GIS in this regard is clear.

c) *Site or Location-Specific Plans:* hazardous premises and areas such as COMAH sites are required to have emergency plans in place. These will be based on a hazard and risk assessment of the site and horizon scanning of the potential emergency scenarios, including their spatial implications. The plans should detail steps to be taken under specific circumstances, although one quality plans should always aim for is flexibility, to support an effective response when the incident is not exactly what has been planned for. As with event plans, location plans can make extensive use of GIS and should also offer guidance on how GIS should be deployed in the event of an emergency.

The ability of GIS to link spatially specific data at a variety of scales (site plan – small area demographics – critical infrastructure) with thematic Standard Operating Procedures (SOPs) has the potential to support the required level of rigour and flexibility. For instance, Figure 46 identifies, in schematic fashion, a set of scene locations and functions that would be employed in managing an incident which required inner and outer cordons to be established. Inner and outer cordoned zones are identified, together with the activities that would be located within those zones.

These activities, arrangements and issues would include:

- An inner and outer cordon, the placement of which would be determined by the nature of the incident and the local environment
- Forward control point
- Incident control point
- Reception point for utility company staff
- Establishment of internal traffic routes for emergency services
- Casualty clearing station(s)
- Ambulance loading point
- Survivor assembly point
- Helicopter landing sites
- Rendezvous point(s) for responding personnel
- Vehicle and equipment marshalling area
- Body holding area
- Media liaison point.

The precise, ‘on-the-ground’ delineation of these zones and the location of facilities such as decontamination, casualty clearing and access points will be determined by the arrangement of factors including the spread of any damage or contamination, wind direction, terrain, road networks, ground conditions, rivers and the availability of suitable buildings, all of which can be held, interrogated and analysed within GIS. Achieving this capability does, however, require that GIS databases are prepared and in place to help frame and direct a response at short notice. At a basic level, access to digital (or indeed hard copy) backdrop mapping will permit a rapid appraisal of an emergency scene and context, for instance to identify potential helicopter landing sites. However, the advantages of an integrated GIS database with multiple thematic layers must be acknowledged; in the context of helicopter landing sites, not all overhead power lines are marked and only in the MoD over-printed 1:50,000 OS maps are they all present and associated with height above ground level figures. This is just one example of adding value through data combination.

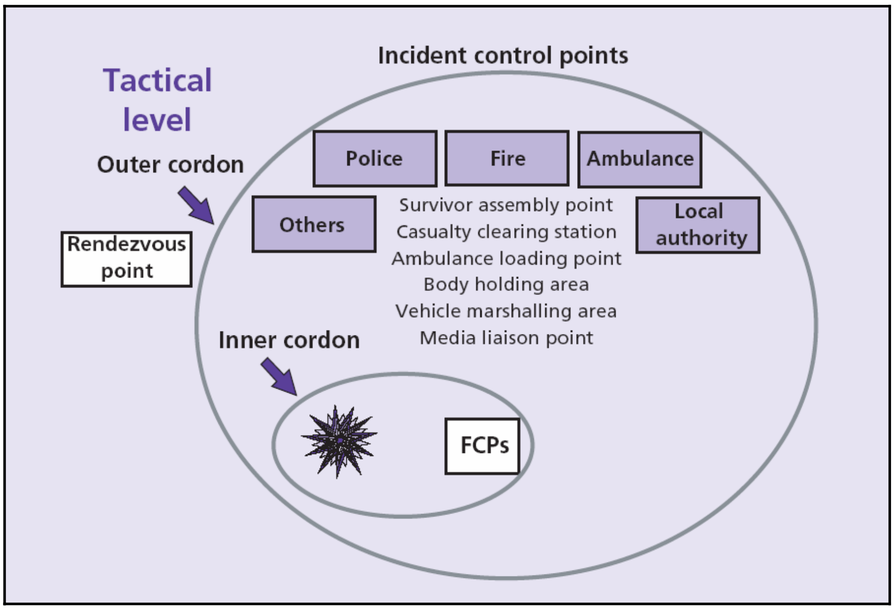


Figure 46: Schematic organisation for incident scene management at the tactical level (Source: *Emergency Preparedness* www.ukresilience.info)

GIS applications in preparing for emergencies are not restricted to developing a multi-agency database for integrated emergency management, contingency planning and table-top exercises, for they also include the ability to analyse the distribution of resources relative to identified hazards, risks and vulnerabilities with a view to optimising response, something that is at the core of the IRMP project referred to in 7.2.1.

7.3.1 Case Study: Preparing for Severe Weather Emergencies

The Met Office has developed a Severe Weather Impacts Model (SWIM) that is based on multiple layers of spatial data and a knowledge-base that is distilled from extensive research into the impacts of severe weather incidents. Severe weather is defined as events that lie at the boundaries of what is normally experienced. These include extremes of temperature (both hot and cold), precipitation and wind.

The Met Office is seeking to support emergency planners and responders in both the public and private sectors in their ability to anticipate, plan for and respond to severe weather events. It should be noted that although this model will predict impacts from flooding there is no significant overlap with the Environmental Agency's work as the latter focuses on fluvial (rivers) flooding while SWIM focuses on pluvial (directly from rainfall) flooding.

SWIM itself is comprised of a number of elements, which enable the prediction of impacts from:

- Strong winds
- Heavy snow
- Heavy rain
- Dense fog
- Ice accretion

Scenarios can be defined to run within defined parameters (type and severity of weather conditions, geographical area, and model outputs) and there are a number of information outputs, primarily:

- A map illustrating spatial disaggregation of impacts
- A table providing more precise figures for defined areas
- A report on the economic implications of the scenario
- A report on the workload implications (e.g. in restoring service) of the scenario.

Figure 47 illustrates the system calculating the number of electricity company customers who are predicted to experience a loss of power in the Midlands. The darker the colour, the higher the number of those who will be affected.

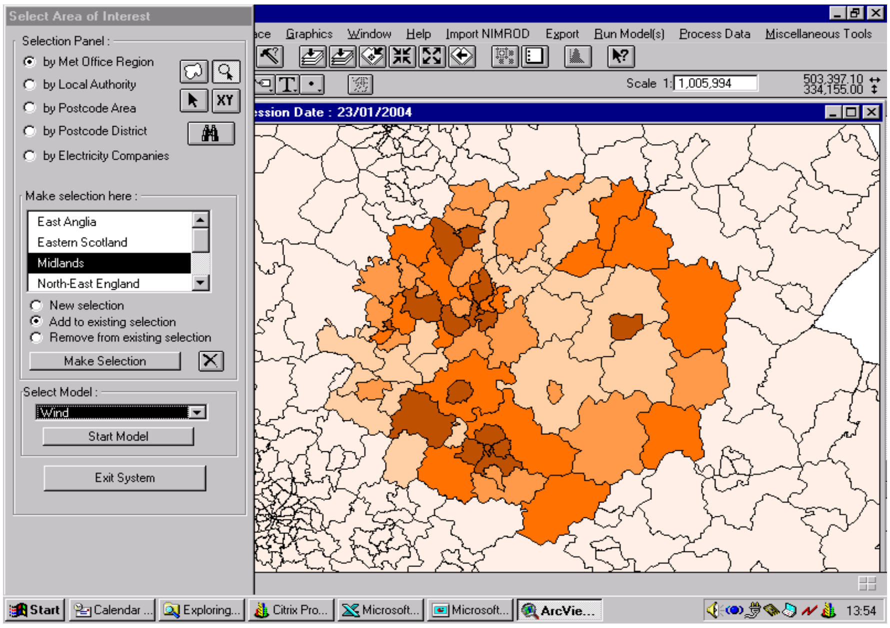


Figure 47: predicted levels of power loss consequent upon severe winds (Courtesy of the Met Office)

The results are also made available in tabular form, and can be aggregated to a range of geographical units including postcode areas and local authorities (Figure 48).

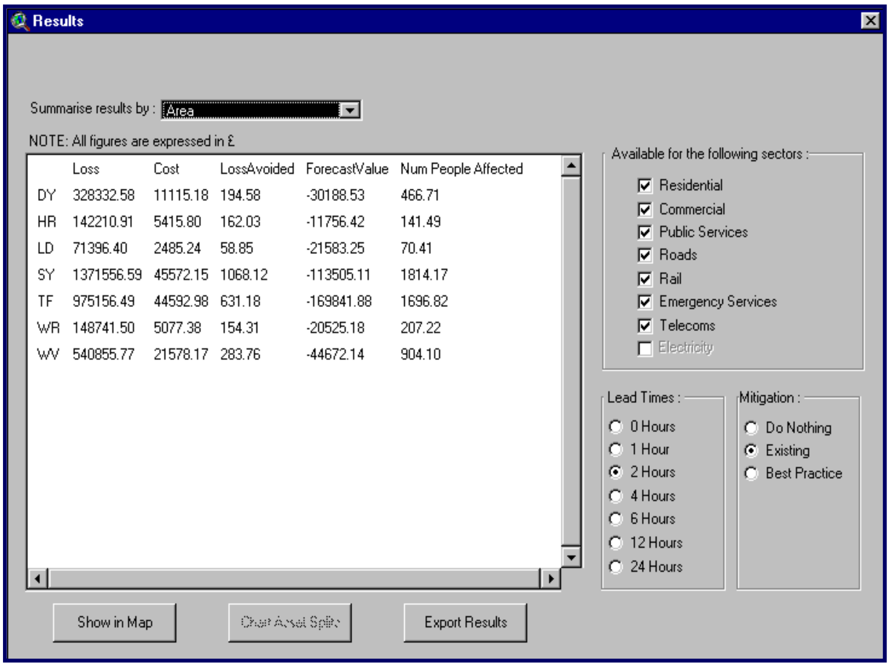


Figure 48: tabular reporting of impacts from SWIM (Courtesy of the Met Office)

In addition to aggregated impacts information such as this, SWIM also supports more highly disaggregated predictions for infrastructure damage. For example, Figure 49 illustrates three layers of information:

1. forecast maximum gust speed
2. forecast direction of maximum gust
3. the location of specific high voltage electricity transmission lines.

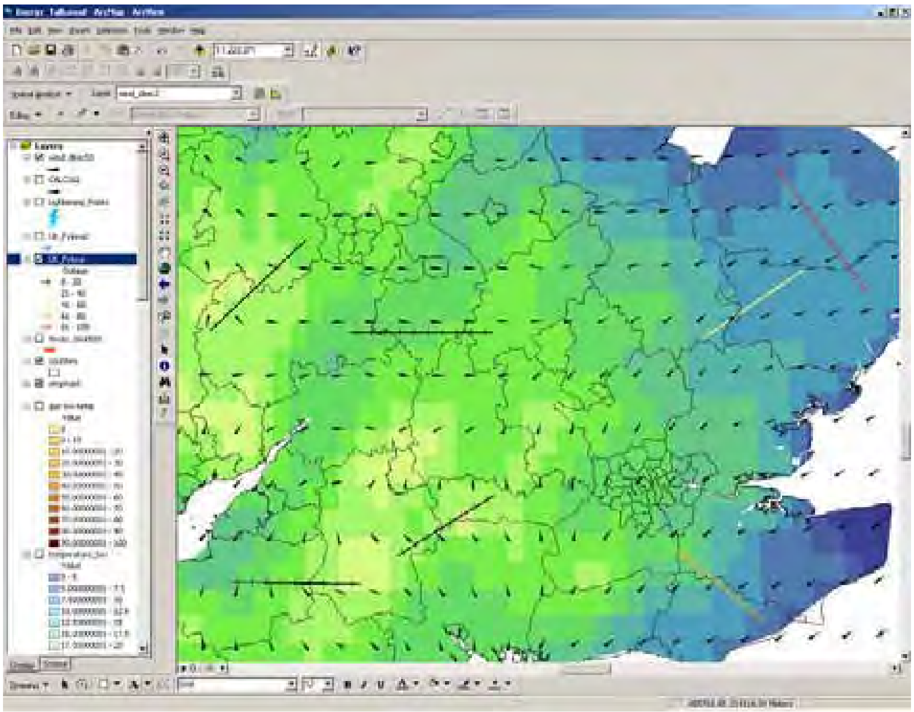


Figure 49: predicted maximum gust speed and direction, overlain with vulnerable electricity transmission lines (Courtesy of the Met Office)

The combination of these three variables, when combined within the model with a range of additional characteristics of the transmission lines such as age, type and construction, enables a more precise estimation of damage, and where it is likely to occur. Supported by this information Distribution Network Operators can undertake planning to mitigate the impacts of infrastructure damage, which is typically carried out in a very tight timeframe for decisions.

This is by no means a comprehensive overview of SWIM, but given that average losses per annum from severe weather range from £1.2 to £1.5 Billion in the UK, the significance of the model to assess risks, evaluate scenarios, warn relevant authorities of predicted impacts and support mitigation of those impacts is very clear. SWIM is an excellent example of the knowledge-based analytical applications of GIS that individual planners and responders are unlikely to undertake internally, but where the ability to assimilate such GI into decision making is critical.

7.4 Responding to Emergencies

7.4.1 Introduction

If data are available to a GIS, staff to operate the system are present and trained, expectations of the system have been appropriately managed and the organisational structures to support inter-agency working are in place, then GIS can enhance the efficiency and effectiveness of an integrated emergency response. Some of the key elements of this contribution might include:

- Support for tasking and briefing
- Producing hard copy maps which remain a key information product for responders and planners
- Integrating data from multiple sources that may flow in during the course of an emergency
- Developing a Common Operational Picture for multi-agency staff
- Supporting two way flows of information through mobile GIS
- Assessing likely consequences and supporting forward planning
- Managing assets and resources for current and projected future demands
- Keeping the public and other affected parties informed through internet or intranet mapping systems
- Establishing one element of an audit trail
- Supporting the transition to recovery with a baseline database that also integrates a full picture of the emergency itself.

As introduced in section 2 the nature of the emergency is all-important, perhaps most critically whether it is a rapid or a slow-onset emergency. Two case studies are included to illustrate different scenarios. In the first a deliberate contamination of public drinking water supplies is threatened and the response needs to rapidly address the public health consequences and then longer term environmental and service delivery aspects. In the second a fire at a chemical plant has widespread impacts on both a resident and working population and a busy transportation network. Both of these are clearly rapid onset emergencies, and the emphasis is on sound and well established Standard Operational Procedures that are allied with GIS databases and tools to guide the location-specific details of the response in the short, medium and long terms. Following these case studies, the range of GIS applications in human and animal disease surveillance and control are presented, and finally the emergence and significance of mobile GIS for emergency operations is reviewed.

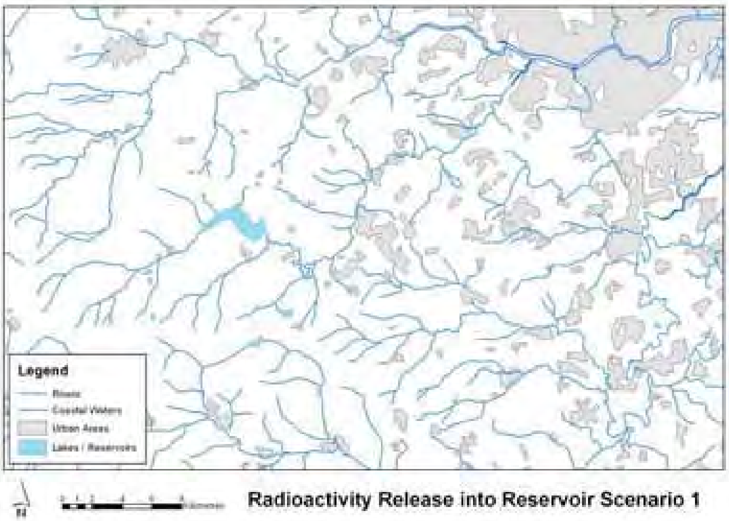
7.4.2 Case Study: Radioactive Waste Entering the Water Supply

<u>Scenario</u>: an anonymous caller claims to a newspaper that ground up radioactive waste from a hospital (Caesium-137) has been deposited in a certain reservoir that supplies a major city. No further details are available and it has to be assumed, if this is genuine, that contaminated water has now entered the downstream rivers and public water supply system.

The overriding objective in the short term is to prevent contaminated water from reaching homes and businesses and, where this has already happened, inform those affected of the actions they should take. In the longer term, contaminated water bodies and rivers must be identified for appropriate controls to be implemented. From a nature conservation perspective such as event would have limited implications unless the dose was massive, so it would be allowed to ‘flush through’, but fishing, water sports and other activities would need to be controlled.

Step 1: Identify the affected area.

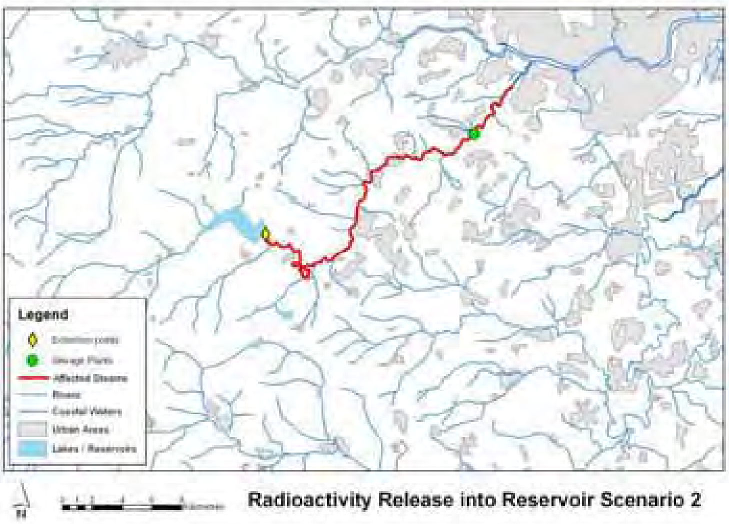
In this map the affected area is identified. The map should be kept relatively simple to avoid 'information overload', and it is restricted here to the contaminated reservoir, rivers and streams and urban areas.



Step 2: Identify all streams flowing from this reservoir, any potable water abstraction points and they supply and associated sewerage plants.

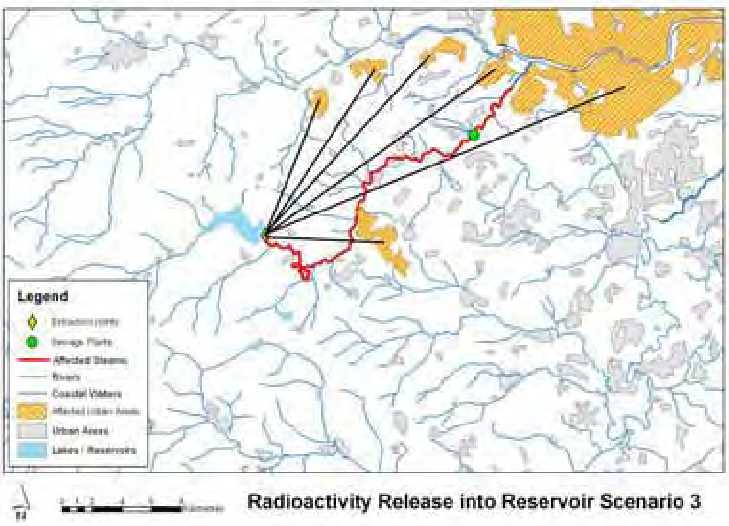
Here data on water abstraction points and sewage treatment facilities that are associated with the reservoir and the outflow stream are called up and mapped.

Abstraction and sewerage facilities that are affected would be closed down.



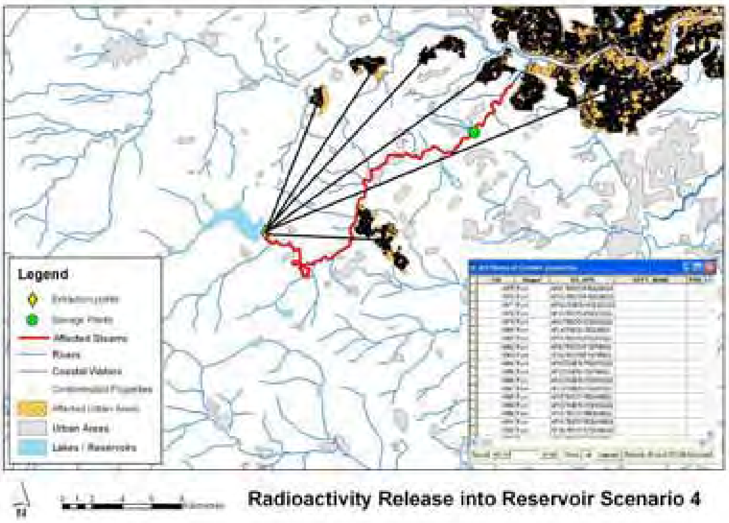
Step 3: Identify the urban areas supplied by contaminated water.

Data on the potable water supply networks emanating from the extraction point at the reservoir are mapped out, and the urban areas thus supplied are identified.



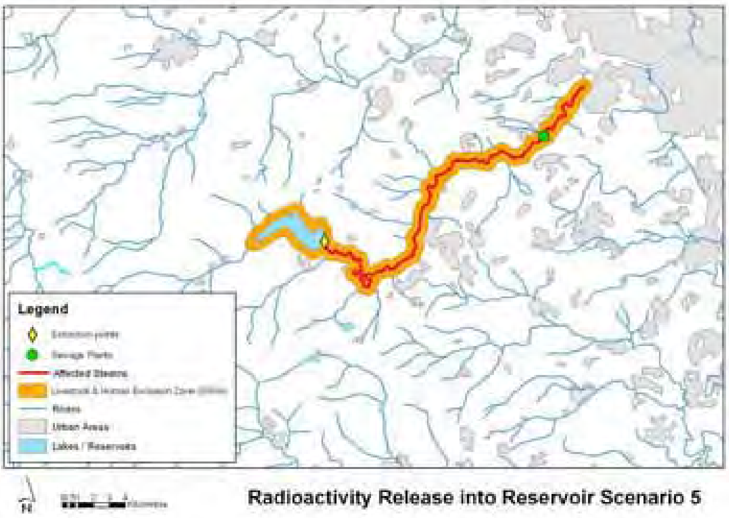
Step 4: Inform affected homes and businesses of appropriate actions to take.

Using a dataset based on the OS Addresspoint™ framework, all the properties within the affected urban areas are highlighted. Using a 'Reverse 999' telephone system (or cell broadcasting – see Box 7) residents and workers within these areas could be contacted and advised on appropriate steps to safeguard their health. This would require the association of the geographical location of each property with its phone number and implementation of software to facilitate this.



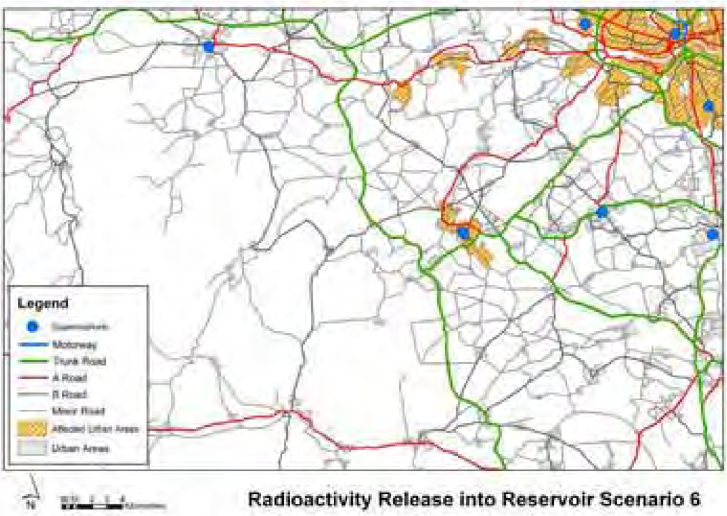
Step 5: Establish a cordon around the affected water bodies and streams.

With regard to animal health, protection of the human food chain and the control of recreational use of the contaminated stream until the threat and its potential impacts can be verified, a 500m buffer is drawn to identify an exclusion zone for livestock and humans. This would also be applied to the reservoir itself.



Step 6: Initiate the supply of clean water to affected areas.

The supply of safe water is an allocation problem, and GIS can be used to identify the location of water bowsers and safe filling points and then plan the optimum route to supply the affected population, starting with the most vulnerable sites such as hospitals. This could make use of network analysis, as described in 6.2.3. In the first instance the location of supermarkets that could be called on to supply bottled water to priority facilities can be identified.



Box 7: Cell Broadcasting

Cell Broadcasting is a technique that can disseminate information, including warning messages, to mobile telephones in a defined area. It is a powerful tool to rapidly distribute information (for instance the basic message illustrated below) and does not suffer from some of the problems associated with SMS multi-casting, that is the simultaneous sending of SMS text messages to large numbers of recipients. Three key features of Cell Broadcasting are:

1. every mobile phone has the capacity to receive messages in this way, although it will be enabled on very few at the moment;
2. there is no significant requirement for infrastructure investment;
3. it causes no load on the network, which is a critical consideration under emergency conditions when the network may be heavily loaded and when preferential user priorities may have been imposed.

With Cell Broadcasting individual mobile phones are not identified, it fact it is a much simpler system which targets towers and messages sent through those towers are then received by all mobile phones in those service areas within 30 seconds of the broadcast being made.

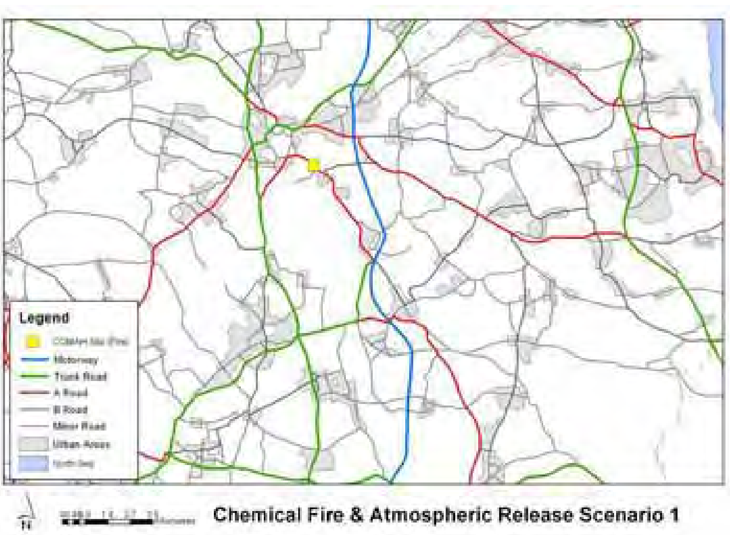
For further details on cell broadcasting see the website of the Cellular Emergency Alert Systems Association at www.ceasa-int.org

7.4.3 Case Study: Chemical Fire and Resultant Atmospheric Pollution

Scenario: a fire at a COMAH site (hazardous chemical production site) has led to the explosion of a fuel tank and the release into the atmosphere of an unknown quantity of hydrogen chloride.

Step 1: task response crews

Vehicle Mounted Data Systems (see 7.4.5) are used to access site hazard information by response crews and relay situational information back to incident control.



Step 2: establish cordons and commence evacuation

Establish, at first notice of the fire, an inner cordon of 400m and an outer cordon of 1000m around the plant.

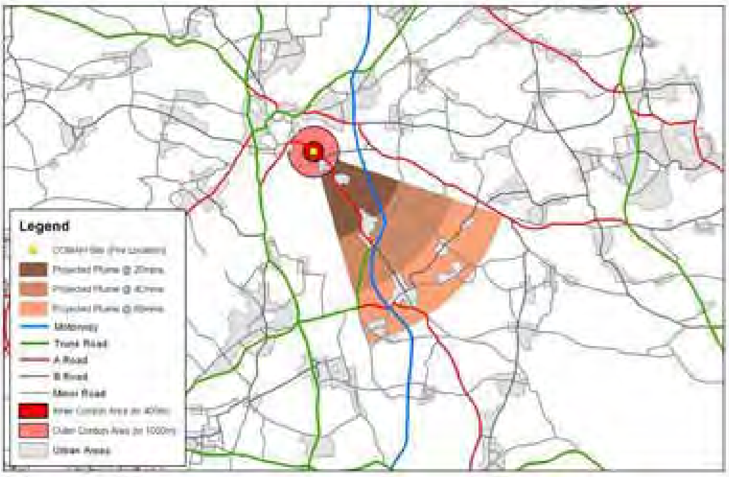
Fire crews attending the scene assess the risk of a major explosion to be high, so plans to evacuate homes and other buildings closest to the fire are implemented.

During the evacuation the anticipated explosion occurs.

Chemical Fire & Atmospheric Release Scenario 2

Step 3: response adjusted to deal with atmospheric release

Explosion causes atmospheric release of hydrogen chloride (HCl), the evacuation is suspended and all homes and businesses within 1km are advised to ‘get in, stay in and tune in’. This could be effected through Reverse 999 calling and/or cell broadcasting. To refine the area at risk, the predicted atmospheric diffusion of HCl is modelled using software integrated with GIS, and predicted spread for 20, 40 and 60 minutes is identified.



Chemical Fire & Atmospheric Release Scenario 3

Step 4: Establish Forward Control Point and traffic controls.

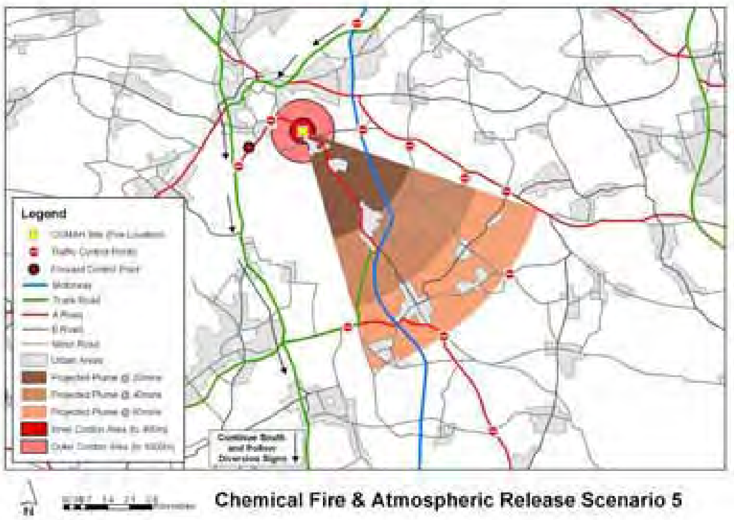
With the new information on predicted atmospheric pollution, traffic control points can be identified and resources tasked to block roads and set up advisory traffic control points.

A Forward Control Point has by this point been established and is illustrated on the map.

Chemical Fire & Atmospheric Release Scenario 4

Step 5: Consider impact minimisation on Motorway Traffic Flows

Northbound Motorway traffic has been diverted and Southbound traffic approaching the area at risk is diverted as illustrated and maps illustrating this can be distributed in digital form.



In addition to these stages there would clearly be a host of other, much more detailed tasks that GIS could support, perhaps involving very large scale mapping, including site plans or Ordnance Survey Mastermap^{TM}, for instance.

7.4.4 GIS applications in slow-onset human and animal health emergencies

Although slow-onset (chronic) emergencies may seem to be preferable to rapid-onset (acute) emergencies in respect of having time to consider an appropriate response, there are often complexities with such chronic emergencies that managers do not have to consider in an acute situation. That very complexity makes sound information management, including spatial analysis, extremely significant, and the 2001 case study of avian influenza in Pennsylvania has already demonstrated the effectiveness (timeliness of disease control and restriction of spatial impacts) and efficiency (financial savings) gains from such evidence-based practice.

The study of human and animal health shares many characteristics, both theoretical and methodological. The starting point for GIS applications in health studies was focused upon established datasets such as disease registries and early studies, particularly into the spatial distribution of cancers and their statistical relationship with other variables, did much to raise the profile of GIS as a set of tools in the health professions.

Common applications of GIS in epidemiological studies and outbreak control would include the following (see section 6 for details):

- *Overlay analysis:* establishing spatial relationships between layers of map data, which may be either thematic or time-series for an individual theme. Relationships based on location can be identified, quantified and tested for statistical significance.
- *Neighbourhood analysis:* identifying features that meet defined spatial and attribute queries can be used in risk analysis. For instance, in the case of Foot and Mouth Disease (FMD) atmospheric transmission was a primary concern. If livestock on a farm was confirmed as being infected then a query to identify all livestock farms within a 10km radius would be a necessary first step in controlling the potential 'domino effect' of successive infections. In reality, during the 2001 FMD outbreak in the UK, MAFF's GIS staff were supported by the Met Office who applied plume modelling techniques to define likely airborne spread of the virus. All livestock farms within that plume could then be identified through a spatial query.

- *Spatial Statistics:* the application of spatial statistical tests to point-based datasets permits analysts to differentiate between statistically significant clusters and those which, although they may appear to be clustered, are not statistically significant in their pattern. This may be critical in supporting a decision to investigate further or mobilise resources to control a suspected outbreak.
- *Modelling disease spread:* in a slowly unfolding emergency that is extensive and serious, considerable resources will be required to control and manage the emergency and promote recovery. Rather than adopting a purely reactive stance, epidemiologists may be able to model potential scenarios for the future development of the outbreak. Modelling is of course based on assumptions and as such the outputs must be regarded as being of uncertain reliability, however the ability to rehearse and establish plans for future development possibilities it is extremely significant.

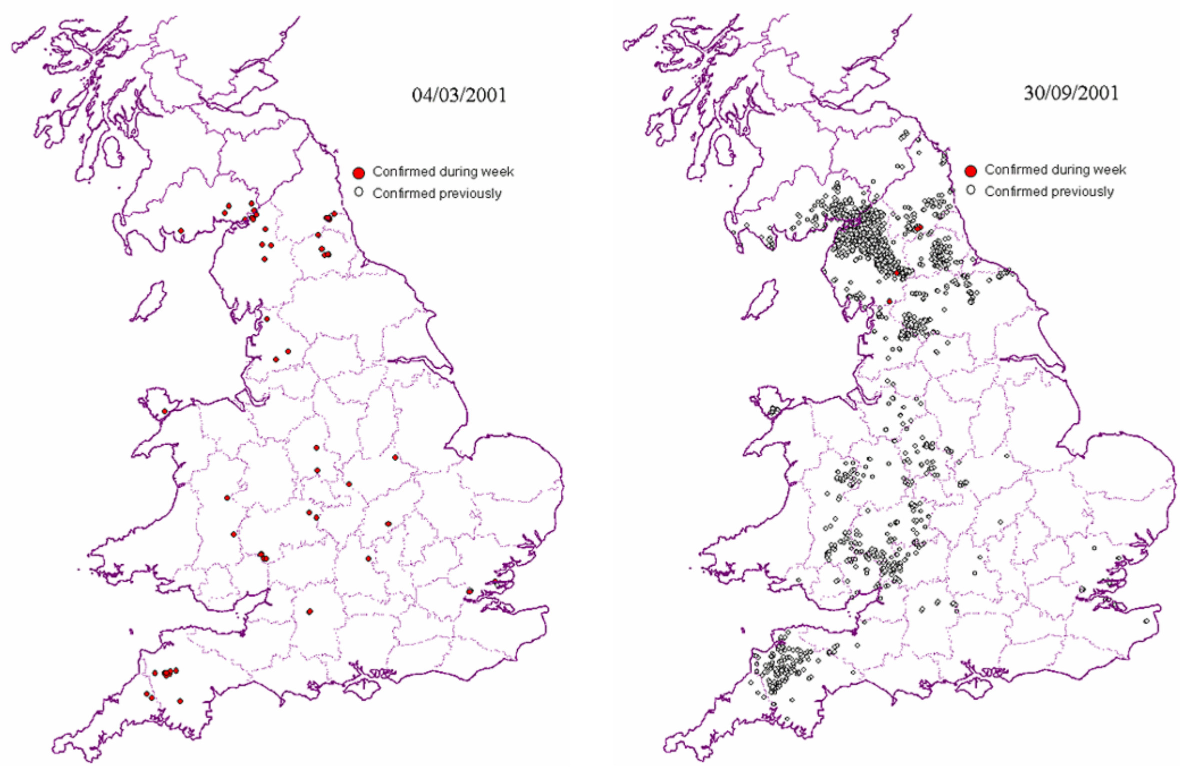


Figure 50: the spread of FMD during 2001 (Source: DEFRA, Central Science Labs [11])

- *Buffering:* this basic GIS tool is extremely helpful in defining potential areas of risk, especially at the early stage of an emergency when little detailed information is available. For instance, until plume models which account for a wide range of atmospheric, topographic, environmental and subject-specific information (e.g. survival rates of virus outside of the human/animal body) are available to emergency managers, a simple buffer around infected premises or individuals is a sensible initial step for disease control measures to be applied.
- *Network analysis:* many animal disease outbreaks are managed through controlled and carefully targeted livestock slaughtering. The disposal of carcasses is problematic on many levels, and site selection itself is highly suited to GIS, but transporting infected carcasses to disposal points requires careful planning, most critically to avoid non-infected areas. This kind of problem is highly suited to route

[11] http://footandmouth.csl.gov.uk/secure/fmdstatistics/spat.cfm

planning through network analysis, for example <identify route from Farm A to Disposal site avoiding roads that travel within 5 miles of Farms Q to T>.

In addition to analytical functions of GIS, the ability to visualise datasets in map form is in itself highly significant. For instance, during the 2001 FMD outbreak, small scale maps were used at the national level for monitoring spread of the disease and for briefing purposes, livestock populations and their movements were used by epidemiologists working to understand and then manage the spread of disease, and mid-scale maps were used by the army to identify potential burial sites. Large-scale maps of farm buildings were used for briefing and recording the work of cleaning and disinfection teams[12]. Later in the outbreak, when the outbreak was coming under control and the GIS element of the response had developed significantly, the Ministry for Agriculture, Fisheries and Food (MAFF, now DEFRA) intranet mapping facility was used across the Ministry for a range of applications, including the issuing of movement licenses and responding to queries relating to restricted areas.

7.4.5 Mobile GIS

GIS have been around, in one form or another, for approximately 40 years, although it was the early 1980s before systems first became commercially available. For the vast majority of that time the software was limited to essentially immoveable computers (mainframes, workstations and desktop PCs). With the advent of laptop and notebook computers that had comparable processing power to desktop machines, GIS could be mobilised for use out of the office. Although this was most significant when laptops could be combined with GPS units and other data logging devices, for most GIS users laptops only promised a change of scenery rather than a dramatic shift in working processes.

Figure 51: a PDA with map viewing software and GPS linked by Bluetooth wireless communications

It was with the advent of 'ruggedised' computers (which were typically far lower on processing power than mainstream laptops), quite closely followed by the emergence of Personal Digital Assistants (PDAs) that software developers began to offer mapping software and lightweight GIS for field applications.

A range of COTS software are available today that support data logging in the field through integrated GIS (Figure 51), and more recent developments have exploited the rapid emergence of digital wireless communications to support two-way data transfer between 'office' (desktop) and 'field' (laptop or PDA) GIS. Such capabilities have potentially dramatic implications for emergency operations.

Box 8: Location-based information

By definition, spatial information is location-based information. However, the term is specifically used to describe the communication of specific pieces of information that are 'triggered' by spatial location. For example, many UK mobile phone operators have reciprocal arrangements with service providers in other countries. Shortly after switching your phone on in Paris, Munich or Cairo you may receive a text message welcoming you to

[12] *Managing a crisis: Foot and Mouth Disease,* Ordnance Survey.

this network and offering you some service-related information. By extension, mobile phone users can request information from service providers on the nearest facility such as a restaurant. Most commonly at the moment, location is calculated using the cell from which the call was made. However, an increasing number of mobile phones now contain a GPS receiver which permits such queries to be executed with much greater precision; the technological boundaries between GPS, in-car navigation systems, PDAs, mobile phones and digital radios are breaking down. Just as users can *request* information based on their location, unsolicited information, potentially including emergency messages, can be sent to all such devices within a given area.

As a final example of this, some years ago Cambridgeshire Police control room took a 999 call that was an automated emergency message giving a location at which there had been an accident. The location was given in latitude and longitude. The corresponding OS grid reference was worked out and a patrol car was dispatched to find an American car had driven off the road. The airbag had inflated, triggering a call from an embedded phone that was associated with a GPS. Being an American phone it was set to dial 911, but this was re-directed to 999. The driver, a US serviceman, was recovered from the vehicle and survived the accident.

The Fire Service has been developing Vehicle Mounted Data Systems (VMDS) over several years. A range of models exist, but they have a common focus on permitting fire and rescue personnel to access risk information relating to locations they have been tasked to attend. The initial stimulus to develop VMDS was the death, in 1993, of two firefighters in Herefordshire who were killed when a suspended ceiling collapsed on them; had the incident commander known that the building was constructed in this way, the firefighters would most likely not have been tasked to enter the building. As a result of this and following HSE reviews of the incident, a programme of work to develop mobile Decision Support Systems (DSS) to enable crews and commanders to access site-based risk information was initiated by the Chief and Assistant Chief Fire Officers Association (CACFOA).

Figure 52: a Vehicle Mounted Data System with integrated GIS in use at Sembcorp Utilities Wilton Site, Middlesbrough (Courtesy of James Elliott, Northumbria University)

Although a range of technical models and data bearers exist within the wider initiative, the basic principle is that of combining the dissemination of risk-based information as, where and when it is required, with the longer-term development of two-way voice and data communications between field units and command and control systems.

7.4.6 Case Study: Automatic Vehicle Location System in Durham Constabulary

Durham Constabulary are developing the Airwave digital radio system as a data bearer to enhance their Command and Control (C2) systems. Although Airwave has the potential to support two-way data flows of many different types between control and field units, their initial focus in developing the system has been to support an Automatic Vehicle Location System (AVLS). A GPS transmitter in police vehicles is allied with the Airwave radio, and the location of that unit is passed back to control every second, although more frequent updates are triggered when the unit is travelling above 50mph or when the blue lights are activated (Airwave coverage within Durham is in excess of 97%). These track data are archived and each point on the route can be associated with a range of attributes including speed, direction, whether the blue lights are on and, in the case of Armed Response Vehicles, whether the box containing the weapons has been opened. This is of clear relevance of post-incident de-briefing and retaining an audit trail for possible legal proceedings. In a similar vein, local authorities are using the same technology with resources such as road gritters where the recorded attributes for each point include time, level of grit remaining in the hopper and rate of dispersion onto the road surface.

Although the flow of data from Airwave is mediated through the ‘Co-ordinator’ system, the data are mapped in real time onto the force’s standard GIS software, ‘Blue 8’. This permits staff to see the distribution of mobile units as they are at any given time, and each location is associated with its call-sign, supporting ease of understanding and communication. Although officers in mobile units do not have access to mapping in their vehicles, the ability of control room staff to integrate a range of geographical datasets and to overlay these with the locations of their mobile units has considerable potential for effective and efficient working. For instance, if an area can be identified on the control officer’s screen which shows an area that is known to be contaminated following a chemical incident, units in that area can be almost instantly advised of risks and how they should respond for their own safety and in implementing the required response.

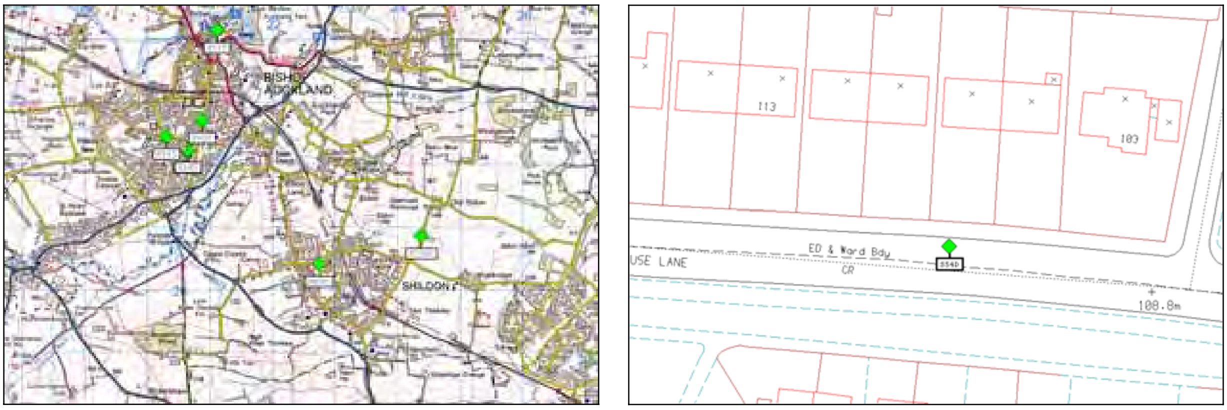


Figure 53: Illustration of AVLS operating in Durham Constabulary on a medium scale map (left) and a large scale map, illustrating the positional accuracy of the system (right). The green diamonds illustrate current location of police vehicles and their callsign.

Control staff are also able to access emergency plans and procedures through the GIS and a range of ‘triggers’ for SoPs are embedded into the system, and updated as required. This enables control staff to advise officers on appropriate actions if called to premises that are known to be hazardous and then initiate a wider, multi-agency response as appropriate. Trials to extend the same approach to individual officers with hand-held Airwave sets are underway at the time of writing.

Durham Constabulary are in the process of implementing a digital C2 system which will support tasking of resources on the basis of location (which unit is nearest), attributes (is it the right kind of resource, the right number of officers and with the right level of equipment) and availability (have the officers indicated that they are available for tasking). It is acknowledged that implementing such systems, and placing them at the core of C2, will require significant changes to business processes, but Durham Constabulary are working to effect these changes to realise the effectiveness and efficiency gains that they promise. The Force is also liaising with other emergency services and council emergency planning staff to identify the most appropriate way to use the emerging framework and systems to support multi-agency response to serious and wide-area emergencies.

7.5 Recovering from Emergencies

The transition from emergency response to recovery is not sharply bounded and there is strong evidence that a recovery which is initiated as early as possible will be more effective and efficient than one which is effectively a separate operation in the aftermath of an emergency response. Although it is not a neat distinction, recovery can be divided into short and longer term processes.

Short-term recovery is focused on the restoration of what might be termed 'life-support systems', notably the provision of water, food, medical assistance and shelter. It is at this stage that overlap with emergency response is the clearest. Following closely behind these most basic provisions are the restoration of electricity, sanitation and transport and communications. Ensuring that resources are allocated effectively, equitably and efficiently, within an overall plan, can be significantly promoted through the application of the GIS tools that have been set out previously.

Longer term recovery can take months through to years and beyond, and many of the requirements are not for physical reconstruction but for more human forms of support to individuals and communities that are recovering from trauma and loss. In respect of physical reconstruction, it is important to remember that many of the earliest public sector applications of GIS were in land-use planning, an innately spatial activity, and the hazard and risk 'landscape' may have shifted through and after the emergency in such a way that planning for re-development (and not necessarily a simple restoration) is required.

Many emergencies will be scrutinised very closely for issues of liability, and there may be criminal investigations in some cases. Similarly, where there have been fatalities, extremely rigorous standards for the recovery of human remains have to be observed. In such cases the accuracy of recording and auditing is paramount and two cases where GI technologies have been used in this way come from the US (Box 9).

Box 9: GI technologies in recovery operations

GI technologies such as GPS and GIS can offer those managing a recovery operation an efficient and effective set of tools to record what has been found and where and then, if required, literally track them as they are recovered. Two examples of this are (a) wreckage recovery from the Space Shuttle Columbia in 2003, and (b) the clearance of the 'Ground Zero' site in New York following September 11th 2001.

Recovery of Space Shuttle Columbia

The explosion over Texas of the Space Shuttle Columbia, on 1st February 2003, created a debris field over a wide area due to the high altitude at which the Shuttle disintegrated. Three main agencies (the National Aeronautical and Space Administration, the Environmental Protection Agency and the Federal Bureau of Investigation) had separate reasons for needing to rapidly and accurately map the debris:

(i) concerns that the debris may be toxic and/or explosive and as such, represented a public health risk
(ii) the requirement to rapidly recover the human remains of the astronauts

(iii) the need to accurately record the spread of debris for a forensic engineering investigation
(iv) the fact that heavy rain threatened to obscure debris in mud and leaf litter if the task was not accomplished rapidly.

To facilitate this mapping and recovery operation large numbers of individuals were given GPS receivers for logging the location of debris. However, in retrospect, the fact that there was insufficient training given meant that many units were set to different map projections and co-ordinate systems, so many hours had to be spent converting field records prior to data integration and mapping. This is a clear case of a failure to recognise the need for a common standard and make a limited investment to converge on this at the start of a project, causing disproportionate additional work further downstream. In many cases the use of different co-ordinate systems was not down to personal decisions, but reflected the fact that many US government agencies utilise different map projections and coordinate systems. In the UK it is unlikely that there would be this level of divergence in spatial referencing, although the map projection settings in GPS need to be consistent for data from different receivers to overlay without additional transformation and reference to technical manuals must be made prior to any data collection exercise.

The speed of map production was further hampered by the extremely slow printing of what were physically large and complex maps – this is a clear bottleneck in the use of GI in emergency operations. Together with the need for achieving standardisation for a common effort, based on awareness and training, these were the key lessons in relation to the use of GI, from the Columbia recovery operation[13].

Recovery Operations at Ground Zero

Aspects of the GIS operation in the aftermath of September 11th 2001 have been quite widely documented and Greene (2002) in Appendix 2 brings together most of this in a single source. It is well known that the emergency response to this operation was in many respects extremely short, given the magnitude and severity of its impacts, and from the earliest days the operation as a whole was dominated by the recovery effort. A specific characteristic of this emergency was that the NYC EOC, which was located in the WTC complex, was evacuated and subsequently destroyed when the building collapsed shortly after the attacks themselves. It was then necessary to establish a temporary GIS operation which was achieved in a short space of time through the combined efforts of core staff from the City Authorities, the Office for Emergency Management and a wide range of other partners ranging from Universities and Colleges, the National Park Service and the military, with private sector support to ensure hardware and software was in place very rapidly.

A wide range of datasets were required, many of which were not readily available, some of which had to be captured for the first time (see Box 10 on remotely sensed data sources in this operation) and others of which where there were serious quality and compatibility issues. During the recovery operation an extremely wide range of GIS techniques were applied, including three-dimensional modelling of both the surface rubble pile and the many sub-surface floors of the WTC complex, all of which were instrumental in the search and recovery operations and the subsequent site clearance operations.

The site clearance operation itself was of course a massive undertaking, and the requirement for an audit trail itself made use of GI technologies. For each lorry load of rubble, which were taken outside of New York for sorting and disposal, GPS was used to map the path of the lorries. This enabled records to be maintained in the event of investigators requiring access to specific pieces of debris, the lorry routes were recorded in

[13] Brown, S.C., Crum, S. and Foote, V.S. (2003). GIS and GPS Emergency Response Lessons from the Space Shuttle Columbia Disaster, *Journal of Extension*, 41(4).

the event of any concerns around debris contamination and the process was managed as efficiently as possible, with safeguards in place to prevent illegal sale or use of WTC debris.

It is also important to bear in mind that it is not just the public sector that is involved, and private sector applications of GIS may include the verification and resolution of insurance claims, where the interests of the individual are for rapid settlement and the private sector company is ensuring that potentially fraudulent claims can be reliably identified.

In information terms placing a comprehensive picture of what has happened at the centre of the recovery plan and implementation is critical. A number of key themes are identified:

- *Damage assessment and resource allocation:* establishing the context for recovery operations in the aftermath of an emergency is critical, and recovery operations themselves need to be planned.
- *Revised risk assessment:* the emergency may in itself indicate that the initial risk assessment was flawed, and/or the new situation has introduced new hazards and altered the risk profile.
- *Public Facing Systems:* the requirement to keep the public, media and other stakeholders informed does not end when the emergency services leave a scene and the recovery operation gets fully underway.
- *Recovery and resilience:* improving the systems themselves.

7.5.1 Damage assessment and resource allocation

Accurate damage assessment is critical to a recovery operation. Distinguishing, for example, between buildings that are dangerous and to be demolished from those with different levels of repairable damage can be effectively recorded with GIS, often following data capture using field methods and aerial photography. The various capabilities of GIS, from data integration, classification and analysis through to mapping and visualisation can be extremely valuable in this regard. Figure 54 illustrates satellite images of Banda Aceh in Indonesia before and after the 2004 Boxing Day tsunami. Such visualisation of impact is a necessary first step in framing an appropriate response.

Banda Aceh June 23rd 2004

Banda Aceh December 28th 2004

Figure 54: QuickBird Satellite Imagery illustrating the Impact of the December 26th 2004 Tsunami in Indonesia © Digital Globe[14]

In the immediate aftermath of the massive earthquake of 8th October 2005, centred in Pakistan administered Kashmir, high resolution imagery was used for initial damage assessments. 'However, in the absence of available corresponding pre-disaster imagery and the low lateral displacement of buildings (which tended to collapse vertically) it was difficult

[14] www.digitalglobe.com

to assess the appraisal of urban damage; on the other hand landslips were in many cases very obvious and this assisted route status assessment in several cases' (Personal Communication with Mapaction http://www.mapaction.org/).

At a more analytical level, resource allocation decisions can be rationally supported through the GIS tool box which can, for instance, help to define priority areas of greatest need and then analyse the distribution of resources and their movement to the areas of greatest need.

7.5.2 Revised risk assessment

In many emergencies risk of re-occurrence is not affected by the event itself. Although there is an underlying trend towards increased incidence of flooding over time, the statistical probability of an event is not changed by the fact that one such event may have just happened. What can happen however is that new hazards are created, or exacerbated and risk assessments must be open to this possibility.

7.5.3 Public Facing Systems

The disruption following a serious emergency can be extremely widespread and severe for a great many people. The long-term evacuation of residential areas, closure of workplaces and service centres, disruption to transport and infrastructure networks and other implications needs to be communicated to affected and interested parties.

In the aftermath of the September 11th 2001 attacks in New York the City website carried regularly updated maps which illustrated zones of access and other restrictions that the physical damage and ongoing recovery operations had imposed on lower Manhattan (Figure 55).

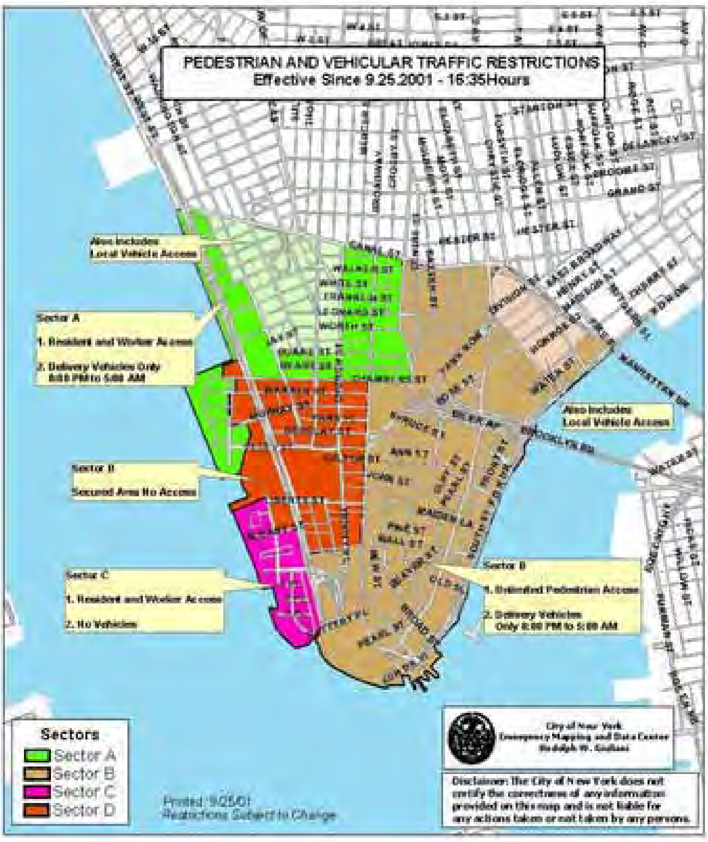


Figure 55: web-accessible mapping for public information

7.5.4 Recovery and Resilience

It is often said that attention is paid when potential problems become actual problems and until that time their significance goes unrecognised. A fundamental theme in this guide has been that adequately resourced, data-rich, appropriately operated and managed systems have the potential to effectively and efficiently support all aspects of emergency management, but realising that potential requires adequate preparation i.e. do not leave it until it is needed, because at that point it is too late. However, learning from the experience of emergencies is critical, however well prepared the staff, systems and processes were. The emphasis should be on ensuring that the information infrastructure itself is resilient in respect of secondary and backup facilities, something that was notable by its absence on September 11th in New York, when the NYC Emergency Operations Centre was lost in the attacks and building collapses. Other lessons from 9/11 are covered in Section 9.2.

Section Eight

Acquiring and Implementing a GIS

Summary

This section provides an overview of the key issues involved in the acquisition, effective implementation and efficient maintenance of a GIS. Issues around data, hardware, software and staffing are covered, and in addition the significance of metadata, quality, data security and confidentially issues are introduced.

8.1 Overview

The potential gains of GIS in the context of IEM has been established, but how can these gains be realised? For many users their organisations may already have invested in GIS, and for others this may have been extended to the emergency planning function. If this is the case then the following section should be reviewed to see if it addresses any shortcomings that you may have identified. If you have no access to GIS capability, then it is intended to serve as an overview of how, and where, to get started.

Clearly there are costs associated with GIS and hardware, software, data and training are the main headings. Figure 56 illustrates the fact that costs tend to increase sharply at the start of a project, while benefits (whether they are measured in financial or in more broadly referenced terms) accrue more slowly.

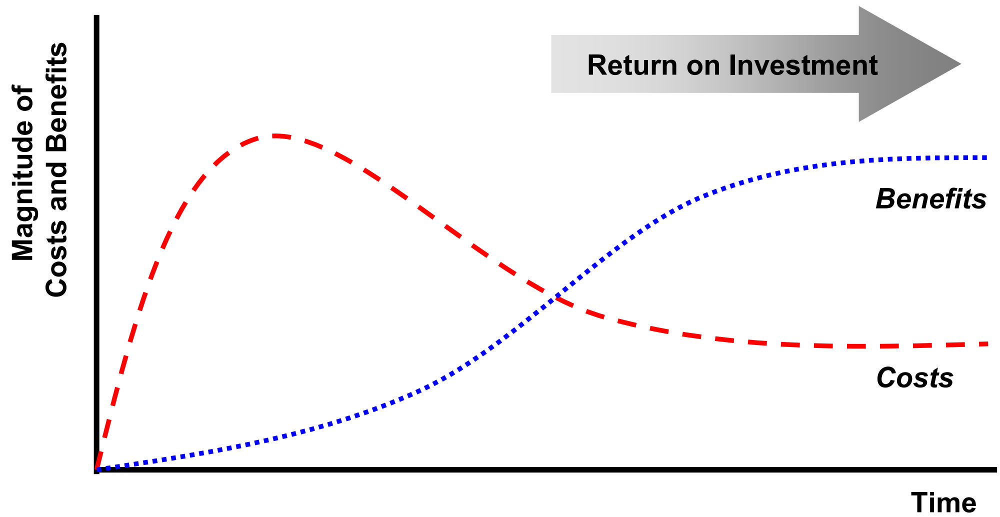


Figure 56: costs and benefits are apparent over different timescales with GIS projects

It should be borne in mind that costs will fall, and from the point they meet accelerating benefits there is a return on investment, but there are costs such as licenses, hardware renewal, data cleansing and data purchasing that are recurrent over various timescales. The rate of benefits growth will slow over time, but the level of benefit will be maintained over time as effectiveness and efficiency gains are realised.

Figure 57 provides a general overview of how an organisation should approach the acquisition of a GIS, and it has a great deal in common with any procurement process, certainly in the IT field. The figure is drawn from Longley *et al*., 2005 (see Appendix 2) and reference to chapter 17 'Managing GIS' should be made for an elaboration of each stage. In general terms, however, the process is self-explanatory.

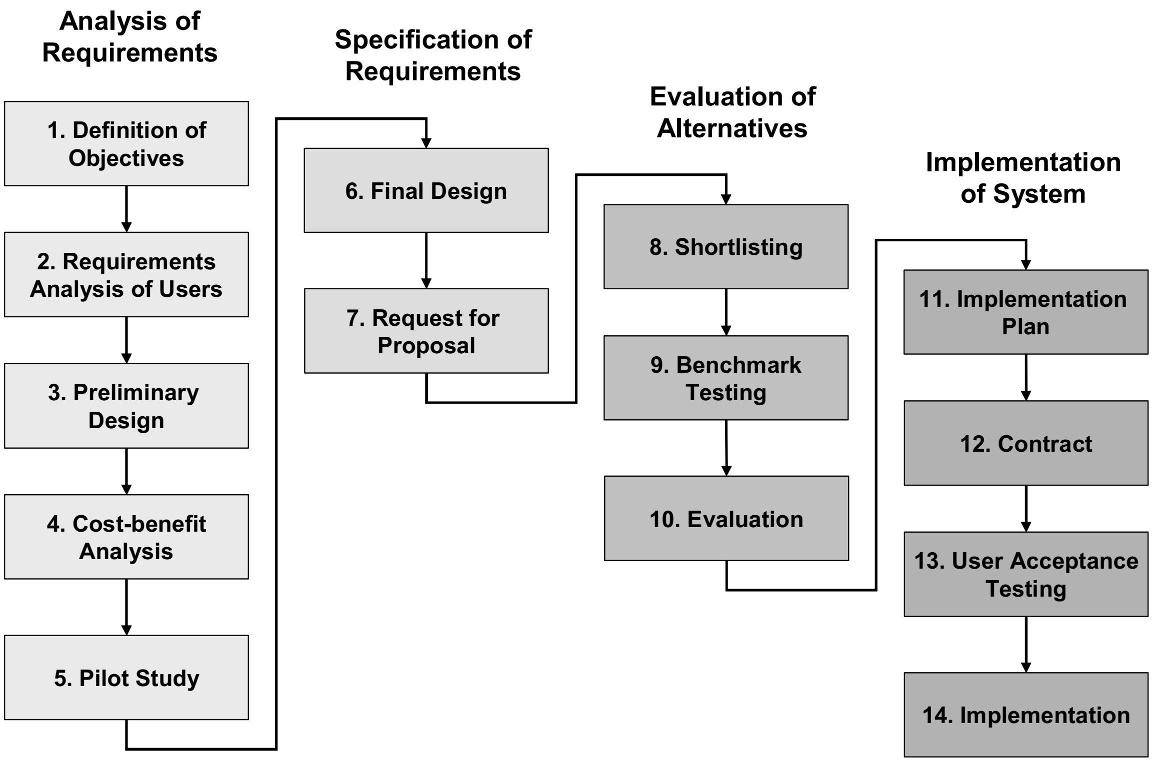


Figure 57: General model of the GIS Acquisition Process (Longley *et al*., 2005)

Although this section starts with hardware, software and data, the critical point is that the emphasis in your approach must not be on equipment, but rather on embedding GIS as a bundle of capabilities into the business processes of IEM.

8.2 Hardware

GIS software will run on most modern desktop PCs and dedicated workstations such as those required 10 years ago are no longer necessary. If buying a new PC then as fast a processor and as much memory (RAM) as possible is recommended. A substantial hard disk drive is appropriate, especially if the machine is to be used 'standalone' (i.e. not usually connected to a network, with the consequent requirement that data are stored on the PC itself), such as a laptop for field use. A second hard drive for backup and additional capacity is also recommended.

Remember that the resilience of this element of the IEM structure is critical so the ability to back up data (which will include data created during a project or incident, in addition to basemap and pre-existing thematic data layers) must be considered. A CD writer for PCs should be included in the specification and more portable devices such as 'USB Memory Sticks' that plug into USB ports are valuable and can rapidly transfer data, maps, documents and other files between machines if there is no network facility available (servers and networks are briefly discussed in Box 11). It should also be noted that wireless communications, for instance through the 'Bluetooth' system, can easily support PC to PC communications and the establishment of a limited network, rapidly, easily and at low cost in almost any operating environment.

A PC without a printer is of limited use. Although other forms of display, such as LCD projectors and interactive display boards (Figure 58) are becoming increasingly widely and effectively used, the demand for paper maps will always remain high. An A3 colour printer that can also print at A4 and work at high speed in draft setting should be regarded as the minimum specification. Above this size printers become increasingly cumbersome, although A1 or A0 maps are ideal for wall display and briefing purposes, and maps of A1/A2 size are well suited to annotation and planning work by groups.

Figure 58: Interactive Whiteboard, combined with GIS in an EP Context (www.smartboard.co.uk)

The vast majority of computer software has been developed with a single-user in mind, and one PC or terminal with one screen, one keyboard, one mouse and associated peripherals such as printers is indeed the 'normal' configuration for desktop GIS. However, the development and application of GIS in a multi-agency environment, especially when decisions are being made in a collaborative fashion under a level of pressure, makes a strong case for new ways of supporting information requirements. The concept of a Common Operational Picture and the ability of GIS to generate this in a map form that can be readily updated moves the main output form from paper to a projected display board. This in turn is being increasingly replaced by interactive white-board technology which permits not only display, but also permits users to interact directly with the software, creating new features such as inner and outer cordons and creating, reallocating and attributing points such as Incident Control Points from the screen itself. Control of the system is thus much more easily passed between individuals who may be assessing options and scenarios, and GIS is more directly supportive of collaborative approaches at all stages of IEM.

8.3 Software

There is a wide variety of GIS software products on the market, although it is dominated by a small number. It is not the place of this document to review individual products. For a catalogue of government-listed suppliers consult the Office for Government Commerce (http://online.ogcbuyingsolutions.gov.uk/).

8.4 Data

Data are key to GIS and data capture, assembly and integration are typically the most costly, and time-consuming elements of any GIS project. A wide range of different types of data can be integrated within GIS, including:

Points	e.g. the location of fire hydrants, telecommunication masts, police stations, hospitals or COMAH sites. Technically, the last three of these are not point features as they can cover wide areas, but in small scale maps which are suitable for strategic use at a regional or higher level, they are best generalised to appear as points.
Lines	e.g. roads, rivers, power lines, telecommunications cables and sewerage network.
Areas	e.g. housing estates, Census Wards, Health Authority areas.
Grids	These are made up of a regular matrix of values and are usually used to represent modelled output, for instance predicted pollution concentrations (see Box 5 and Figure 27).
Images	A variety of image formats can be handled within most GIS, but typically these might comprise: • Digital aerial photographs that are ortho-rectified[15] to overlay accurately onto other digital datasets. These may be of a resolution of down to 25cm, although 1m resolution is more typical. The use of oblique aerial photographs is also increasing in GIS, and can be of particular relevance in an emergency situation. • Satellite images that are similarly geo-referenced. The spatial resolution of satellite images varies between 1m to 1km. • Graphics files: any digital image can be 'hotlinked' to a geographical feature so that it can be called up through a query. This can be very helpful if a field-worker needs to check they have arrived at a given point through calling up a picture of the location, or in allowing an image of the 'normal' state of an object or area to be accessed for orientation purposes. • Digital video: archived or real time streams of digital data such as CCTV footage can be associated with features in a GIS, so that clicking on a point (e.g. a CCTV camera) can bring up a window of footage associated with that point.

[15] Orthorectification is the process of adjusting a vertical aerial photograph to account for the nature of the terrain and distance away from the vertical below the camera. This enables aerial photographs to be integrated within GIS and overlain with other layers of data.

Box 10: the use of remotely sensed data in the aftermath of the 9/11 Trade Center attacks

In the aftermath of the terrorist attacks on, and subsequent collapse of ,the World Trade Center Twin Towers on 11th September 2001 there was a critical need for information about the site. The base mapping available for the area had become suddenly out of date and there was a need for new sorts of information, including hazards on 'Ground Zero'. Some of these demands for data were met by using remote sensing of two types: (i) terrain analysis, and (ii) surface temperatures.

(i) **Terrain analysis:** in the days following the collapse of the Twin Towers there were concerns that the rubble pile was very unstable and that recovery operations were at risk of a further collapse. To assess this risk, a technique known as LIDAR was applied to the site. **LI**ght **D**etection **A**nd **R**anging uses an aircraft-mounted device to gather height data at a high level of accuracy that can be used to create detailed terrain models such as the one illustrated here of the Ground Zero site. In addition to helping visualise the new landscape of the site, this technique confirmed that the rubble pile was not undergoing any significant subsidence.

Figure 59: LIDAR data of WTC site (Image Courtesy of FEMA)

(ii) **Surface temperature mapping:** another concern for rescue workers on the site was that fire hoses kept melting due to the heat generated from the collapse and underground fires. By using an airborne heat sensor and then overlaying the 'hotspots' on an aerial photograph of the site (illustrated here) the fire-fighters were able to better plan the location of their hoses to cool and ultimately extinguish these underground fires.

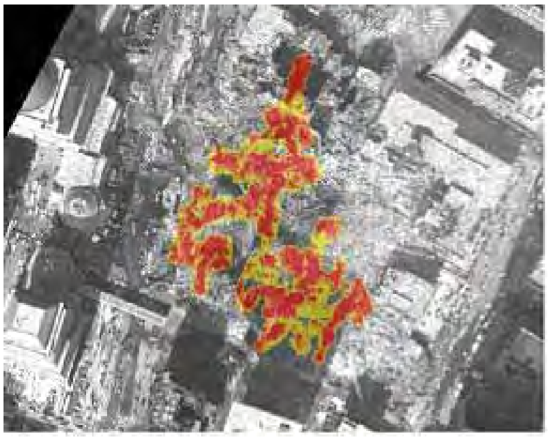


Figure 60: Thermal imagery of WTC site (Image Courtesy of FEMA)

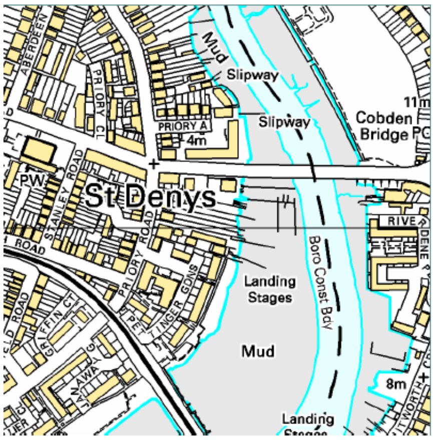
These examples are not included here to suggest that such datasets would be a 'normal' part of an emergency response and longer-term recovery, but to make the point that a wide range of data sources can be integrated within GIS for purposes that may be unforeseen prior to an emergency. However, it should be borne in mind that, under Military Aid to the Civil Community (MACC) arrangements a range of sensors not normally applied outside of a military context may be available to responders. No details of these capabilities are given here, but responders should be aware that such resources may be brought forward in an emergency context and an approach under MACC that defines a particular need may initiate this.

Backdrop and framework mapping (see Glossary) are usually commercially supplied and the Ordnance Survey is the leading UK provider. Many thematic datasets are referenced to OS products (see Figure 61) such as Addresspoint™ , Boundaryline™ or Mastermap™ which facilitates sharing between departments and agencies as the spatial framework is common and there may be a common attribute or identifier which can be used to integrate datasets.

1:250,000 Scale Colour Raster

Strategi™

1:50,000 Scale Colour Raster



1:10,000 Scale Colour Raster

MasterMap™ Imagery

MasterMap™

Figure 61: examples of Ordnance Survey Digital Map Products relating to Southampton (Courtesy of the Ordnance Survey)

Additional relevant datasets from the OS include a Points of Interest dataset of over three and a half million entries which can help to fix a location and they include details of features, business and leisure sites and the OS Master Map^{TM} Integrated Transport Network, which has road routing information such as one way streets and bridge heights which are critical for detailed route planning and service analysis. In addition to the OS there is a range of private sector spatial data suppliers, most of which specialise in added-value products such as historical maps, flood defences, coal mining affected areas, explosives sites and groundwater vulnerability data.

8.4.1 Data Quality Issues

'Quality' as a term is often used in a rather loose fashion, so a wider view of the relevant issues is taken at the outset. The primary measures of data usefulness are:

(a) *availability*: data may exist somewhere in a form that is highly suited to a required application, but if it is not available at the point and time of need it is effectively useless.
(b) *utility*: data may be available, but it may just not be suited or relevant to the intended application. For instance, if data on the distribution of infants of 12 months or less is required and the only available data are for the population as a whole, you are clearly looking at two different things and cannot safely use one to support decisions relating to the other.
(c) *quality*: if the data are available and relevant to the application but for one or more reasons (see below) are of a standard that is unacceptable to the required application, it may even be worse than useless as the evidence that decisions are based on may be misleading or otherwise erroneous (remember the term Garbage In – Garbage Out).

Having access to data does not in itself guarantee an effective and efficient GIS application. Data quality as well as availability is a key issue to be considered. As previously discussed, data and information are rarely perfect. However, how good data and information are can only be judged in a specific context. There is no single, universally applicable, quality standard for spatial data. Rather the concept of 'fitness for use' is adopted. For instance, a GIS that is used to establish a situational picture at a regional or national level does not need to adhere to the same standards as a VMDS which has to direct fire crews to a specific entry point and then locate hydrants and specific pipelines and silos on site. For the latter application both detail and a high level of spatial accuracy are required.

'Fitness for use' is not a concept that has any relevance without context and it is the users of information who ultimately determine this. In Figure 62 the whole cycle of generating information from data must start with a specification of information requirements, and the parameters of timescale, accuracy and quantity which will determine, in the technical sphere, precise judgements about fitness for use. Figure 62 defines two broad realms, one with a focus on end users and ensuring as far as possible that information is appropriate and valid for the intended applications, which in turn rests on the other (technical) realm within which the application requirements are translated into technical requirements and the required quality (of data, process and information) can be determined.

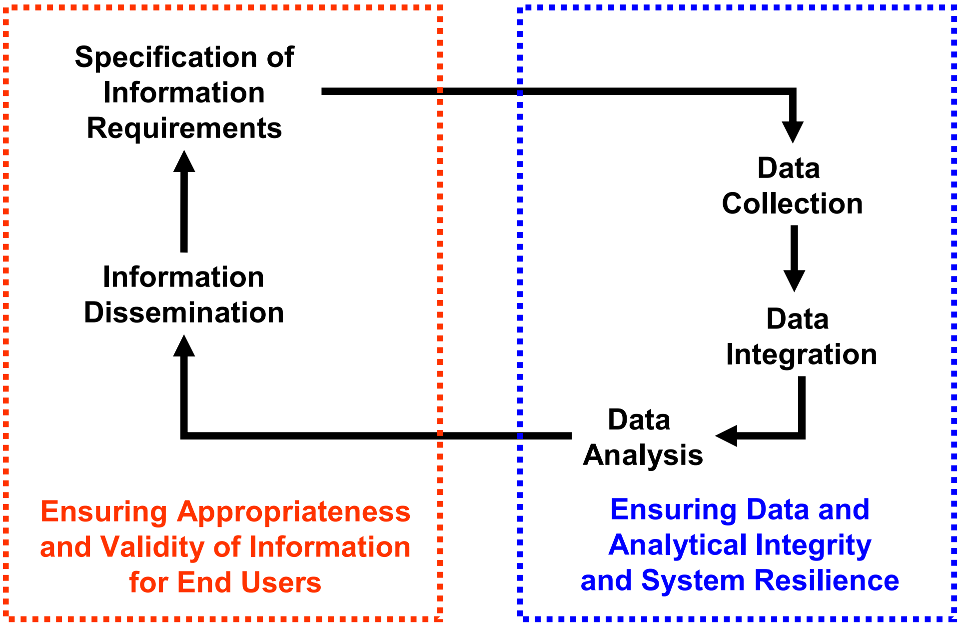


Figure 62: The cycle of specifying and meeting information requirements

Ultimately GIS are decision support tools: they assist people in making better decisions through providing evidence, information on what has happened, what is happening, what might happen in the future and what might happen if different courses of action are taken. The term 'Garbage In – Garbage Out' makes the point that the support for these decisions will be partial, even misleading, if the underlying data are not fit for purpose.

Properties of Data and Information	Operational Level	Strategic Level
Type	Structured, categorised & quantified	Includes qualitative data
Sources	Internal	External
Breadth of Sources	Narrow and task-oriented	Broad and context-dependent
Frequency of use	High	Low
Precision	Highly precise	Limited precision required
Resolution	Highly detailed	Low level of detail required
Time span	Focus on current situation	Focus extends to future

Table 5: Fitness for Use

Data quality has a number of different dimensions:

- *Spatial accuracy*: in short, things need to appear on the map in the correct place. If roads are not aligned with buildings and elements of the road network are not completely joined up then information based on these data may be seriously flawed.
- *Attribute accuracy:* even if buildings are located in precisely the right place, if they are wrongly attributed or confused with other buildings this could have serious repercussions for IEM, from anticipating and assessing through to responding and recovering.

- *Temporal relevance:* if data were accurate ten years ago it is unlikely that they will remain as accurate today. Maintaining spatial databases is essential to ensure quality remains appropriately high.
- *Metadata extent:* metadata is information about data and it is important that they are accessible to users and would-be-users of data. Without metadata, users cannot make informed decisions about suitability, appropriateness and fitness for use. This is elaborated in the next section.

8.4.2 The Significance of Metadata

If data are known or suspected to be flawed in some way, it is critical that anyone using, or looking to use that data is aware of its shortcomings. Decisions made in the knowledge of uncertain information are likely to be different to those where the information is (perhaps wrongly) understood to be of high quality in all regards. As with other forms of data, it is crucial that metadata are kept up to date. Metadata are often divided into Discovery Level Metadata and Application Metadata[16].

Discovery Level Metadata (DLM) is intended to support searches for data. On the premise that you cannot hope to find what you are looking for unless details of existing / available data are published in one form or another, DLM is effectively a summary of what the dataset refers to, a description of how it was created and information to help people access and use it. To support wide access, DLM should be accessible over the internet, or other networks and searching of one level or another should be supported. Sufficient information to enable a potential user to judge whether this meets their requirements should be made available. This may be a sub-set of a full set of metadata records. As an example of this, in the UK the Association for Geographical Information (AGI) operates a metadata search engine, the Data Locator, which can be accessed at http://www.gigateway.co.uk/ (see Figure 63).

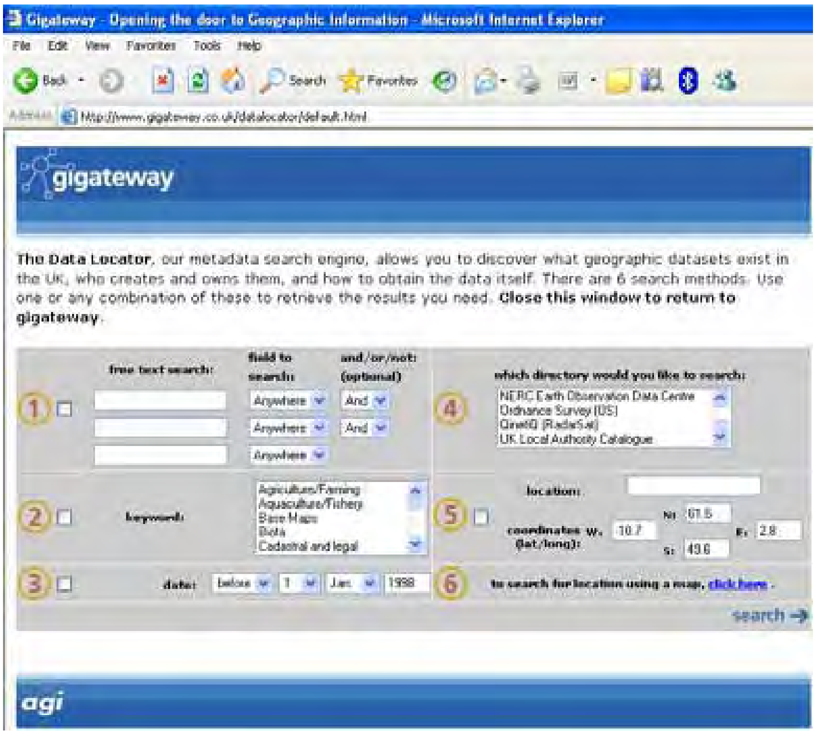


Figure 63: the UK Gigateway Data Locator

[16] Application metadata is divided in some references to exploration and exploitation metadata, but as both relate to using the data rather than finding it in the first place they are treated as one in this overview. See the metadata section of Global Spatial Data Initiative *SDI Cookbook* http://www.gsdi.org/gsdicookbookindex.asp

Application Metadata should be a full-set of metadata to enable a user to make informed decisions about appropriate applications of the dataset. It is critical that application metadata is supplied and subsequently stored alongside data. Metadata should not be seen as static, and as new data are created new metadata should also be generated and then made available in both discovery level and application forms (Figure 64).

Discovery Level Metadata refers to the minimum amount of contextual information necessary to introduce new users to a resource and allow them to assess its suitability for use.

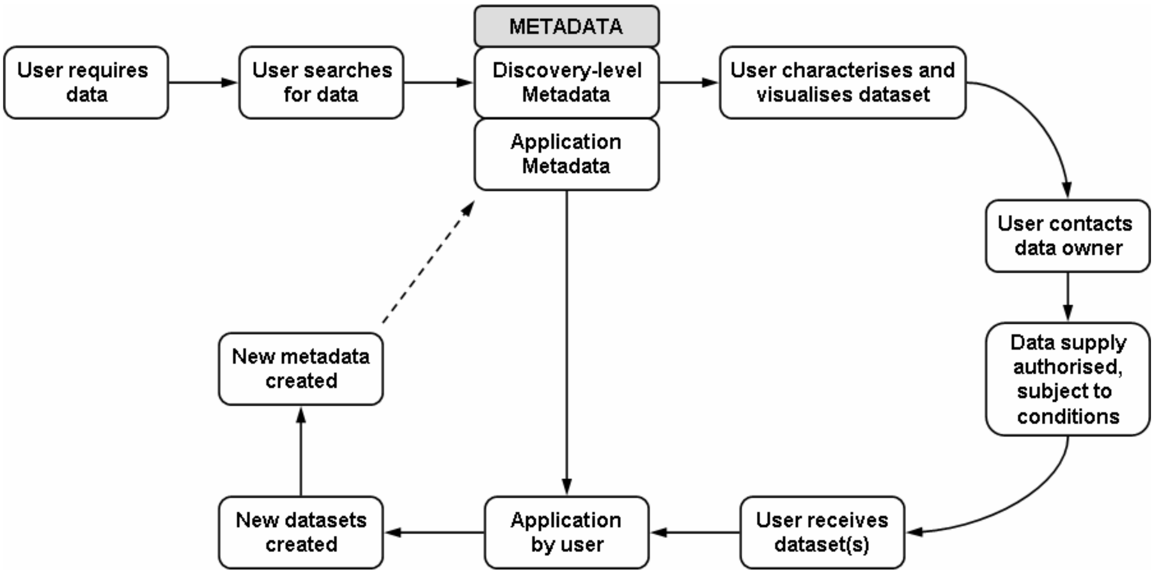


Figure 64: Discovery and Application Metadata

The GEMINI Standard[17] defines the minimum records for metadata records, and the key variables are:

- Title
- Abstract
- Date
- Frequency of update
- Topic category
- West bounding coordinate
- East bounding coordinate
- North bounding coordinate
- South bounding coordinate
- Extent
- Spatial reference system
- Data format
- Additional information source
- Supplier + web address
- Date of update of metadata
- Dataset reference date
- Dataset language

This is intended to flag up the significance of metadata and provide an overview of the subject, and the IGGI Guide: *Principles of Good Metadata Management* provides an excellent introduction to this subject[18].

[17] The UK GEMINI Discovery Metadata Standard is a defined element set for describing geo-spatial, discovery level metadata within the United Kingdom (www.govtalk.gov.uk).

[18] www.iggi.gov.uk/publications/index.htm

8.4.3 Security, Confidentiality and Access to Data and Information

Data and information can be highly sensitive, either for commercial, personal confidentiality or national security reasons. It can also be (potentially) commercially valuable, and the European Directive on Public Sector information (PSI) has opened the door for public agencies to realise that value. Freedom of Information (FoI) is also pertinent, and can be used by members of the public to gain access to public-sector information. The context for data and information sharing is relatively complex.

In this section the terms ‘data’ and ‘information’ are used extensively. The Civil Contingencies Act refers to *information* sharing which also embraces *data* sharing. The position taken in this guide is that information is created through the processing of data (see section 5). As such they are closely related and in some contexts they are used interchangeably. In some cases the terms ‘geographical information’ or ‘spatial data’ are used as overarching terms for both. At the risk of being clumsy, this section refers to the sharing of data and information for the sake of completeness.

As stated above, this is a complex area, and this section is limited to an overview of the main issues, covering the following:

a) Principles of e-Government
b) The Civil Contingencies Act and Sensitive Information
c) Data and Information Sharing Agreements and Protocols
d) Freedom of Information
e) Public Sector Information

(a) Principles of e-Government

e-Government concerns the use of technology, particularly computer and communications developments, to modernise and improve government services. The guiding principles of e-government are:

- building services around citizens’ choices
- making government and its services more accessible
- social inclusion
- using information better.

It is the last of these that is most pertinent here, and one of the principles that flows out of this can be paraphrased as ‘collect it once, get it right and use it many times’. The re-use of information, often in contexts for which it was not originally envisaged, is key to e-government. Although there are restrictions on the legitimate use of information (see below), and issues around the fitness for use of data in unforeseen applications and settings, this principle is intended to drive wider use of information for evidence-based practice and this is strongly applicable in an IEM context.

(b) The Civil Contingencies Act and Sensitive Information

Chapter three of *Emergency Preparedness*[19] deals with information sharing, and a familiarity with its contents is strongly recommended.

As set out earlier, the initial presumption of the Civil Contingencies Act is that all information that is required to meet obligations defined under the Act should be shared by category one and two responders, and it also establishes that local responders have a *duty* to share information. However, it is recognised that many agencies and personnel have reservations

[19] available at www.ukresilience.info

about the sharing of information, so this section provides an overview of the roles, rights, responsibilities and obligations in regard of IEM and the Act.

As with all data and information sharing issues, the first point to consider is whether *vires* (legal powers) exist for the activity in question, including any data sharing which is a necessary part of that activity. Section 2 of the Local Government Act 2000 provides local authorities with the power to do anything (unless otherwise barred in law from doing so) to promote or improve the economic, social or environmental well-being of their area. This power is likely to provide the lawful basis for such systems, but issues of Human Rights, confidentiality and compliance with the provisions of the Data Protection Act 1998 will still need to be considered.

Examples of the types of data and information that need to be collated for the processes of IEM have been set out in table four. It is very clear that this is a wide range of data that will be held by an almost equally wide range of authorities, agencies and private sector organisations. For various reasons these data may be regarded as sensitive and there may be degrees of unwillingness of share them. Although the initial presumption is that information should be shared, certain types of information may be subject to controls if its release would be counterproductive or otherwise damaging. *Emergency Preparedness* (Section 3.17) defines four different types of sensitive information which may not be shared:

i) *information prejudicial to national security* - where public disclosure would be counter to the interests of national security. National security considerations limit the supply of certain datasets beyond a core group of approved users. These may either be datasets that describe inherently sensitive resources or they may be less inherently sensitive at an individual level, but have been aggregated in such a way that causes the larger database to be of heightened sensitivity.

ii) *information prejudicial to public safety* - where public disclosure would endanger public safety.

iii) *commercially sensitive information* - information that relates to the business interests of an individual or organisation and where disclosure would significantly harm the legitimate interests of the data owner or the interests of the subject of the information. Commercial data and information are frequently considered sensitive for reasons of competitive advantage, and this can extend to risk information which is required for effective emergency planning.

iv) *personal information* – where disclosure would be in breach of data protection principles or Section 10 of the Data Protection Act (1998) (DPA) which protects the rights of individuals to prevent the processing of information that is likely to cause damage or distress.

Where data are judged to be sensitive for any of reasons (i) to (iv) then they should not usually be shared. However, these considerations should not reasonably apply to the vast majority of the datasets relating to hazards, community and demographics, built environment and economy, natural environment, infrastructure and resources. Where these sensitivity considerations do not reasonably apply then sharing of data and information as it is required for IEM can, and should, take place.

The Department for Constitutional Affairs observes that 'there is no need to always rely on express powers (often referred to as information gateways) to enable data sharing. Data sharing is usually incidental to the exercise of a function; it is a tool that helps achieve a designated activity. If the powers are there to carry out a function or activity, then it is likely that a power to share data can be implied (as long as the data sharing is clearly for the purposes of achieving that function)'[20]. The CCA defines the roles and responsibilities of

[20] http://www.dca.gov.uk/foi/sharing/faqs.htm

Category One and Two responders and the power to share data and information for the purposes of IEM flows from this.

The underlined section above is significant: the Civil Contingencies Act does not entitle agencies to share, or seek to share, data without a clear rationale for why individual datasets are required for IEM. As data sharing takes place to permit category one and two responders to fulfil their responsibilities under the legislation, the data they are seeking to share must be directly relevant to those responsibilities.

Perhaps the most significant piece of legislation in this regard is the Data Protection Act, and it is also the legislation that causes the most anxiety amongst would-be data sharers. The key aspects and implications of the DPA are set out below (with the relevant sections of Emergency Preparedness in brackets):

a) The DPA is concerned with the sharing of personal data.
b) Personal data are those which identify individuals. Such datasets are held by the public and private sectors alike, and the legislation exists to protect the rights of individuals to privacy and, where data sharing is required, to operate in a way that is both lawful and fair.
c) A tight definition of personal data is one that includes name, date of birth, address and/or other attributes or characteristics that allow an individual to be identified. However, the definition also includes *potentially identifiable* records in a dataset. An example of this might be a postcode where just one person is resident – under these (albeit unusual) conditions the individual concerned can be identified.
d) The DPA does not prohibit the sharing of personal data (including potentially identifiable records). Category one responders in public authorities must ensure that any data sharing they undertake which involves the processing of personal data has a lawful basis, whether explicit or implied. An example of the need to share personal information in an emergency context would be the requirement to know the location of kidney dialysis patients during a water outage; if social services cannot provide information that identifies individuals to the emergency managers then the care of these vulnerable individuals cannot be assured.
e) The first data protection principle requires that personal data are processed fairly and lawfully. In short, in order for personal data to be processed fairly, individuals must be informed of the purposes for which their personal data are to be processed including details of to whom it may be disclosed and given any further information that in the circumstances would be necessary in order that the processing would be fair. This is, of course, assuming that the information can be lawfully shared in the first place (see section 3.28b).
f) The second principle states that personal data should not be further processed in any manner incompatible with the original purpose for which it was obtained. In the view of the Department for Constitutional Affairs, the requirement of compatibility does not have to mean "identical to" and provided the further processing is for a purpose that is not contradictory to the original purpose or purposes, it will be consistent with the second principle. Compliance advice can be found on the Information Commissioner's website at www.dataprotection.gov.uk
g) Agencies seeking to share personal data should apply a ‘necessity test’; public authorities must only collect and use the information that is legally permissible and strictly necessary in order to fulfil their obligations in protecting the public in the case of emergency. So, datasets which are not required to carry out activities in relation to IEM, thereby executing responsibilities under the Civil Contingencies Act, should not be shared.
h) In relation to (f) a dataset can be rendered non-personal, through anonymisation or aggregation. For instance, if the only requirement for a risk assessment was the

number of pupils with physical disabilities in any given school then aggregated data rather than full records should be shared. It should be noted that even records that are aggregated in this way can be potentially identifiable, but if a necessity test identified this level of aggregation as the minimum requirement, then this passes the test. As another example, providing the name, age, sex, address and treatment details of kidney dialysis patients for risk analysis is clearly not consistent with the original purpose for which these data were collected. However, if the details of the individual and/or their location are generalised in a way that retains their validity for IEM this should be acceptable to both sets of interests. The basic issue is that where there is a lawful basis for the sharing of personal data, only the minimum data that needs to be shared should be.

Full Record – Personal Data	Depersonalised Record
Name: Mr Peter Small Age: 36 Address: 39 Main Street, Midtown, BB27 8XY Telephone: 0111982 Condition: Kidney Failure, Weekly Dialysis Reference: BB7645HG981Q Consultant: Dr C.Monk	Condition: Kidney Failure, Weekly Dialysis Sex: Male Postcode: BB27 8XY

Table 6: an example of the depersonalisation of individual records for emergency planning and management purposes. Note that depersonalisation in itself is no *guarantee* of anonymity and confidentiality (see above).

i) Article 8 of the European Convention on Human Rights, which provides that everyone has a right to his private and family life, his home and his correspondence will always be a consideration in respect of data sharing – this is because Article 8 rights can only be interfered with by public authorities where it is allowed by the law and deemed necessary in the interests of a democratic society in the interests of national security, public safety, or the economic well being of the country, for the prevention of disorder or crime, for the protection of health or morals, or for the protection of the rights and freedoms of others. As emergency responders deal with situations where the health and welfare, even the lives of members of the public may be placed at serious risk, it is likely to be the kind of scenario envisaged by Article 8 where some intrusion into the private lives of individuals by public authorities may be legitimate. However, public authorities would have to evaluate the pressing social need and ensure that the level of intrusion into the private lives of the populations affected is proportionate to the objective pursued (see section 3.28b).

j) There is a clear difference between sharing of personal data between public agencies acting in the public good, and the release of personal data to the public domain. The release of personal data (including potentially identifiable records) into the public domain is simply not permissible under the terms of the DPA and CCA. This must be borne in mind in the context of public-facing systems and Community Risk Registers (see section 3.31).

k) Finally, the Information Commissioner emphasises that it is for organisations engaging in data sharing to be absolutely satisfied that they are acting lawfully in doing so. Advice should be sought from an organisation's legal and/or data protection staff at an early stage, and their involvement is critical in drawing up and implementing any multi-agency data and information-sharing protocols that are required (see below). Be aware that this can be a drawn out process; forward planning and perseverance are required!

It is important that potential restrictions on the sharing of data and information are considered and any conditions carefully adhered to, but the support of the Act for information sharing as a cornerstone of collaborative working must be borne in mind and Category one and two responders must be active in this regard.

(c) Data and Information Sharing Agreements and Protocols

One concrete step that can be taken to achieve transparency of aims, objectives and processes is the development of data and information sharing agreements or protocols. Note that Chapter three of *Emergency Preparedness* (sections 3.7 to 3.11) indicates that formalisation of requests for information is not a preferred option, recommending that existing and/or informal information sharing arrangements are pursued in the first instance. This principle, that data and information sharing should not be over-bureaucratised, is echoed here, but it is recommended that some form of written agreement (for instance a Memorandum of Agreement) that sets out the purpose and specific requirements, quality and technical standards and update frequency of data is established.

It is critical to note that a formal protocol or other form of agreement, however well received by partner agencies, does not alter the legal requirements under the legislation outlined above. It does, however, formalise what will be done and what roles and responsibilities flow from this. Some key issues around data and information sharing agreements and protocols are:

- The responsibility for maintaining and updating the data should rest, and be understood to rest, with a single agency (the data originator).
- Protocols for sharing, providing and maintaining data must be at the organisational rather than inter-personal level, and clearly-defined roles and responsibilities should be established and developed between those organisations and relevant competent staff.
- The establishment of any agreement will not make unlawful processing lawful. The reasons for such arrangements are to clear up uncertainty about what is and what is not permissible, ensure openness and transparency and to ensure consistency of practice.
- Protocols or other forms of agreement should include appropriate steps to be taken if the data or information transferred from one agency (the data originator) to another is requested by a third party.
- Protocols make sure that everyone is clear about their data exchange responsibilities and liabilities. They promote trust between partner organisations and the public. Agencies do not necessarily need a separate protocol for each area of work – it may suffice to have one protocol that deals with all circumstances where data and information are exchanged.

Section 3.41 of *Emergency Preparedness* proposes that Category one responders should, wherever possible, seek to channel requests for information through as small a number of routes as possible. So, if economies of scale in sourcing information can be realised (for example in working through the LRF or RRF or even at national level. In addition to the efficiency dimension, this can help to ensure consistency of process and data and information across wider areas.

(d) Freedom of Information

Under the Freedom of Information Act (FoIA) 2000, which came into force on 1st January 2005, anybody may request information from a public authority which has functions in England, Wales and/or Northern Ireland[21]. The Act confers two statutory rights on applicants:

- To be told whether or not the public authority holds that information; and if so,
- To have that information communicated to them.

The Freedom of Information (Scotland) Act 2002 confers equivalent rights in Scotland[22]. There are exceptions to the freedom of information and these are broadly the same as those defined in the Civil Contingencies Act (i.e. considerations in relation to national security, public safety, commercial sensitivities and personal information).

The FoIA is concerned with giving people a general right of access to information held by or on behalf of public authorities, promoting a culture of openness and accountability across the public sector. This should lead to a better understanding about how public authorities carry out their duties, why they make the decisions they do and how they spend public money. The development of public-facing systems that proactively make such information available is of course consistent with the principles of the FoIA, but information released under the terms of the FoIA must itself be consistent with other relevant legislation, including the Data Protection Act.

(e) Public Sector Information

Regulations on the re-use of Public Sector Information (PSI Regulations) came into force on 1 July 2005 SI 2005 no. 1515). They implement a European Directive on the re-use of Public Sector Information (PSI) which was adopted by the European Parliament and Council in 2003, and the regulations became binding on 1st July 2005. The directive recognises that the public sector is the largest producer of information in Europe and that this is a resource with considerable economic potential, which can be realised by re-use. In a sense, the PSI regulations takes FOI a stage further in that it covers how the information is used once it has been received. Re-use of PSI is different from FOI in that FOI is about access, on request, to information whereas the PSI regulations relate to the dissemination of information to others. It therefore has obvious copyright implications. This can be illustrated by the fact that supplying information under FOI does not automatically confer a right of re-use. This means that if a company that had received information under an FOI request would need to obtain permission if it wanted to publish the information. Dissemination often takes place within a market environment and PSI can be sold onto users with a range of intended purposes. For further details consult the Office for Public Sector Information[23].

In summary:

- **Access to information** held by public authorities is governed by the Freedom of Information Act 2000, regulated by the Information Commissioner.
- **Re-use of information** held by public authorities is governed by the Re-use of Public Sector Information Regulations 2005, regulated by the Office of Public Sector Information

It is possible that Category one and two responders who are seeking to access data and information for IEM purposes will be treated as 'customers' in the reuse of information

[21] http://www.foi.gov.uk/index.htm

[22] http://www.itspublicknowledge.info/

[23] http://www.opsi.gov.uk/

market and expected to pay. However, there are specific conditions relating to IEM which mean that such requests should be exempted. These are that:

a) the Civil Contingencies Act is enabling legislation that supports and facilitates data and information sharing;
b) the data and information are not, under the terms of the Act, being sought for commercial exploitation.

As requests for data and information sharing are to fulfill legislative obligations and because there should be no intention to pass on this data or information to any third party for commercial gain, no charges for re-use of PSI should be levied. This is because such activities do not constitute re-use under the PSI Regulations as the activities described form part of the public task of the organisations concerned.

8.4.4 Copyright Issues and Licensing

Copyright issues are different to those surrounding data protection, but they are both concerned with proper and legitimate use of data and information. To summarise quite a complex field, many spatial datasets, especially those which are purchased or otherwise licensed for use in a given context, will be subject to conditions that prohibit or constrain their use in other applications or by other organisations. Copyright and licence conditions will always need to be consulted before granting approval to use data in a new application, or context, or by a larger number of users. In the specific case of the Ordnance Survey, all agencies should have a defined OS Liaison Officer (OSLO) who can advise on such issues. Finally, most data suppliers require a licensing statement to appear on maps using, or derived from their data (see, for example, OS maps in this document).

8.4.5 Spatial Data Storage

Figure 65: Developing a clear and accepted structure for GIS data is critical

Once imported into GIS, data can be managed for subsequent retrieval or application. Different systems (both GIS software and wider organisational structures) manage this in different ways, but in software terms there are templates which can be established through which backdrop mapping and core thematic datasets are pre-loaded up, symbolised and ready for use. There is no single standard for this; different individuals and organisations operate in different ways, but the key principle is that data and information must be structured, and understood and accepted amongst those who need to use the system.

The issue of semantic consistency is developed in section 10, and it will suffice to mention here that overly individualised or otherwise esoteric approaches to structuring and naming data should be avoided in the wider interests of transparency, accessibility and usability.

A quick reference should be available to users to illustrate the relative location of different datasets, such as that illustrated in Figure 65. Clearly there is a need for semantic clarity and acceptance of the terms used. For instance, elements of the critical infrastructure such as hospitals and schools (buildings) are both resources and vulnerable sites in an emergency context.

In the interests of effective Knowledge Management (KM) a searchable directory of datasets should be considered, especially where the user group is large and datasets are frequently updated or added to. It is also critical that protocols for effective metadata recording are observed and that metadata are stored in association with their respective datasets. Meeting the potential demands of users is paramount: if the user group is discrete, small and experienced with the systems concerned and well trained in their use, then a self-managed system is likely to work. If, however, the user group is much larger, open-ended even, and the level of experience with the systems is low or diverse then an effective KM system to allow users to search for relevant data and then enable them to access and understand the data is critical[24].

[24] see www.knowledgemanagement.org.uk

8.5 Staffing and Training

People and their skills and experience are a critical part of realising a GIS that will adequately meet an organisation's needs. Public sector staff, including those in emergency planning roles, that have an appreciation and experience of GIS are becoming more common as the technology pervades ever more sectors. However, skilled GIS professionals remain in relatively short supply. In terms of resilience, a system that is designed, developed and used by a single, highly skilled member of staff, but remains a mystery to all others in that organisation, is of little use if the operator is on leave and out of contact when it is needed. Conversely, if an organisation undertakes to bring a larger number of staff up to speed on the basic operation of a system, it is well known that regular use to retain and develop that knowledge is required, and higher-level requirements may be out of their reach. These are two extremes and appropriate training and continuing professional development are the key to developing and diffusing competency in core skills throughout a body of staff.

Section Nine

Embedding GIS in, and across, organisations

Summary

GIS are most commonly implemented within single organisations, but the reality of Integrated Emergency Management is that agencies need to work closely and co-operatively together. This means that spatial data and information must be able to move both within and between organisations, and this section provides an overview of structures, processes and standards to achieve this, along with a discussion of functional, organisational and technical issues to be addressed to achieve this.

9.1 Introduction

One of the key benefits of using GIS that has been identified in a series of studies is the ability to integrate data from seemingly disparate sources, in pursuit of a common objective. This is accepted, yet realising this level of data integration can be problematic. GIS are most commonly developed and used within organisations. The history of GIS is that most public sector applications were specific to individual departments, for instance planning or facility management. There is no doubt that designing, implementing, embedding and using GIS is simpler within smaller organisations that have a unified and focused purpose for that application. More recently, the emphasis has been on 'corporate' or 'enterprise' GIS where the system is rolled out over the whole of an organisation[25]. The gains that can potentially be realised from a corporate-level approach include:

- increasing access to data for enhanced decision-making
- leveraging additional benefit out of existing resources, including data and staff (following the e-government principle of 'collect only once, use many times')
- addressing redundancies, duplication and inaccuracies in data, and doing it only once
- improving communication between departments and agencies
- recognising commonalities in problems and associated requirements for data
- achieving efficiency in practice
- promoting effectiveness in policy.

However, designing and implementing a pan-organisational system and then ensuring its effective uptake and application is far more complex than the process within a smaller and more tightly focused unit. Different departments may be resistant to changes that the new system requires and the potentially significant 'not invented here' syndrome is self-explanatory. These problems are compounded when a system is intended to tie together the work of a number of different organisations. Competing conceptions of the costs and benefits, data models, technical standards and organisational structures pose severe challenges to data and systems integration for multi-agency working. However, the benefits

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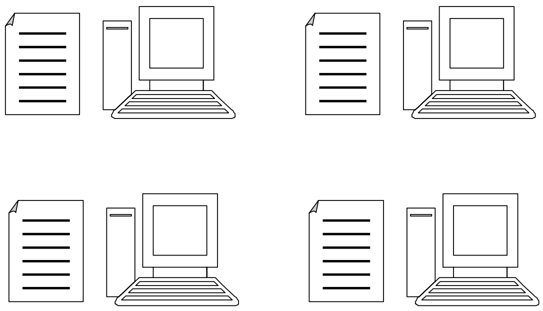
[25] Enterprise GIS does not necessarily imply that all potential users have a fully-fledged GI System on their desktop. Intranet mapping systems or customised, 'stripped down' versions of the full software installations has been widely and successfully implemented in many organisations, with financial savings for the organisation and a simpler system to stay on top of for relatively infrequent users (see Box 11).

of getting this right are considerable, broadly reflecting those observed above, but with the enhanced benefits of a wider coverage and participation.

Box 11: GIS Architecture Overview

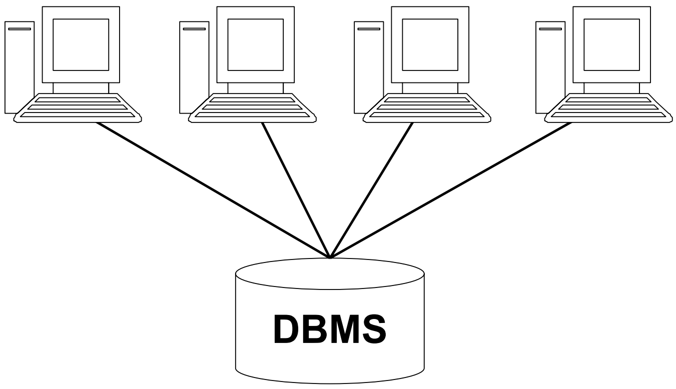
GIS can be configured in different ways, depending on a range of factors including the requirements of users, the availability of resources and finance and the physical distribution of users, including access to mobile devices and wireless connectivity. This box gives a brief overview of the primary configurations.

1. *Standalone PCs with desktop GIS software and data on local hard drives*



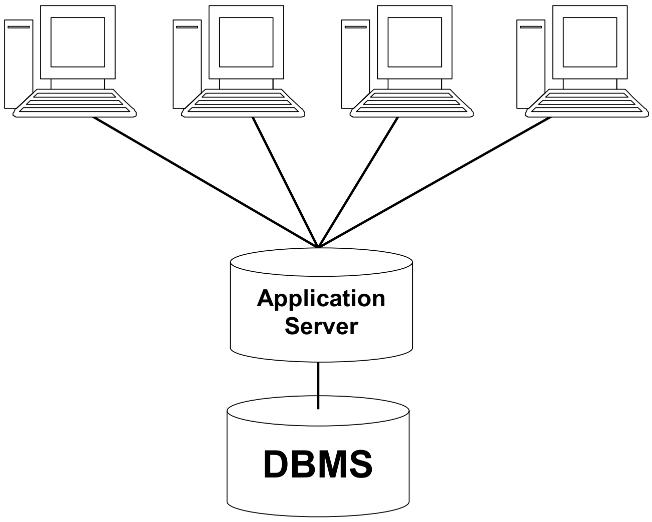
In this configuration individual desktop PCs have GIS software on them and all the data that are required are stored locally, on the PC's hard drive or associated peripherals. This is not incompatible with the PCs being on a network or the internet, but this connectivity is not used to access or serve data from other locations.

2. *Networked PCs with desktop GIS software and data on centralised / workgroup fileserver*



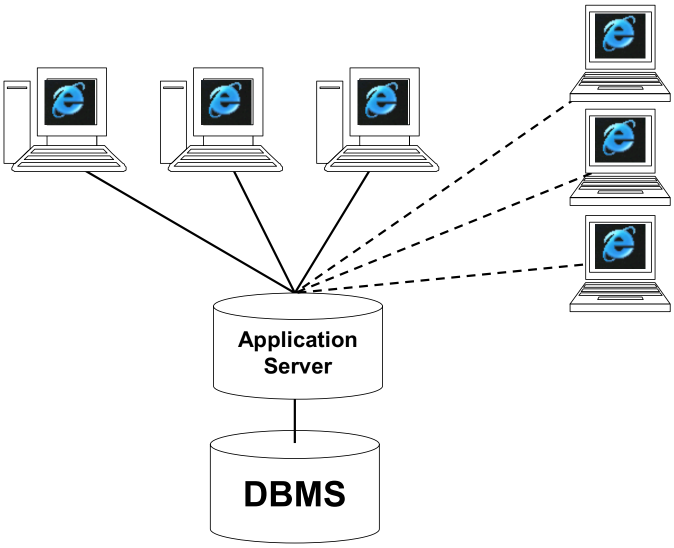
In this approach PCs have desktop GIS software installed on them, but the data are centralised to one degree (e.g. an entire organisation) or another (e.g. a single workgroup) on a fileserver. This server would contain both read-only (e.g. OS backdrop mapping) and read-write (e.g. thematic layers for editing and analysis) layers. In this configuration users can be differentiated with different levels of access, or no access, to some datasets if required.

3. *PCs operating as Thin Clients, with Desktop GIS software accessed through an application fileserver and data on centralised / workgroup fileserver*



In many larger organisations desktop PCs are used as 'thin clients' and do not have GIS software installed on them locally. Instead, the application is accessed through software such as Citrix, which gives PC users access to the software, but from a central application server. This approach can have financial advantages as the number of concurrent users can be limited. Typically, data are also served from a remote location in this configuration.

4. PCs and Mobile Devices access mapping application and data through web browsers from remote application and data servers



One of the constraints of the previous configurations is that it they tend to be specific to individual organisations, with limited scope to offer the application or datasets to third parties. The development of web-mapping applications, sometimes termed 'Server GIS', enables remote users (including mobile devices accessing through wireless connections) to access an application through a standard web-browser, which in turn accesses data from a fileserver. The user's interface with the system is entirely through the browser, so the scope to interact directly with the data (which has issues for system security) can be very tightly controlled.

Although these are presented as separate and discrete configurations, within an organisation they may be combined for different types of users and application settings. For example, some GIS projects have a high level of sensitivity especially in respect of data that are held, so these may operate only on standalone PCs. Another variant might be of configuration (2), where external network links to other organisations or the internet complement data that are held on a local fileserver. Also, option (4) does not preclude individual PCs, which may be used to access a web-mapping application over the internet, also being configured with local GIS software and data (1) or as appears in (2).

Achieving evidence-based multi-agency working requires that a series of potential problems are identified, and where relevant, addressed. These may include:

- variations in priorities and foci between participants
- differences in level of awareness of GI, spatial data handling skills and GIS capacity and consequent differences in commitment to the wider project
- availability of staff resource
- semantics: differing data definitions
- differing data models, data formats and data standards (e.g. relating to quality)
- issues around IT, networking and access to data and information
- issues around data security
- differing perceptions of risk and the distribution of (perceived) costs and benefits
- institutional impediments
- disciplinary 'silo' mentalities through which a culture of difference rather than co-operation dominates
- the failure of organisations to think inventively and act decisively on information and knowledge management
- a problem-orientation amongst managers in which reasons not to act out-stack the reasons to act
- legal issues: issues around data protection (which are often misconceived – see 8.4.3)

- lack of leadership at a level appropriate to the project to ensure that progress is real, appropriate and not just superficially 'overt'.

> *For effective utilisation to be achieved it is vital that the process of [GIS] implementation starts from an understanding of how particular organisations operate in practice and not an idealised notion of how they should.*
>
> (Campbell & Masser, 1995[26])

This is a long and rather discouraging list of potential obstacles to effective data and information sharing, but there are concrete steps that can be taken to achieve a much more positive experience. Successful coordination projects have been characterised by:

- Unity of purpose: a cultural acceptance within and across organisations of their common problems and overlapping information needs
- A recognition that individual agencies' information needs are at times best met through other agencies' data
- Demonstrable gains in effectiveness relative to purpose
- Demonstrable cost savings
- A preparedness to identify barriers and explore potential solutions
- A preparedness to identify and observe standards around semantics, formats, quality, metadata and other application relevant issues
- A preparedness to investigate practical tools to enhance coordination, cooperation and collaboration through accessing, using and sharing relevant best practice
- Demonstrating the value of GIS and an integrated approach to relevant staff, leading to active rather than passive, participation
- A 'champion': leadership and executive authority at a level appropriate to the project.

Box 12: Data and Information Hubs

There is no single or simple template for data and information sharing for IEM in the multi-agency environment. As schematically identified in Figure 66, the processes associated with emergency preparation, response and recovery are different in the kind of information they require and where it can be sourced from.

For example, and as elaborated in section 6, preparing for emergencies is associated with a range of activities around risk assessment, emergency planning, scenario development and training and exercising.

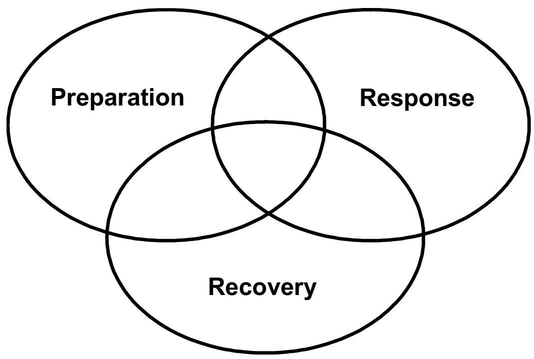


Figure 66: data requirements and sources vary for preparation, response and recovery

The data and information requirements to support these activities are wide-ranging and sourced from a range of category 1 and 2 responders. Some form of data and information hub is required to manage these for applications. In its simplest form, such a hub could be a

[26] Campbell, H., and I. Masser. 1995. *GIS and Organisations: How Effective Are GIS in Practice?* Taylor and Francis, London.

single computer hard drive, although networked access to such files are more appropriate and longer term developments towards interoperability are elaborated in section 10.

During an emergency response, data and information are often generated very rapidly and in considerable volumes. During the initial response phase, the majority of this will come from the emergency services. Integrating such data and information with the hub that is available for emergency response is problematic, but an effective multi-agency response demands that such integration is pursued. For example, an emergency services control centre might be able to capture and display incident information and the deployment of resources from one or more of the blue-light services. If this was a major incident, such as an atmospheric release of radiation, the Met Office might be requested to model the diffusion of radiation. At the present time this information would be faxed through to the control centre, as required. In the future, however, transmission in a digital format such as GML (see Section 10) could result in rapid and precise integration of this within the command and control system. To start to characterise the affected population and facilities however would require data from a hub that may be located in a local authority.

There are short and longer term issues here. In the short term, the ability to supply data and information as required to support an effective multi-agency response must be considered, developed and rehearsed. In this model the hub(s) is/are physical entities and transfers have to be managed, usually through manual processes. In the longer term, interoperable systems that can automatically 'fetch' data and information as required have to be the objective (see section 10).

9.2 Issues Arising from GIS applications within Multi-Agency Operations

Up to this point, the treatment of GIS in organisations has been relatively generic, drawing on case studies of 'what works' and what does not work, from a broad range of application areas. This next section explicitly focuses on evaluations that have been conducted in the aftermath of GIS applications within multi-agency emergency, and humanitarian operations including the World Trade Center attacks of September 11th 2001[27] and Civil-Military Co-operation following NATO intervention in Kosovo from 1999. There is a wide range of material available on these projects, some of which is referenced in the appendix, and the intention here is to provide a distilled version of the key points.

There is a high level of convergence between the case studies on what the **drivers** for GIS applications were, although their specific circumstances were disparate. These included:

- The need to develop situational awareness and a Common Operational Picture that is accessible, both literally and culturally, to a range of organisations with differing ways of working and missions.
- The increasing acceptance of, and focus on achieving, cooperative and collaborative working in pursuit of common goals.
- An appreciation of the need to undertake evidence-based practice, driven in part by considerations of effectiveness and efficiency, and in part by the negative drivers around litigation following failure in degrees from sub-optimisation through to mission collapse.
- An increasing acceptance of the potential of GIS to serve as the conceptual basis for information sharing, planning, operational coordination and evaluation of progress towards common goals.

[27] See Greene (2002) and Kevany (2003) in Appendix 2 and the very thorough treatment in Kevany, M. (2002). *GIS in the World Trade Centre Attack. Critique: What was done? What can we learn?* http://www.plangraphics.com/publications/urisa2002papers/kevany_urisa.pdf

Key **functional requirements** that were identified include:

- The need to be prepared across the range of functions and to include GIS and related technologies in emergency plans.
- The need to combine datasets from disparate sources across functional areas. For instance, in Kosovo, once Serb forces withdrew and refugees began to return, GIS facilitated the integration of data on minefields and other post-conflict hazards such as unexploded ordnance (from military sources) with data on potable water and state of the housing stock (from humanitarian agencies) to better manage the process of resettlement.
- The need for an 'electronic base map' to become the cartographic basis for all agencies' operations. This relates to the pre-digital certainty that when things do go wrong, it is going to be at the boundary of four (paper) map sheets and that different responding agencies will have (a) different versions, (b) different scales or (c) no versions of the base map for the area.
- The need to anticipate needs for GIS applications, data and information requirements through a familiarity with the cyclical, and to a degree predictable, nature of emergency operations.
- The need to distribute information rapidly and efficiently as emergency operations may be widely distributed, decision making will be devolved and the ability to manage different forms of information will be highly variable. This is elaborated below.

Key **organisational issues** to be addressed to realise the potential of GIS to support the information requirements of emergency managers include:

- The need to ensure that key decision-makers within and across agencies understand what capacities exist that they can draw on, the range of standard information products they can produce and the toolsets they have access to.
- The lowering of institutional barriers to inter-agency working, including data and information sharing.
- The need to develop a strategic information plan addressing the following issues:
    - Establish the data needs to meet the information requirements for IEM within the context of the Community, Regional and National Risk Registers
    - Determine priorities: data and information sharing is complex and time-consuming and a timed, staged and prioritised approach to establishing a sustainable data and information sharing framework is required
    - Determine resource constraints and opportunities.
- Staffing issues are paramount:
    - The significance of training around awareness for decision makers and technical skills for key users and other potential users, many of which might be widely distributed, and across different organisations
    - Recognise the importance of exercising to test and embed the systems
    - Staff must be available on a 24/7 basis
    - Designate an information sharing co-ordinator with appropriate (potentially delegated) authority – the wider issue of leadership is critical, especially under emergency conditions, in forming, managing and motivating a team

    - Develop a database of "who is doing what and where"[28] – this relates in part to the concept of a Common Operational Picture, although it can also be advantageous in respect of potentially accessing emergency staff backup in the event of a serious emergency.
- Improve response time to supply information products at the point of need. The extremely slow rate of map production during the Columbia recovery operation in the US during 2003 has previously been identified in Box 9.
- Consider the appropriate structure for data management and dissemination.
- Consider the appropriate structure for information management and dissemination. The ability to disseminate information is critical and a series of issues must be considered:
    - The plan, infrastructure and logistics for information dissemination must be developed as part of the wider emergency planning framework.
    - The widely distributed, and potentially difficult working conditions of emergency responders needs to be considered. Physical and information infrastructure may have been compromised (e.g. blocked roads, reduced bandwith) by the emergency itself and a response to this must be considered.
    - Standard products have both supply and demand side advantages: producers can work to a standard template and users have a continuity of experience – they know what to expect and what to do with it.
    - Electronic media are the most efficient mode of information distribution for a range of map users, but there will always be a strong demand for paper maps and this needs to be met.
    - Paper map production (printing) has frequently been a bottleneck in the past and needs to be adequately resourced.
- The need for a request tracking system to be established: experience suggests that the demand for maps and map- based information can be high from the outset and then accelerate to unforeseen levels during a major incident. Meeting all requests rapidly may be out of the question, so a prioritisation and tracking system needs to be established, in part to ease pressure of the GIS staff themselves.
- Ensure resilience under field constraints. Although a primary office facility may be adequately resourced, backup sites or field locations may be below standard in respect of office space, power availability, internet and network connectivity and staffing. In respect of staffing, a (potentially reciprocal) system to draw appropriate staff from other departments, agencies or agencies external to the region should be agreed and established.
- Resilience of the systems themselves is critical:
    - Off-site backup of data and resources is critical in the event that the designated operations centre is affected in the emergency. Where data are networked and accessible from multiple locations, it is critical that the data themselves are backed up and accessible in an alternative manner.
    - Communications are vulnerable and alternative plans for voice and data communications in the event of loss of primary systems is critical. This should of course be part of the wider emergency planning process.
    - Potentially accessing emergency staff backup in the event of a serious emergency has been referred to above and reciprocal arrangements to facilitate this are good practice.

[28] The UK Charity Mapaction (http://www.mapaction.org/) uses the acronym W3 data to describe "Who-What-Where" data and information.

Key **technical issues** to be addressed to realise the potential of GIS to support the information requirements of emergency managers include:

- Develop common standards for data, metadata and information recording and reporting.
- Develop a comprehensive and consistent baseline dataset for the potential area of operations.
- Address the cross-referencing of frameworks, both spatial-spatial and attribute-spatial. For instance, during the WTC recovery operations GPS signals at Ground Zero were weak and relatively unreliable due to the surrounding high buildings which obscured and degraded the satellite signal. For this reason, the Fire Department generated a 75' x 75' grid over the rubble pile for the recording of debris and human remains and associated finds. Clearly, this spatial framework needed to be (and was) linked to the wider spatial framework used in the Emergency Mapping and Data Centre. Also during this operation, significant problems were experienced at the outset of the operation as the digital outlines (footprints) of buildings were not linked to the Building Identification Numbers (BINs), which were themselves used to associate a wide range of attributes relating to those buildings.
- Assess security implications relating to individual data layers and sensitivities relating to the aggregation of data layers.
- Quality Assurance, a critical consideration in any GIS project, is no less significant in an emergency situation, where the implications of errors are potentially life-threatening. Such a QA process needs to be appropriate to the operational context, and must be developed as part of the planning process.

This is a long list of considerations, but given the significance of information in decision making, the need to embed data access, management and information creation and provision in emergency planning more broadly, these are all worthy of careful attention.

Section Ten

Working across boundaries: the significance of interoperability

Summary

Interoperability describes the ability of systems to work seamlessly together. To a large degree this is a set of technical issues which are covered, but the most significant issues and problems to be addressed concern issues around the meaning of data and information (semantics) and ensuring the political will to ensure convergence around the standards upon which interoperability is founded.

10.1 Introduction

The main focus in this document has been on the provision of appropriate information in support of effective decision making. Much of this, it has been shown, depends on agencies working together. In the context of information sharing, interoperability has been defined as 'the ability to exchange and use information across different hardware and software without special effort'[29]. So, interoperability describes the ability of different organisations' systems to work effectively, indeed seamlessly, to achieve this. The *Oxford English Dictionary* definition is '**Interoperable** – able to operate in conjunction, derivative 'interoperability''.

Figure 67: agencies interoperate, but do their data, information and communication systems? (credit: freefoto.com)

As an important element of this, users should also be able to search for data and information and have an enhanced understanding of what is available and for what it might be used. To use an analogy, this turns a set of unknown buildings with books in them into a referenced library and, to stretch the analogy, this library should ideally have a catalogue that is searchable over the internet and reciprocal lending arrangements should exist.

However, interoperability as a term is one that is surrounded by a degree of mystique and is regarded as "tomorrow's problem, not today's", by too many agencies.

The objective of this final section is to establish what interoperability is, why it is important and establish what organisations need to consider now, to ensure future systems interoperability.

[29] Rose, M., Gabriel, M. and Jones, N. (2004). *Achieving Interoperability and Information Sharing*, Report on Environment Agency Data and Information Exploitation Unit Seminar on Interoperability and Information Sharing, February 2004.

Box 13: the length of a piece of string

Consider a conversation around the question, “how long is a piece of string?” The point of the conversation is to establish whether the string is “long enough” for the job it is required for. It may be “quite long” to you, but perhaps I’m used to “really long” pieces of string and this one is “fairly small”. This conversation is clearly going nowhere quickly. Perhaps a picture would help. You send a picture but I’m lost as it is grainy and there is nothing to indicate the scale.

If we measure the string using a quantitative scale then this must take us forward. You measure the string and it is 24 inches. That’s no good to me as I work in metric, but your ruler is imperial. Perhaps we could try other measures of which there are plenty: chains, furlongs, feet, leagues, rods, links, hands and yards. All these are imperial, not metric. We are still no further on.

Now imagine that this conversation has taken place by a mix of telephone, mobile, fax and email. Telephone was no good as it could not relay a picture, mobile was little better as only one of you had a camera on your phone, the fax was OK but poor quality and black and white, and email was looking good until the attachment was removed due to security protocols on your mail server.

There are also a whole series of other characteristics that may need to be taken into consideration such as size, strength, colour, age, materials and what the string has previously been used for. It is clear that the above conversation, or something like it, could be had for each of these additional variables.

The end point of this exchange is that both parties remain unsure of whether this really is the right piece of string for the job. A decision made might be the wrong one and the consequences might be serious.

Interoperability is about ensuring that information exchange is efficient, effective, meaningful and that errors are avoided. To a large degree interoperability is a technical issue, but it will be demonstrated that it is also a human and cultural one as well.

The INSPIRE (Infrastructure for Spatial Information in Europe) initiative and proposed directive, which is focused on environmental policy making and the harmonisation of spatial information to support this, has established the following principles:

- Data should be collected once and maintained at the level where this can be done most effectively;
- It must be possible to seamlessly combine spatial data from different sources and share it between many users and applications;
- It must be possible for spatial data collected at one level of government to be shared between all levels of government;
- Spatial data for good governance should be available on conditions that do not restrict its extensive use; and
- It should be easy to discover which spatial data are available, to evaluate their fitness for purpose and know which conditions apply for their use.

In respect of enhancing access to information these principles are important, and the role of the internet in supporting portals for accessing metadata and data is at the heart of the directive, both for public-private-government data flows and also for intra-government data mobility. The Commission adopted the proposal for a Directive on INSPIRE in July 2004, yet on both practical and political levels there will be many steps in the future to realise the vision behind the directive itself.

10.2 Obstacles to Interoperability

The INSPIRE initiative defines principles rather than a description of reality, and there are four essential obstacles to interoperability at the present time:

1. a great many local solutions have been developed for locally defined problems. These solutions, however, are sub-optimal within the evolving context for effective integrated working within and across agencies;
2. Interoperability between Commercial Off The Shelf (COTS) GIS software is limited, although improving;
3. Communications interoperability and data transfer is problematic, although data bearers such as TETRA (TErrestrial Trunked RAdio) promise the means to wirelessly and digitally transfer both voice and data between systems in an operational environment;
4. The significance of a shared understanding of data, its definition, limitations and intended and potential applications is a major shortcoming, and a very serious issue, although one that is introduced in less than serious style in box 13.

Do emergency planning, category one and category two agencies and their staff need to consider these kinds of issues? To answer this with another question, do these agencies and their staff need to be able to transfer information about hazards, resources, vulnerabilities and emergency incidents and their consequences? The answer to this is yes, and the Civil Contingencies Act establishes the significance of information transfer. It is however too easy for such agencies to regard interoperability as the software developers' problem and carry on sharing (or not sharing) problematic data through manual means such as a CD in the post.

The following kinds of problems are commonly observed in a GI/S context, and all of them are symptomatic of a lack of interoperability[30]:

- An inability to share maps over the web or other networks utilising web-browsers as the viewer;
- An inability to deliver data between internal departments' and external agencies' systems without a high level of user intervention in converting;
- The absence of a common language to talk about spatial data and the attributes of spatial data;
- An inability to integrate data from real-time sensors or allied databases over a network.

These may be problems with a strongly technical flavour, but their operational consequences may be profound.

10.3 Working towards Interoperable Systems

The objective of this section is to establish that the responsibility for working towards interoperability rests with <u>all</u> agencies that have a role in preparing for, responding to and recovering from emergencies.

[30] Maslen, J., Peltenburg, J. and Morrison, K. (2004). *Interoperability in geospatial technologies: an introduction to the UK context*, White Paper Version 1.0, Geowise, Edinburgh. www.geowise.co.uk

So, up to this point we have established some of the cornerstones of how Category one and two responders and other responsible agencies should regard, and start to work towards, interoperability. At the risk of being repetitive, these are:

- Benefits of interoperability are broadly the same as those which can be realised through organising, indexing, permitting searching and preventing duplication of records within an organisation – it is inconceivable that an organisation would not attempt to systematise its own internal approach in this way;
- There are costs at the local, agency-specific level in addressing issues around interoperability, but the costs of *failing* to address these issues are much more widely felt and strong leadership is needed to take these steps;
- People have to know about data as a prerequisite to attempting to access it;
- Common standards are critical if datasets are to be integrated;
- Integration is not the same as interoperability, although the ability to integrate data is a foundation;
- Geography is in itself an integrative framework and while different approaches to geo-referencing can be reconciled, differences in how attributes are recorded (the semantics of a dataset) are less easily addressed;
- Achieving interoperability is not a simple process, but as with all problems an analysis and breakdown into technical, human and organisational dimensions is helpful in identifying a way forward.

Figure 68 identifies a framework for appreciating the intermeshed nature of technical, operational and communications systems. All such systems are underpinned by data and they are linked through the construction, appreciation, interpretation and communication of information. If these systems are not interoperable then breakdowns will occur, both between levels of command and between responsible agencies. With the development of systems such as TETRA digital radios and intra-organisational data, information and knowledge management solutions, individual agencies are getting increasingly better at creating suitable quality information, knowing what to do on the basis of this evidence, how best to define and take the required actions, and how to communicate not just tasking instructions, but also information to stakeholders, the wider public and also cope with reverse data and information flows which permit monitoring and assessment of the situation. This capability is relevant in fields as diverse as regional policy and street-cleaning services. All steps of this ‘ladder’ are essential, and if rungs are missing (for instance semantics) then progress will be hampered as divergent interpretations will be inevitable.

In the context of multi-agency working, progression ‘up the ladder’ is equally contingent upon all the rungs, but the likelihood of the technical, operational and communications systems being concordant is presently remote.

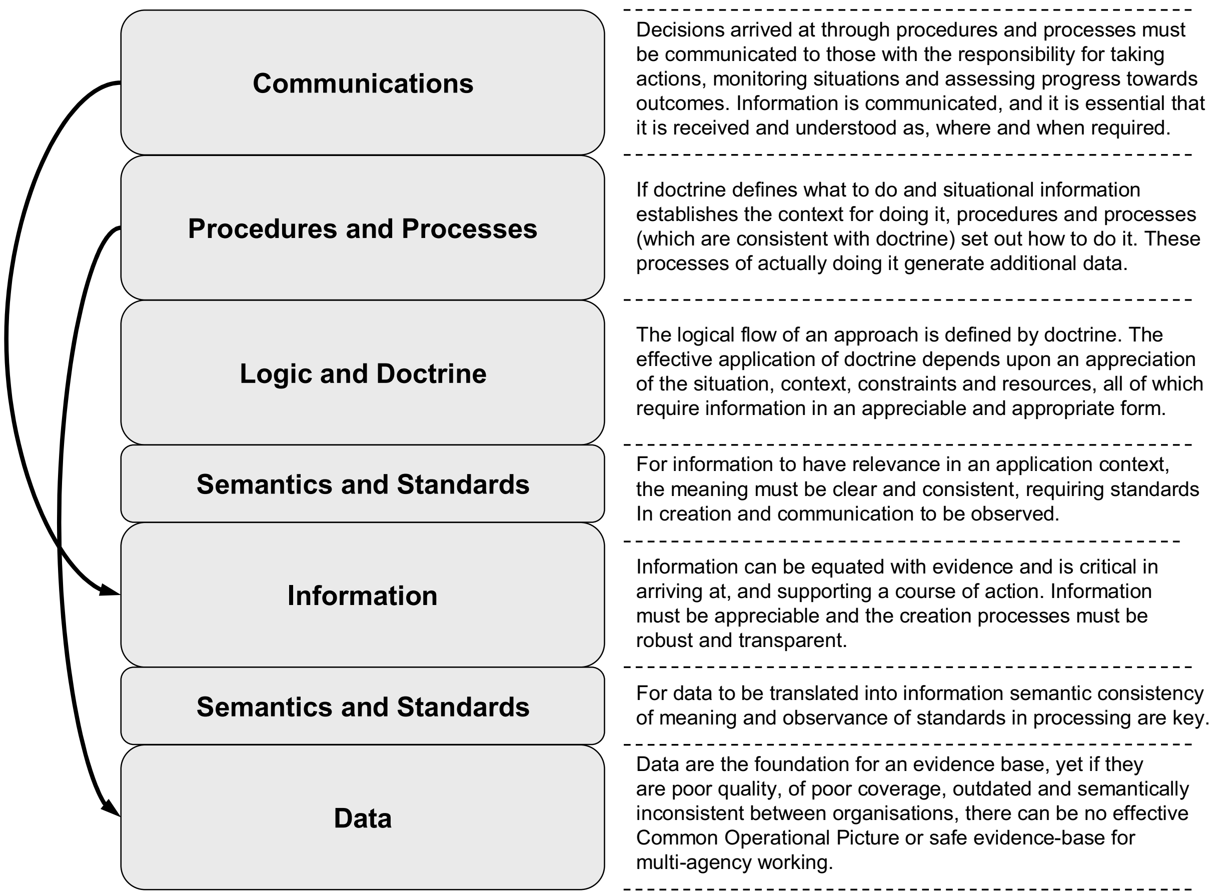


Figure 68: technical, operational and communications systems are underpinned by data and intermeshed by information

There are five sections that follow, each of which is summarised here:

- *Web Services:* true systems interoperability requires the internet (or intranet or extranet) as a framework for data transfer, applying standards for data interpretation and application and developing open systems for processing data and reporting information. This is collectively termed ‘web services’.
- *Metadata Standards:* without metadata (information about data – see 8.4.2), datasets are just masses of records without any conceptual or technical application-relevant details. Metadata permits users and would-be users to understand what a dataset is about, what it can be used for and what potential weaknesses or drawbacks there may be. When discovery-level metadata are replicated in a searchable form that is independent from the dataset itself, this contributes to a powerful dictionary of available data and is in itself a significant driver towards consistency for interoperability. At a very basic level you have to know about a problem to be able to address it, and publicising metadata can be very valuable in identifying, for instance, differential quality standards, semantic inconsistencies and variable geo-referencing approaches.
- *Semantic Interoperability:* if two datasets contain a field that has the same header/descriptor and all the records appear to be comprised of common categories (e.g. extreme, high, medium, low, negligible) they would *appear* to be consistent. However, if the two datasets derive from different agencies, each of which has different ideas about, and thresholds between these severity classes, they are clearly, and significantly inconsistent. Working towards semantic consistency is a significant foundation in achieving interoperability.

- *Commercial Off The Shelf (COTS) Software:* although the GIS marketplace is heavily concentrated in favour of a relatively small number of software suppliers, a significant number of projects in the past have seen the development of proprietary, or customised software. COTS packages, in contrast, have a wider user-base, derive from a larger development budget and have had to respond to pressure from users for data format compatibility with other suppliers. As a general principle, COTS software should be considered most appropriate for any GIS project unless there are overriding reasons to the contrary.
- *Political Will:* as introduced above, although interoperability is to a large degree a technical issue, in common with many projects that require a shift in organisational and individual behaviour, leadership at an appropriate level is critical to success.

10.3.1 Web Services

The development of GIS has paralleled the development of IT at large, in which we can identify several phases and key developments:

- Early development on mainframe computers placed them out of wide reach for reasons of cost and complexity;
- Development of Workstation and PC-based desktop systems reduced the cost, and with the advent of Windows software, the interface complexity;
- The basic toolkit of GIS, in common with other tools such as word-processing, databases and spreadsheets, has grown in power and efficiency over the years;
- Local and Wide Area Networks (LANs and WANs) enabled users to manage and share data and work in teams more efficiently;
- The advent of the Internet built on the gains of networking, but enabling wider searches and links to be made between individuals, agencies and communities of interest. Critically, information served over the internet was platform independent, so it could be accessed irrespective of the hardware, operating system and software profile of your computer;
- The development of the Internet saw the advent of ‘distributed computing’ whereby not only data could pass between users over the Internet, but the use of remote processing resources (i.e. other peoples’ computers) could be achieved, through the appropriate protocols;
- The development of ‘Open Systems’ or ‘Open Source Software’ which are wholly transparent and may be developed or embedded into other applications without license or copyright issues has been very significant in permitting the development of systems that can effectively relate to each other;
- The shift from physical networks to wireless networking capability enabled data flows between, for example, a field worker who is surveying structural damage following a storm and a base office which could receive data entered onto a PDA (Personal Digital Assistant) and transferred wirelessly through a GSM phone or even a satellite link;
- The technical enablers identified above have driven increased expectations of ‘real-time’ data flows. These may include reports from automatic chemical release sensors at a known location or on-board train fire detection systems which combine GPS with status indicators. If the data from such sensors is flowing at predetermined intervals into GIS then the current status (the lag time is effectively the separation period between reports from the device) can be mapped and decisions made on the basis of an unfolding situation.

Thus, there has been a progression away from big computers that were stuck in rooms, towards more powerful, user-friendly and portable computers, and also a shift away from computers that could not 'talk to' any other computer, through data and information transfer over a limited network, to a global internet which can enable the seamless transfer of data and information, and indeed facilitate the remote processing of data and the serving of resultant information back to a wirelessly networked PDA or other mobile device in a field environment. Web services is the term that describes this linking over the internet of information systems and business processes through web-based protocols.

The UK government has established that interoperability for the sharing of information and co-ordination of activity amongst public sector bodies can be achieved through the media of web services, and this also holds for geo-spatial technologies. It would be naïve, however, to suggest that this represents the short term objective for all emergency planners and category one and two responders in the UK. It has to be acknowledged that the route to interoperability is at best unclear, certainly with specific reference to GIS applications in IEM. The drive to ensure interoperability between systems that support effective Command, Control, Co-ordination and Communication will proceed, but currently there are few tight guidelines to influence interim developments. What appears here are a set of principles and issues that should be observed and considered in developing GIS applications in IEM.

Interoperable web-services can take users from the ability to instruct systems to 'read these data' to 'read these data, carry out some sophisticated analysis, send them onto another service, undertake further processing then post them onto another system to use'[31]. This critically depends on systems being able to interpret the data in a consistent way. XML, the eXtensible Markup Language, is a development of HTML (HyperText Markup Language) and is what is termed a 'metalanguage', that is a language that describes other languages. In the same way that HTML uses 'tags' to instruct a web browser how to display text and images, tags in XML describe the data in such a way that data in XML format is 'self-describing'. XML 'schemas' are in effect languages which describe data and in line with the principle of transparency and openness that these are widely published and the 'best of breed' are in effect sponsored by bodies such as the UK Office for National Statistics or Office of the e-Envoy so that they become standards for application in a given area.

The key idea here is that of data which are 'self-describing' and as such as highly mobile, and meaningful, between systems.

10.3.2 Metadata Standards

> Information production [is] growing at about 50% a year … yet the amount of time people spend consuming [information] is growing by only 1.7% each year … a critical task ahead will be to stop volume from simply overwhelming value.
>
> Brown, J.S. and Duguid, P. (2002). *The Social Life of Information,* Harvard Business School Press

A GIS is a tool for generating information. Data is the fuel that drives that tool. Users require GIS to help them define solutions to their problems. As a prerequisite for this they require data and this usually requires a search of some description. In the absence of any sort of signposts to the right data (see section 8.4 for a discussion of quality issues and what makes a given dataset 'right') this search could be frustrating, time consuming, involve a lot of queries to already busy people and may be ultimately unsuccessful. Metadata provides the required signposts.

The definition of metadata is information about data. Consider a basic example: if you receive a CD in the post, which of the following options would be preferable?

[31] Maslen, J., Peltenburg, J. and Morrison, K. (2004). *Interoperability in geospatial technologies: an introduction to the UK context*, White Paper Version 1.0, Geowise, Edinburgh. www.geowise.co.uk

i) No label, no covering note
ii) No covering note, but a label that says 'Risks'
iii) No note, but the label says 'Community Risk Register'
iv) No note but the label says where it relates to, the date, the title and the file format
v) As above, but there is a covering note which gives the name and contact details for the person and organisation who sent the disk
vi) As above, but the covering note refers the user to a database file, replicated in txt format, which contains the following attributes about the dataset:
   - What – title and description of the dataset
   - Why – an abstract which summarises why the data were created and its uses
   - When – when the dataset was created and how (often) it is updated
   - Who – originator, data supplier and possibly the intended audience
   - Where – the geographical extent
   - How – how it was built and how to access the data.[32]

It is clear that options (i) to (vi) represent a shift from less to more desirable. So, metadata helps us establish what data are 'out there' and what we could reasonably do with them. This is in itself critical as people who create and maintain data are not always accessible: they may move jobs, be on leave, be ill or be stuck in the traffic jam that is a consequence of an emergency they would ideally be helping to respond to. The arguments for having such contextual and application-relevant information available within an organisation are very strong. However, the Civil Contingencies Act places an obligation on Category One and Two responders to share information, much of which will be spatial information. If metadata records are available and correctly maintained they provide a resource for partners to search. This in itself does not imply a right of access, indeed where constraints apply they should be recorded in the metadata. The benefits from holding and maintaining metadata in an accessible form (e.g. an extranet site) equate directly with those of having a library catalogue – the subject, age, origin, abstract, location and availability all help you to identify what you need and how to get it.

Standards for metadata (already been referred to in 8.4.2) are themselves important, and recording only what seems to the originator to be the main issues may be to disregard key considerations of a range of users. ISO 19115 (International Standard) was established with regard to international practices in 2003 and ISO 19139 (Draft Technical Specification) has subsequently proposed a standardisation of the expression of geospatial metadata using XML. It is imperative that metadata records are compliant with these standards. See the IGGI Guide: *Principles of Good Metadata Management* for a more detailed overview of this subject[33].

10.3.3 Spatial Frameworks

This Guide has been premised on the ability of GIS to overlay layers of data, and the ability of GIS to manage, integrate, analyse, model and display is effectively contingent upon this ability. This, again, relates to standards. 'Third party information' is a term used by the Ordnance Survey to describe spatial data such as census geodemographics, the location of nature reserves and contaminated land. These are located with what the OS terms 'reference information'. It is only through a direct link between the data and the spatial framework that we are able to overlay data, as illustrated below, and all that flows from this basic capability.

[32] Nebert, D.D. (2004). *Developing Spatial Data Infrastructures: the SDI Cookbook* (Version 2.0), Technical Working Group, Global Spatial Data Infrastructure.

[33] http://www.iggi.gov.uk/publications/index.htm

This reference information establishes the ability for geometric interoperability, something that was introduced in Box 4 (Integrating disparate datasets using a 'spatial key'); unless locations can be related to each other data cannot be spatially integrated. If problems do exist with spatial frameworks (for example the Columbia Space Shuttle recovery operation – see Box 9) they can have serious and time-consuming consequences. Due to consistent use of Ordnance Survey referencing systems and products this is not often a severe problem in the UK, but where users need to share data or have access to information of a consistent quality the appropriateness of different addressing and geo-referencing frameworks and standards needs to be considered and recorded in full in metadata.

10.3.4 Semantic Interoperability

Semantics define the meaning of records within a dataset. Think back to the last time you heard someone say "what I'm trying to say is…" - usually that person is struggling to find a way of expressing themself that will also make sense to you. Their idea of how big a fire, how serious a hazard, how widespread a flood, how large a crowd, how steep a slope or how large an area may be different to yours (see Box 13).

Semantic consistency demands that the representation of reality is done in a consistent fashion. This is less of problem for operations within a local area of responsibility with partners who have a common appreciation of the meaning of data and information. If the person referred to above was able to point back to a common experience in the past, and say "this is almost the same as that one we dealt with in November 2005", then some commonality will have been achieved. However, this does not work with people who have no common ground, and it is a poor basis for introducing rigorous common standards. It is a fine example of local solutions that are sub-optimal at higher levels and/or over wider areas.

There is a need to work towards commonality between agencies in the way that phenomena are represented. At a (literally) basic level this has been done with the way in which geographical objects are represented. GML (Geographical Markup Language) is a variant of XML which defines, in universally appreciable terms, the key spatial characteristics of geographical features. Spatial features can be defined by lines of code that define what kind of basic object it is (area, line, point) and its coordinates.

There are technical part-solutions to the communication of what objects are and some of their core attributes, the main example being SVG, Scaleable Vector Graphics. SVG is a vector graphics language written in XML which describes two-dimensional graphical objects. As such it can be used to determine how users see and can interact, albeit at a relatively basic level, with maps in a web browser. Maps can be annotated, re-scaled and mouse actions such as clicking to determine attributes and rolling grid coordinates with the movement of the mouse can be set up, all with the gains of transparency and transferability that XML and OSS brings. However, although GML can define spatial features and their core attributes, and SVG can define the visual representation of the data, the *meaning* of what they represent depends upon semantic consistency and this lacks standardisation.

At present there are differences between key agencies such as Police Forces, Fire Services, Social Services Departments and Ambulance Services in the way that they classify incidents. There are examples of standards such as the World Health Organisation's International Classification of Diseases. Some examples of these are illustrated in Table 7, although it is clear that full consistency requires the semantics of contingent categories such as 'residential institution' and 'trade and service area' to be realised.

ICD-10 Code	Meaning
X1.1	Exposure to smoke, fire and flames - Residential institution
X1.2	Exposure to smoke, fire and flames - School, other institution and public administrative area
X1.3	Exposure to smoke, fire and flames - Sports and athletics area
X1.4	Exposure to smoke, fire and flames - Street and highway
X1.5	Exposure to smoke, fire and flames - Trade and service area
X1.5	Exposure to smoke, fire and flames - Industrial and construction area

Table 7: example of semantic consistency in coding from health

This is an area where GIS applications are currently very weak but such issues need to be addressed, and not just at the local level.

10.3.5 Spatial Data Infrastructures

Spatial Data Infrastructures (SDIs) are described by Longley *et al.* (2005) as one of ‘the big ideas’ in GIS. This is not the place for a detailed discussion of the subject, but the basic concept is that data sharing is difficult, and without the development of partnerships to address the issues it will remain difficult. The higher the level at which partnerships are developed, the greater the momentum will be to develop semantic, data and metadata standards, and the means to search for and access data over the internet. SDI is a term that describes a coordinated and partnership-based environment for producing, managing, disseminating and using spatial data.

So, an SDI is not a physical infrastructure in the way that a railway system is, with track, rolling stock, stations, timetables, management structures, consumer representation and service standards. Rather it is much more conceptual, and Longley *et al.* (2005) observe that ‘at a high level, there are few who dispute the merits of achieving data sharing, reduction of duplication, and risk minimisation through the better use of good-quality GI. But how to make it happen for real is a different matter’ (p.458).

The previous sections have established that the standards, frameworks and issues that need to be addressed for an SDI to develop over time. SDIs are fundamental and integral to issues around interoperability.

10.3.6 Commercial Off The Shelf Software

Transparency is the most significant aspect of OSS: in contrast to much COTS Software and many proprietary systems, the code is freely available and there are no Intellectual Property Rights withheld in applying or developing open systems. ‘Open Specifications provide software engineers and developers information as well as specific programming rules and advice for implementing the interfaces and/or protocols that enable interoperability between systems’[34].

As a basic principle, proprietary systems that are not based on open specifications are counter to basic principles of e-government and the wider pursuit of interoperability. With many COTS packages the development emphasis is on creating extensions that permit the seamless integration of diverse data formats, although the core software itself does not conform to open specifications.

[34] Anderson, G. and Moreno-Sanchez, R. (2003). Building Web-Based Spatial Information Solutions around Open Specifications and Open Source Software, *Transactions in GIS*, 7(4), 447-466.

10.3.7 Political Will

In common with many issues around the application of IT to socio-economic and environmental problems, technological obstacles to interoperability are outweighed by the cultural, organisational and (perceived) financial barriers.

> Writing in *GIS Professional* in 2005 , Judith Jerome, a Geographic Information specialist at the Cabinet Office e-Government unit, observed that: *'Technical interoperability is a reality… Semantic interoperability is moving forward but still has far to go… [and that] … The greatest challenge … is human/political interoperability, which involves changing hearts and minds*'.

Agencies are often not used to working closely with other agencies and the primary frame of reference for decisions is internal. For this reason, agencies are at best cautious about initiatives where costs are likely to be internal and short term, and benefits are likely to be both internal and external and realised over the long term. Addressing this in such a way that agencies are prepared to engage positively with initiatives where the benefits are more widely dispersed requires strong leadership from government that is mirrored within individual agencies.

Section Eleven

Future Developments

Summary

In such a fast moving field it can be difficult, even foolhardy, to try and identify future developments with any degree of certainty. This short section identifies those areas where developments are likely to be the most significant for emergency planners and responders.

11.1 Location-Based Information

Location-based information and the increasingly embedded nature of GI into administrative, management information, analytical and decision support systems has been referred to previously, and it is only mentioned here as this is a trend that will continue. To draw a parallel with mobile phones, perhaps the most significant trend over time with mobiles has not been capability (more features on new handsets) but that more users of *any kind of handset* can talk to others at the voice communications level. GI will always require specific techniques to handle, analyse and report it, but to users of systems it is likely to appear less and less segregated from other forms of information over time.

11.2 Data sources

The exponential growth in data has previously been identified. These are not just created through the same sources, as data are expanding not just in volume but also in diversity. Some of these are what might be termed 'value-added' products, created through the integration of existing sources, and the example of geo-demographics is given here. Others are data from sources that are well established at a generic level (remotely sensed data is the example) but where refinements are creating data in much greater volumes and with an ever increasing range of potential applications.

11.2.1 Geodemographics

Geodemographics describes data and information that profile areas on the basis of composite indicators of consumer behaviour. Typically they are commercial datasets, provided by a small number of businesses, which are based in small-area census data, but have added value to these through the integration of other data sources such as surveys and consumer records (Electronic Funds Transfer At Point Of Sale - EFTPOS - links together what someone has bought together with who they are and where they live if they also use a loyalty card). These might seem of very limited relevance to emergency planning and management, but they provide ever richer information on the wider characteristics and behaviour of the population, often down to the level of individual postcodes that is of relevance to risk assessment and emergency planning.

11.2.2 Remotely sensed data

As has previously been identified, remotely sensed data (satellite images and aerial photographs) are raster data. There are two dimensions to resolution in such data: spectral range and spatial resolution. Any form of photography, of which remote sensing are variants, is the capturing of energy being given off by a series of objects. For satellite images this is usually solar radiation that is reflected or emitted from the earth's surface. Such radiation is

Figure 69: panchromatic IKONOS image of the centre of Rome at a spatial resolution of approximately one metre © Space Imaging

Figure 70: Quickbird image of a Freighter breaking up in December 2004 off Unalaska Island, Aleutians, Alaska © Digital Globe

given off across a wide range of wavelengths, and early satellite-based sensors could only measure a small number (three would be typical) of these wavelengths. The capacity to measure a wider range of wavelengths means the ability to more accurately discriminate between characteristics of the earth's surface. Modern sensors have the ability to measure a much wider range, thereby supporting a more diverse range of applications.

The spatial resolution of satellite images and aerial photographs have also been increasing with time. Until recently the highest resolution (smallest pixel size) satellite images that were commercially available to general users were around 20m x 20m. The IKONOS satellite, launched in 1999, dramatically changed this with a spatial resolution of 90cm, followed in 2001 by imagery from the QuickBird satellite, which is reported to have a resolution of 62cm. Figure 69 shows an panchromatic (black and white) IKONOS image of the centre of Rome at a spatial resolution of approximately one metre.

Figure 70 illustrates the real colour imagery available from the Quickbird satellites, showing in this instance a freighter breaking up off the Aleutian Islands in 2004. It is clear from this that the quality of the image is comparable with aerial photography, and as it is a commercial product there is no need to commission such images – although far from cheap, they just need to be purchased from the 'back catalogue'.

11.2.3 Real time data

Real-time describes data that reflect the situation as it is at the present time, potentially with a short delay for processing and display. The use of Automatic Vehicle Location Services, such as those illustrated for Durham Constabulary (see 7.4.6), are an example of this which permits decision makers to see the distribution of resources at any given time. A range of potential devices such as traffic or river flow meters, Automatic Number Plate Recognition Systems or radiation or atmospheric pollution sensors have the potential to issue alerts if measurements exceed defined parameters or another 'trigger' is identified. Where such sensors or devices are integrated with GIS the spatial location of the anomaly and its potential consequences can rapidly be assessed, analysed and visualised. Digital CCTV can also be integrated with GIS, as flows of imagery that are associated with given locations, and which can then be accessed as video feeds for 'diagnostic' or 'confirmatory' reasons. The integration of CCTV with GIS-enabled Command and Control systems in Police control rooms is a good example of this.

The number and range of sensors feeding real time or near real time data in a form that is compatible and accessible with GIS will increase over time with significant implications for emergency management. One example of such sensors feeding information in real time (or near real time i.e. with a short delay due to processing or transmission) to a web-site is the facility of the Centre for Environment Fisheries and Aquaculture Science (CEFAS), illustrated in Figure 71.

The CEFAS website reports data from the DEFRA strategic wave monitoring network for England and Wales, which is a network of wave buoys located in areas at risk from flooding. According to CEFAS 'Data from this network will be used to improve the management of flood and coastal erosion risk for which DEFRA has policy responsibility' and the data will be used by Flood Managers, Local Authorities, Consultants, and other stakeholders in order to assess flood risk, and on a longer timescale will be to help design improved flood defence schemes and to provide data for climate change studies'.

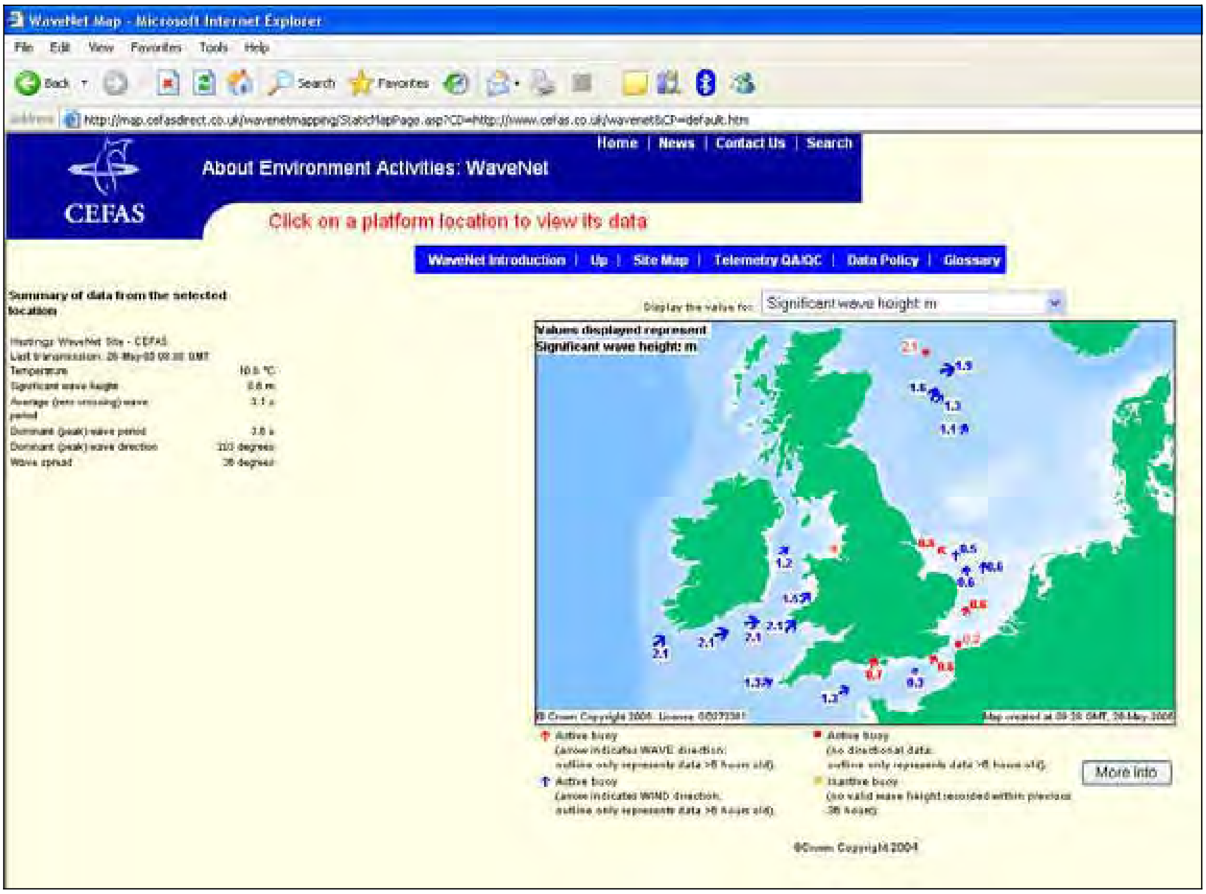


Figure 71: The CEFAS Wavenet website, providing access to real time wave data around the UK (http://www.cefas.co.uk/wavenet/default.htm)

11.3 Mobile Technologies

The linkage of mobile phones with location-based information has been mentioned previously. Just as GI is becoming increasingly embedded in other forms of information capture, management and reporting systems, the decreasing size and cost of GPS and their integration with devices such as mobile phones, digital radios and PDAs means that outgoing messages from mobile devices can include a locational identifier. The increasing processing power of such devices also means that mapping technologies for information and navigation can be accessed from almost anywhere, with clear implications for warning and informing the public. Although it is a seemingly mundane issue, the most significant drawback in the use of such mobile technologies is limited battery life – a clear resilience issue.

11.4 Concluding Comment: From Isolation to Integration to Interoperability

GIS applications in emergency planning and management have mirrored the development of GIS more broadly: early developments were carried out on single machines within separate agencies, and data and information sharing was partial and difficult to achieve. Recent developments have seen statutory, technological and organisational shifts towards the integration of practice and systems that support that; legislation has clarified rights, roles, responsibilities and requirements to share data; partnerships and protocols have promoted this and the increasing mobility of data within systems and organisations, underpinned by transfer formats, common standards, open systems, metadata and web-services have permitted the development of integrated information for decision-making. Future developments will build on integration of data, systems and processes in the development of interoperable data, systems and processes that effectively remove the need for manual interventions to transmit data and information between organisations. The principles, both technical and operational, of interoperability are established (and embedded in the principles of e-government in the UK) and the technical enablers are all proven. It will now require vision and leadership to realise the gains.

Appendix 1: Glossary of Terms

Backdrop Mapping	Maps such as those at 1:250k, 50k, 25k or 10k from the Ordnance Survey which are used in a GIS for the purposes of context and orientation rather than any direct analytical applications. Such maps are usually in **raster** format.
Framework Mapping	Spatial datasets which allow attributes to be spatially referenced. For example, a list of properties that has no direct spatial identifier but which contains an Ordnance Survey Address Point Reference (OSAPR) can be spatially located and then mapped by linking to the Ordnance Survey Address Point dataset. Similarly census data, or indeed any dataset that uses census units such as Wards and Output Areas, can be mapped by linking to the framework map of census boundaries.
Geo-referencing	Geo-referencing describes the process of linking records or datasets that are not in themselves geographical (e.g. social service records or details of chemicals stored in tankers) to a spatial dataset, enabling them to be mapped. Usually this requires that a common link between the records and a **framework map** is identified. This may be a postcode, Ward identifier or OSAPR, although specific pieces of geo-referencing software are increasingly sophisticated as what is termed 'fuzzy matching', enabling less precise locational attributes such as 'near North Street' to be mapped.
Hotlinking	This is the process of linking files to locations. Usually it refers to files other than the standard table of attributes, for instance graphics files, external databases, word documents, hyperlinks or movie files. An example of a hotlinked file could be a jpeg file which illustrates the feature under normal operating conditions. A field worker could access this to ascertain whether any changes or alterations had taken place.
Large Scale Maps	A large scale map is one of a relatively small area that shows a large amount of detail. Some people find this confusing, expecting a large scale map to be one of a large area, but this is not the case – they are termed large scale as 1:5,000 is a larger fraction of 1 than, for instance, 1:250,000.
Metadata	Metadata are information about data. See section 8.3.
Raster data	Spatial data that are stored as a matrix of values in a grid of defined resolution. See Box 5.
Resolution	Resolution has a number of different dimensions in the context of spatial data. At a generic level it refers to the dimensions of the building blocks of a dataset. So, spatial resolution describes the size of the components of the dataset. In this context it is most applicable to **raster data** where the pixel size defines the spatial resolution. The temporal resolution of a dataset describes the level of aggregation of time periods in a dataset.
Small Scale Maps	A small scale map is one of a relatively large area that shows a limited amount of detail. Some people find this confusing, expecting a small scale map to be one of a small area, but this is not the case – they are termed small scale as 1:250,000 is a smaller fraction of 1 than, for instance, 1:5,000.
Thematic Maps	Thematic maps can be distinguished from **backdrop maps**, as they are maps of a specific dataset rather than general topographic maps for the purposes of context and orientation. A thematic map, for example, could be census data describing the distribution of children aged less than 14 in an area or the distribution and attributes of COMAH sites in a District.
Vector Data	Spatial data that are stored as points, lines or areas. See Box 5.

Appendix 2: Annotated Bibliography of Key Readings

Books

There are relatively few accessible books on the subject. The most widely available are:

Amdahl, G. (2001). *Disaster Response: GIS for Public Safety,* ESRI Press, Redlands.

Greene, R.W. (2002). *Confronting Catastrophe: A GIS Handbook*, ESRI Press, Redlands.

These suffer from being (a) almost exclusively US focused, and (b) being from the publisher associated with a particular GIS developer, so a rather skewed view of the whole field is offered.

Briggs, D.J., Forer, P., Jarup, L. and Stern, R. (Eds) (2002). *GIS for Emergency Preparedness and Health Risk Reduction*, NATO Science Series IV: Earth & Environmental Sciences, Kluwer, Dordrecht.

This is an edited collection rather than an authored book so consequently the development of themes is not as strong. However, it is an effective and broad ranging collection that is perhaps of greater relevance to those with interests in public health.

Cutter, S. L., Richardson, D.B. and Wilbanks, T.J. (Eds) (2003). *Geographical Dimensions of Terrorism*, Routledge, London.

This book appears to be rather misleadingly titled but the content is in fact a very effective overview of a series of key issues, both technical and application-related. Again, it is almost entirely US-focused in its scope.

Van Oosterom, P., Zlatanova,S. and Fendel, E.M (Eds) (2005). *Geo-information for disaster management*, Springer, Berlin.

This is an extensive edited collection, with a series of papers that are relatively specific and with a strong technical flavour.

Gatrell, A. and Loytonen M. (Eds) (1998). *GIS and Health*, Taylor & Francis, London.

Although this is no longer a very recent book it remains an excellent collection on health-applications of GIS.

Journal Articles

The academic journals contain a significant amount of papers on various aspects of GIS and emergency planning and management. This ranges from applications in complex emergencies in the developing world through to very specific aspects of data models, interoperable systems and analytical tools. Few of these will be of interest to a wider audience and many such papers have been synthesised and referenced in footnotes, in the writing of this guide, although the following are a starting point in any further exploration:

Cutter, S.L. (2003). GI Science, Disasters and Emergency Management, Transactions in GIS, 7(4), 439-445.

Dymon, U.J. (2003) An analysis of emergency map symbology, *International Journal of Emergency Management*, 1(3), 227-237.

Kevany, M.J. (2003). GIS in the World Trade Center attack—trial by fire, *Computers, Environment and Urban Systems*, 27, *571-583*

Zerger, A. and Smith, D.I. (2003). Impediments to using GIS for real-time disaster decision support, *Computers, Environment and Urban Systems*, 27, 123-141