

ELFORSK



DAM SAFETY

Geomatics for Improved Flood Risk Management

Rapport 07:68

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Förord

Denna rapport är ett delresultat inom Elforsk ramprogram Dammsäkerhet. Rapporten är även finansierad genom medel från Rymdstyrelsen inom fjärranalysprogrammets användardel. Ett stort tack till Elforsk och Rymdstyrelsen för deras stöd.

Elforsk

Kraftindustrin har traditionellt satsat avsevärda resurser på forsknings och utvecklingsfrågor inom dammsäkerhetsområdet, vilket har varit en förutsättning för den framgångsrika utvecklingen av vattenkraften som energikälla i Sverige.

Målen för programmet är att långsiktigt stödja branschens policy, dvs att:

- Sannolikheten för dammbrott där människoliv kan vara hotade skall hållas på en så låg nivå att detta hot såvitt möjligt elimineras.
- Konsekvenserna i händelse av dammbrott skall genom god planering såvitt möjligt reduceras.
- Dammsäkerheten skall hållas på en god internationell nivå.

Prioriterade områden är Teknisk säkerhet, Operativ säkerhet och beredskap samt Riskanalys.

Ramprogrammet har en styrgrupp bestående av: Jonas Birkedahl – FORTUM, Malte Cederström - Vattenfall Vattenkraft, Anders Isander – E.ON, Martin Johansson – Skellefteå Kraft, Olle Mill - Svenska Kraftnät, Urban Norstedt - Vattenfall Vattenkraft, Gunnar Sjödin – Vattenregleringsföretagen, Rolf Steiner - FORTUM, samt Lars Hammar – Elforsk

Rymdstyrelsen

Fjärranalysprogrammets användardel stödjer initiativ inom fjärranalysområdet med syfte att öka användningen av fjärranalysteknik i samhället. Användardelen uppmuntrar och stödjer samarbets- och utvecklingsprojekt mellan utvecklare av i första hand satellitbaserade fjärranalysmetoder och potentiella användare.

Projekt skall genomföras med ambitionen att operationalisera utnyttjandet av satellitbaserade fjärranalysmetoder. Användardelen skall även stimulera svenskt näringsliv inom fjärranalysområdet med inriktning på framtagandet av nya produkter och tjänster.

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Preface

Many people are living in flood risk areas and the problems associated with the hazards as well as the solutions are essentially spatial in nature. Geomatics is the discipline that integrates acquisition, storing, processing, modelling, analysis and display of spatially referenced data.

This report describes how geomatics can improve dam safety and flood risk management. Also, how high resolution satellite images and GIS can help to mitigate the effects of disasters on human life and property. Elforsk AB and the Swedish National Space Board have financed the project.

Sammanfattning

Höga vattennivåer och översvämningar kommer alltid att förekomma och orsaka skador för städer, miljön, infrastrukturen och förlust av liv. Många människor bor i riskområden för översvämningar, problemen och lösningarna är i huvudsak av spatiell karaktär. Geomatik är ett samlingsbegrepp för discipliner som integrerar insamling, lagring, processering, modellering, analys och visualisering av georefererad information. I begreppet geomatik ingår specifika discipliner och tekniker som geodesi, kartografi, fjärranalys, fotogrammetri, GIS, GPS och informationsteknologi.

Uppdaterad och högkvalitativ information är nödvändig inom områdena dammsäkerhet, riskanalys, översvämningsskartering, beredskapsplanering, etc. Över stora delar av världen är de tillgängliga kartorna gamla och visar inte den aktuella situationen. Vidare är kartorna inte gjorda med beredskapsplanering och dammsäkerhet i åtanke.

De senaste fem åren har mycket högupplösande satellitbilder tillsammans med annan digital geografisk information förbättrat och moderniserat arbetssättet inom olyckshantering och beredskapsplanering före, under och efter en olycka. Högupplösande optiska satellitdata i ett GIS system ger en bra kartbakgrund till planerare och beslutsfattare.

Användningen av satellitdata för översvämningsskartering kan grupperas i två huvudområden:

- Nya satellitbilder och satellitbildsklassningar som kartbakgrund åt planerare och beslutsfattare.
- Satellitbilder ger information om avrinningsområdets vegetation, landanvändning, jordfuktighet, topografi, etc. till hydraulisk modellering.

Det moderna hanterandet av översvämningssrisker är idag ofta baserade på satellit-/flygbilder, GPS, digitala höjdmodeller och hydraulisk modellering integrerat i GIS.

Utvecklingsriktningarna är:

- Ökad betydelse av detaljerade satellitbilder, flygbilder, laser, radar.
- Efterfrågan på uppdaterade kartor med hög kvalitet.
- Tillämpning av ny fältbaserad teknik.
- 3-D data får ökad betydelse.
- Nya tekniker för konvertering och uppdatering av data.

Översvämningar och dess förlopp är relativt enkelt att kartera med hjälp av satellit SAR (Syntetisk Aperturradar). Den största fördelen med SAR är dess förmåga att kunna inhämta information under natten och kunna se genom moln. SAR erbjuder ofta den enda möjligheten att övervaka storskaliga översvämningar vid dåligt väder.

Laserradar som nyttjas för att utforska atmosfär, mark och sjö kallas ofta LIDAR (Light Detection and Ranging). LIDAR är en relativt ny och intressant teknik som bl a används för att skapa detaljerad höjdinformation med cm-dm noggrannhet. Tack vare den höga punkttätheten som tekniken erbjuder penetreras små hål i vegetationen och markhöjden kan därmed erhållas. LIDAR är den enda fjärranalystekniken som klarar av detta.

Det är ofta kostnadseffektivt att i samband flygburen LIDAR passa på att ta flygbilder över aktuellt område. Idag är det också möjligt att använda LIDAR för att kartera bottentopografin (batymetri) i grunda områden.

Summary

High water levels and floods will always occur and cause damage to towns, infrastructure, environment, and loss of life. Many people are living in flood risk areas and the problems associated with the hazards as well as the solutions are essentially spatial in nature. Geomatics is the discipline that integrates acquisition, storing, processing, modelling, analysis and display of spatially referenced data. Geomatics integrates the more specific disciplines and technologies such as geodesy, cartography, remote sensing, photogrammetry, GIS, GPS, and information technology.

High quality and up-to-date information is essential for dam safety, risk assessment, consequence analysis, inundation mapping, emergency planning, etc. Today, available maps are often too old, and do not reflect the existing situation. In addition, they are not produced with emergency planning and dam safety in mind.

The last five years, very high resolution satellite imagery together with other digital geographically based data have modernized and improved the way disaster relief and emergency relief groups make decisions before, during and after natural and man-made disasters. Optical high-resolution satellite images in a GIS system can provide cartographic background information to planners and decision makers.

The contribution of satellite data for inundation mapping can be divided into two main fields:

- Provide cartographic background information to the planners and decision makers with up-to-date images and land cover mapping.
- Provide information about the watershed vegetation cover, land use, soil moisture, topography, etc to hydraulic modelling or parameter tuning.

The modern flood risk management approach are often based on satellite images, GPS, digital elevation models, hydraulic modelling integrated in a GIS.

The major trends are:

- Increased importance of detailed satellite imagery, aerial photographs, laser, radar.
- Demand for up-to-date maps with high quality.
- Application of new field based technologies.
- Increased importance for 3-D data.
- Techniques for conversion and updating of data.

Flooding is relatively easy to map and monitor with satellite SAR data. The main advantage of SAR images is their capability of obtaining information at night and through clouds. SAR is often the only available tool to monitor flood events during bad weather conditions.

One of the best and most recent techniques to obtain very accurate elevation data with cm-dm accuracy is by airborne LIDAR systems. Since LIDAR can penetrate any hole in a canopy, it is possible to provide terrain data in vegetated areas. LIDAR is the only remote sensing method that will do this.

It is often convenient and economically advantageous to complement the LIDAR survey with simultaneously taken aerial photographs. Today it is also possible to use airborne LIDAR technology to simultaneously map land (topography) and shallow water (bathymetry).

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1 Introduction

High water levels and floods will always occur and cause damage to towns, infrastructure, environment, and loss of life. High quality and up-to-date information is essential for dam safety, risk assessment, consequence analysis, inundation mapping, emergency planning, etc.

Many people are living in flood risk areas and the problems associated with the hazards as well as the solutions are essentially spatial in nature. Geomatics is the discipline that integrates acquisition, storing, processing, modelling, analysis and display of spatially referenced data. Geomatics integrates the more specific disciplines and technologies such as geodesy, cartography, remote sensing, photogrammetry, GIS, GPS, and information technology.

In this report state-of-the-art technologies for spatial risk management are presented.

2 Satellite data and GIS for disaster relief and emergency planning

The last five years, very high resolution satellite imagery together with other digital geographically based data have modernized and improved the way disaster relief and emergency relief groups make decisions before, during and after natural and man-made disasters.

The satellite images show detailed features such as damaged bridges, houses, roads, oil spills, flooded areas. For instance, the information can be used for:

- identify affected areas
- determine the impact of damage
- prioritize relief efforts
- plan escape routes, identify safe areas
- estimate population
- create detailed base maps

In December 26, 2004, a magnitude 9.0 earthquake, off the west coast of Northern Sumatra, Indonesia, triggered massive tsunamis that affected several countries. Below (Figure 2-1) is a tsunami damage assessment map over Indonesia based on SPOT 5 (2.5 m pansharped) image acquired 30 December (from <http://unosat.web.cern.ch/unosat/>). UNOSAT is a UN initiative to provide satellite imagery and GIS services to the humanitarian community. By this image it is possible to create an up-to-date map describing the situation and plan the relief work. It is important to keep in mind that better information leads to better decisions.

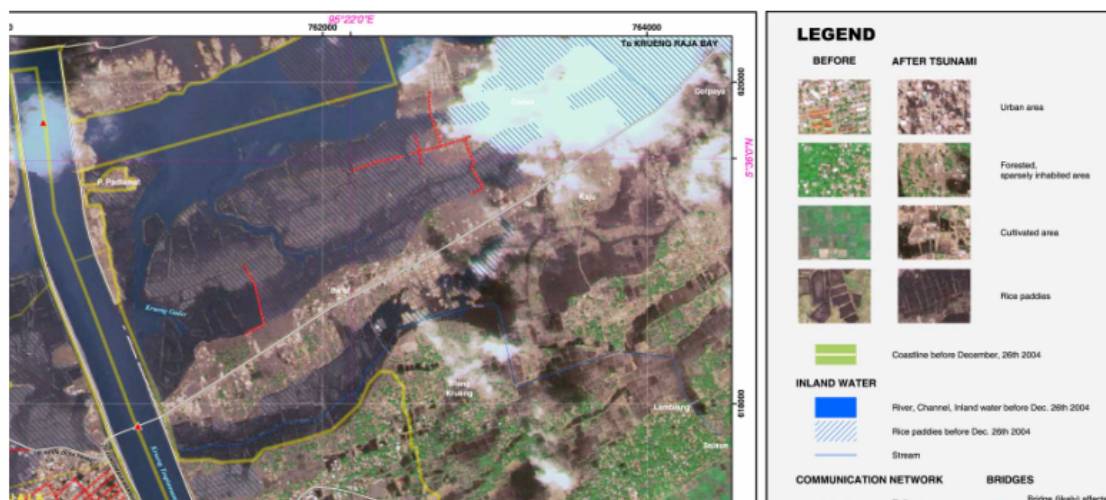


Figure 2-1. Spot 5 image from 30 December 2004 after tsunami in Indonesia (from <http://unosat.web.cern.ch/unosat/>).

2.1 International examples

2.1.1 Earthquake

In October 8, 2005, an earthquake of magnitude 7.6 occurred in the India-Pakistan border. The intense quake killed more than 80,000 and as many as 1.5 million people became homeless and required continued emergency relief assistance. The IKONOS satellite image in Figure 2-2 is provided by UNOSAT (<http://unosat.web.cern.ch/unosat/>). With this 1 m resolution image it is possible to determine the impact of damage, identify affected areas, create detailed base maps and prioritize relief efforts.



Figure 2-2. IKONOS satellite image (1m resolution, acquired 12/10/2005) of Balakot area in Pakistan after earthquake (from <http://unosat.web.cern.ch/unosat/>).



2.1.2 Dam break

In February 13, 2004, the Shakidor Dam in Pakistan burst due to heavy rains. The 150 m long dam was built 2003 to provide irrigation for the nearby farms. Below (Figure 2-3) are satellite-derived maps (SPOT 5, 2.5 m geometrical resolution) before (29 January 2004) and after (17 February 2005) the disaster (from www.alertnet.org).

Reuters AlertNet is a humanitarian web based news network. It started 1997, the aim is to keep relief professionals and the public up-to-date on humanitarian crises around the globe. ESA (European Space Agency) supports AlertNet's satellite imagery and satellite-powered mapping services.

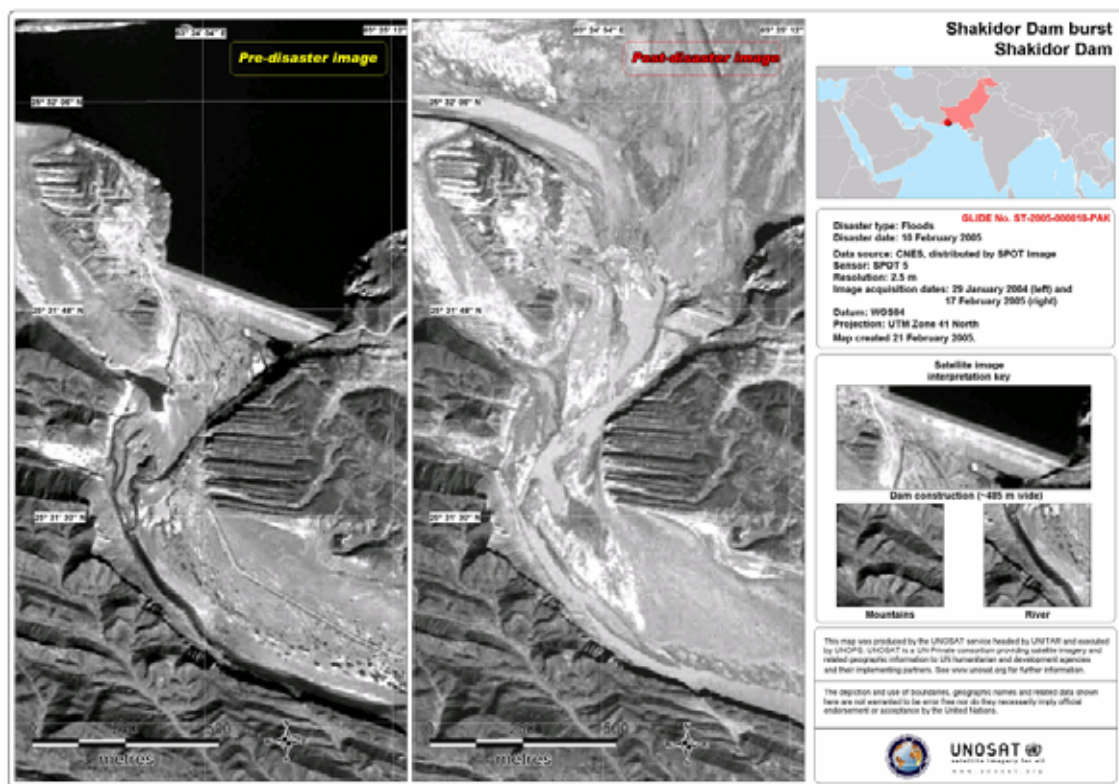


Figure 2-3. SPOT 5 satellite image derived map showing Shakidor Dam and immediate surroundings before (left) and after (right) dam-burst on 10 February 2005.

2.1.3 Hurricane

On August 28, 2005, Katrina the most destructive storm ever to strike the United States reached New Orleans. The storm breached the levee system that protected New Orleans from Lake Pontchartrain and the Mississippi River and flooded the city. Below (Figure 2-4) are IKONOS colour images with 1 m resolution before (13 May 2001) and after (2 September 2005) the disaster (from www.spaceimaging.com).

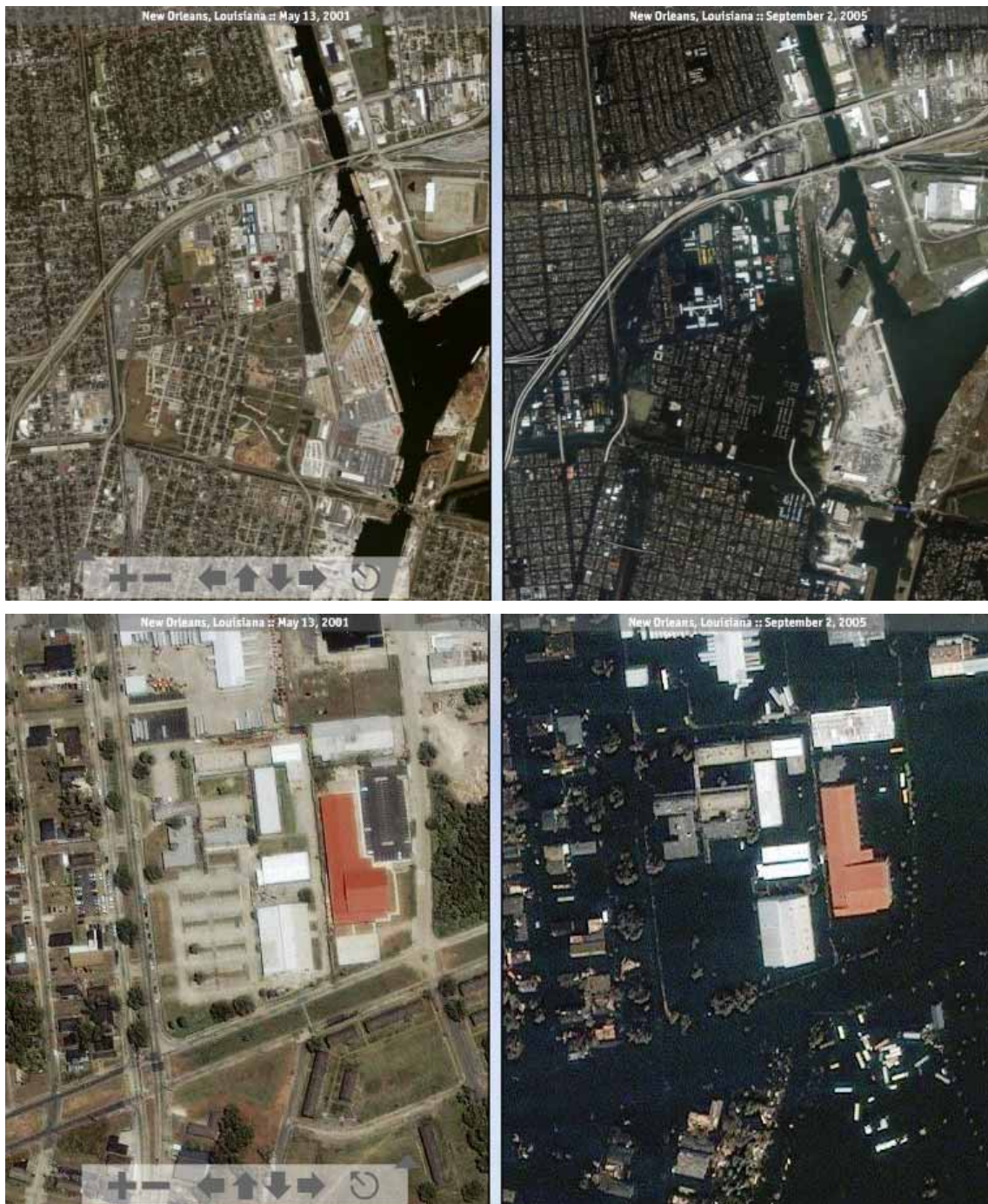


Figure 2-4. IKONOS colour images with 1 m resolution before (13 May 2001) and after (2 September 2005) the Katarina disaster (from www.spaceimaging.com).

2.1.4 Tsunami

On December 26, 2004, one of the world's worst natural disasters struck, a magnitude 9 earthquake about 150 kilometres off the coast of the Indonesian

island of Sumatra. The earthquake generated a tsunami – a series of huge waves that killed more than 150,000 people in Asia and Africa, more than half of them on Sumatra. Figure 2-5 show before and after tsunami images from QuickBird over Banda Aceh shore, Indonesia (from http://www.resmap.com/tsunami/tsunami_images.htm).

Except for the loss of human lives and suffering, the earthquake caused an enormous environmental impact that will affect the region for a long time. High-resolution satellite images are used by the aid organizations to get a general overview of the situation and estimate the extent of the disaster. They are also valuable when prioritizing relief efforts and rebuilding the affected areas.



Figure 2-5. QuickBird satellite images over Banda Aceh Shore, Indonesia.
Above) Before tsunami June 23, 2004.
Below) After tsunami December 28, 2004
(from http://www.resmap.com/tsunami/tsunami_images.htm).

3 Remote sensing data for risk management

Remote sensing data can significantly contribute to flood risk assessment in the prevention phase with mapping of vegetation and land use. Satellite images can also be used for flood forecasting (preparedness phase) and in flood damage estimation (post-crisis phase). For instance, a satellite image acquired during a flood event gives accurate information on the extent of the flooded area. Information over large areas can easily be extracted by satellite remote sensing methods based on optical, Synthetic Aperture Radar (SAR) and passive microwave. The contribution of satellite data can be divided into two main fields:

- Provide cartographic background information to the planners and decision makers with up-to-date images and land cover mapping.
- Provide information about the watershed vegetation cover, land use, soil moisture, topography, etc to hydraulic modelling or parameter tuning.

Today, available maps are often too old, and do not reflect the existing situation. In addition, they are not produced with emergency planning and dam safety in mind. Also, aerial photographs often failure to provide this information since they are out of date.

Most of the potential users are not familiar with obtaining, processing and interpreting satellite images. But custom-made and timely delivered satellite products integrated with expert systems will most likely provide important information to the planners and the decision makers. The modern flood risk management approach are often based on satellite images, GPS, digital elevation models, hydraulic modelling integrated in a GIS.

Four scale levels regarding information needs for flood prevention strategies/action plans can be recognised (GMES, 2001);

1. Global Reliable information on flood events are needed in order to provide a better understanding on the relationship between global change and an increase of natural disasters like flooding.
2. European Availability of relatively coarse catchments information (topography, land-cover, man-made structures, soil types), meteorological and hydrological information, modelling and monitoring tools for flood extent mapping and damage assessment.
3. National For national and European applications there is a need for intermediate scaled data. Availability of catchments information (topography, land-cover, man-made structures, soil types), meteorological and hydrological information, modelling and monitoring tools for flood extent mapping and damage assessment.

4. Local Availability of detailed catchments information (topography, land-cover, man-made structures, soil types), meteorological and hydrological information, modelling and monitoring tools for flood extent mapping and damage assessment.

3.1 Sensors and platforms

Table 3-1 presents some of the current and near-future earth observation satellites of particular interest for flood risk management. The most potential is on the SAR and optical sensors (Panchromatic-PAN, Very Near Infrared-VNIR, Short Wave Infrared-SWIR).

Table 3-1. Examples of current and planned earth observation satellites.

Mission	Instrument	Spatial Resolution (meters, at nadir)					Swath (km)	Repeat Cycle (day)
		PAN	VNIR	SWIR	TIR	SAR/band		
ERS-1/2	AMI-SAR					30/C	100	16-35
	ATSR-1		1000	1000	50000		500	16-35
Resurs-O1 N3	MSU-SK		170		600		600	2-4
Radarsat	SAR					10-100/C	45-500	4-8
IRS-1D	PAN	6					70	5-24
	LISS 3		23	70			142-148	24
	WIFS		188	188			774	5-24
SPOT-4	2xHRV-IR	10	10, 20	10, 20			60	3
	Vegetation		1000	1000			2200	1
Landsat 7	ETM+	15	30	30	30		185	16
IKONOS	IKONOS	1	4				300	11
CBERS	CCD	20	20	20			120	3-26
	IR-MSS	80		80	80		120	26
	WFI		260	260			900	3-5
Terra EOS AM-1	ASTER		15	20	90		60	16
	MISR		240, 480, 960, 1900				370-408	2-9
	MODIS		250, 500, 1000	500, 1000	1000		2300	2
ENVISAT-1	AATSR		1000	1000	1000		512	3
	ASAR					30/C	100	3
	MERIS		300, 12				300, 575, 1150	3
QuickBird 2	QuickBird	1	4				22	1-5
EROS		1,8					13	3-4
Orbview 3	Orbview 3	1	4				8	3
NOAA-M	AVHRR		1100	1100	1100		3000	0.5
Radarsat-2	SAR					3-100/C	10-500	4-8
ALOS	AVNIR-2	3	10-15				35, 70	2, 45
	PALSAR					10, 100/L	70-350	45
SPOT-5a	HRG	5	10	20			60	3
	Vegetation		1000	1000			2200	1

3.1.1 High and medium resolution optical satellite images

Optical high-resolution satellite images in a GIS system can provide cartographic background information to planners and decision makers. Commonly the areas affected by a flooding event are large in size. Up-to-date land cover maps and orthoimages covering the entire inundated area can be produced using high-to-medium (SPOT, Landsat TM, Aster) resolution satellite images. Quantitative estimates of the amount of land cover and infrastructure affected by flooding can be provided by optical satellite data. Figure 3-1 shows Landsat ETM+ false colour composites of the Elbe River before and during a flooding event in August 2002 (NASA, 2003). However in a flood emergency situation the limited temporal coverage of Landsat TM (16 days repeat cycle) and the cloud cover hinders acquisition of images for flood extent analysis.

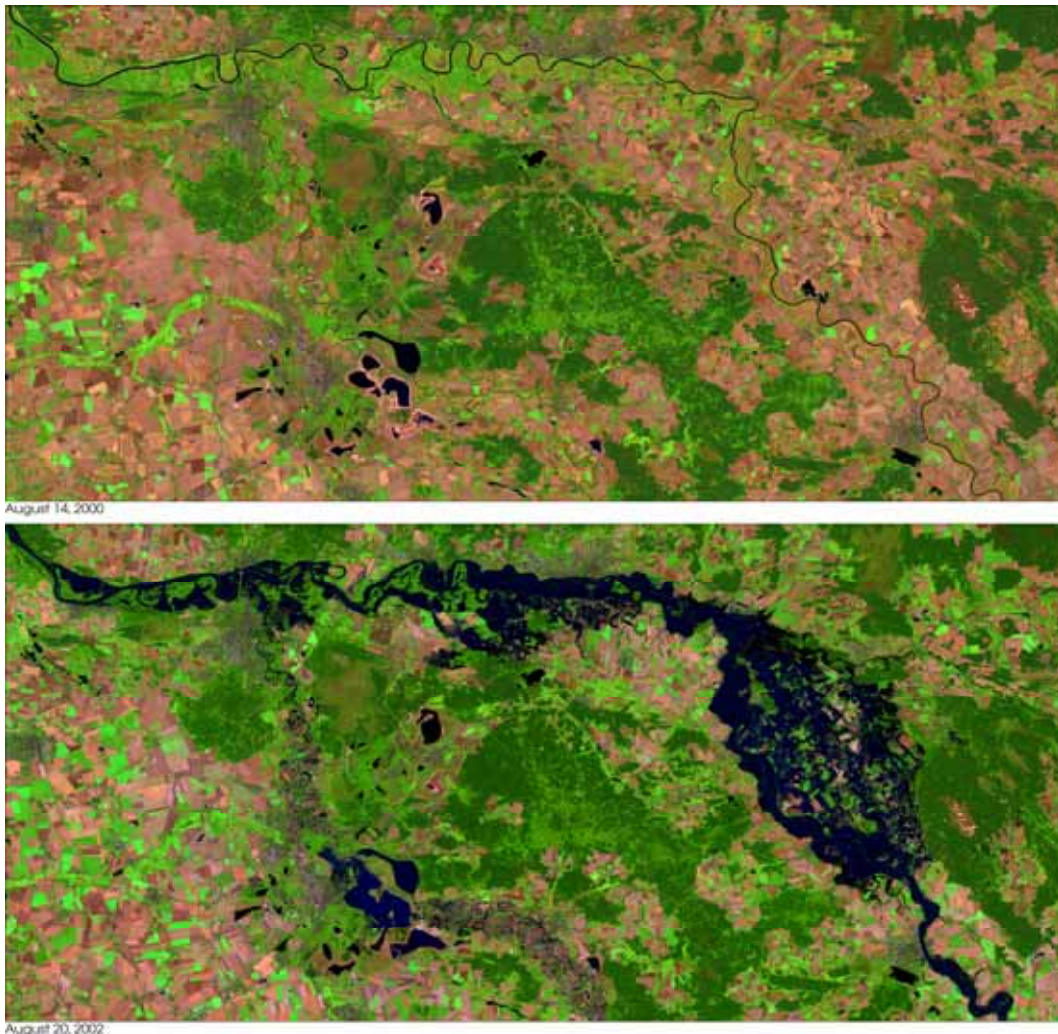


Figure 3-1. Landsat ETM+ false colour composites of the Elbe River before and during a flooding event in August 2002, water in black (NASA, 2003).

Different flooding scenarios can be simulated and illustrated using satellite images together with existing digital elevation models (Figure 3-2).

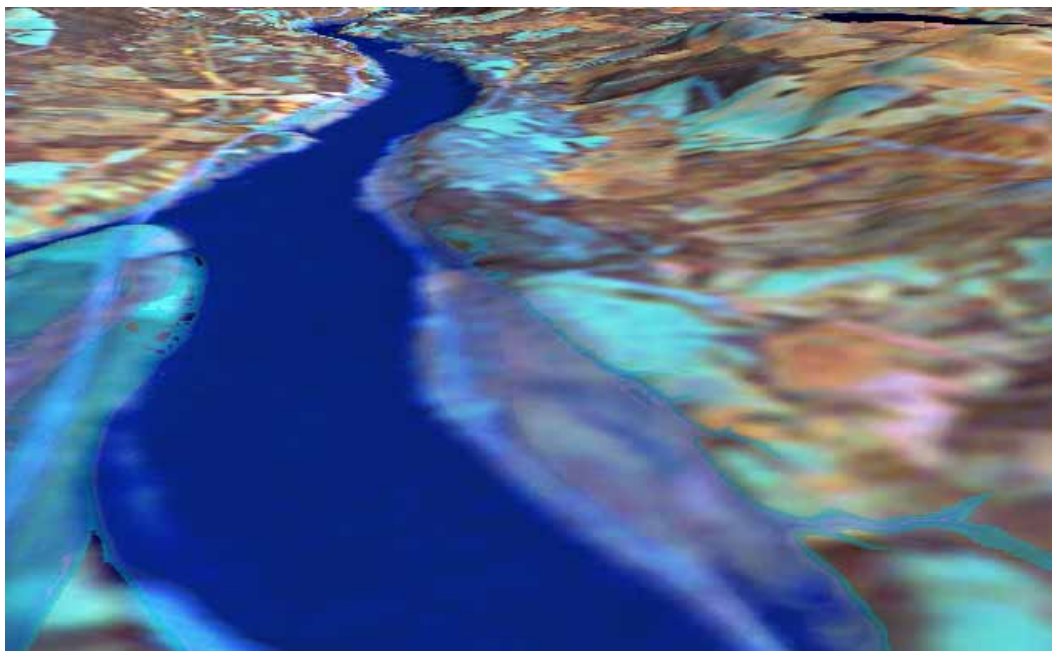


Figure 3-2. Landsat TM composite with simulated flooding (blue) over a part of Lule River draped on a digital elevation model.

A crucial issue for emergency planners is the geometrical resolution and delivery time of satellite information (Figure 3-3). During the crisis phase the emergency planners often work under stress. At this stage a wide geographical coverage is needed with a spatial resolution around 20 metres and a short delivery time (hours). On the other hand, in the post-crisis phase the delivery time is not the critical issue, more central is the availability of very detailed information that can be provided by IKONOS, EROS or QuickBird 2 satellite imagery.

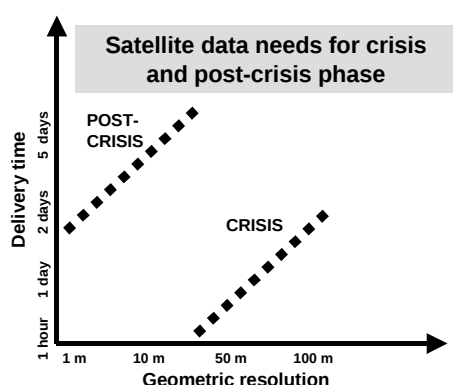


Figure 3-3. Satellite data delivery time versus geometrical resolution regarding needs for the crisis and post-crisis phase (modif. from Gonzales & Matos, 2002).

In August 2002, one of the worst flooding occurred in Europe during 150 years. The IKONOS satellite images in Figure 3-4 shows flooded riverbanks and engulfed trees over Dessau in Germany, during and after the change in water table. This satellite image is suitable for assessing the damage, planning recovery operations and calibrating flood risk maps.



Figure 3-4. European floods 2002, IKONOS 1-meter resolution satellite images over Dessau, Germany. Upper image) During flood, 21 August 2002. Lower image) After flood, 26 August 2002.
(from www.spaceimaging.com/gallery/top10_2002/flood.htm)

Figure 3-5 shows the Moderate-resolution Imaging Spectroradiometer (MODIS) false-colour composites with 250 meter resolution over the Danube River in Eastern Europe before and during a flooding event in April 2002 (NASA, 2003). Over populated and other important risk areas very high-

resolution satellite images (IKONOS, EROS and QuickBird 2) can provide brand new visual information for decision maker and emergency planners (cf. Figure 3-4).

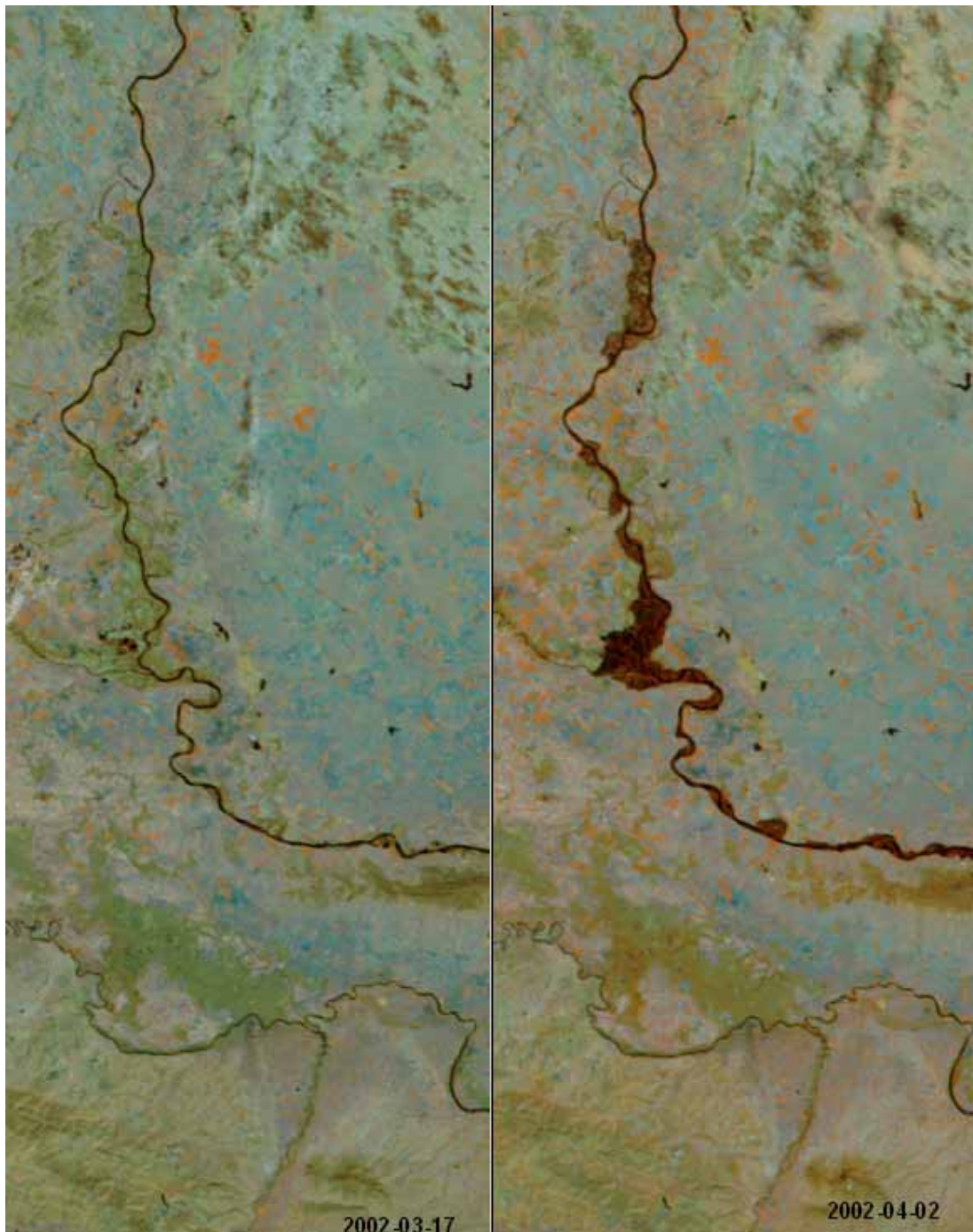


Figure 3-5. MODIS satellite images over Danube River in Eastern Europe. The right image from April 2 2002 shows the worst of a flooding event.
(from <http://earthobservatory.nasa.gov/NaturalHazards>)

3.1.2 Synthetic Aperture Radar (SAR) data

Flooding is relatively easy to map and monitor with satellite SAR data. The main advantage of SAR images is their capability of obtaining information at night and through clouds. SAR is often the only available tool to monitor flood events during bad weather conditions. SAR images can provide flood extent maps and soil moisture data to be used in real time flood prediction and for model calibration. It is convenient to produce flood damage reports from flood extent maps based on radar data combined with land cover information. Rescue efforts and insurance agencies needs detailed information of what areas have been flooded, SAR make that information available.

A multitemporal approach (black and white radar images from different dates are assigned to red, green and blue channels in a colour image) is often used to identify and highlight flooded areas. Figure 3-6 shows an ERS-2 SAR multitemporal image over a flooded area (blue colour tones near the river) north of Prague, Czech Republic.

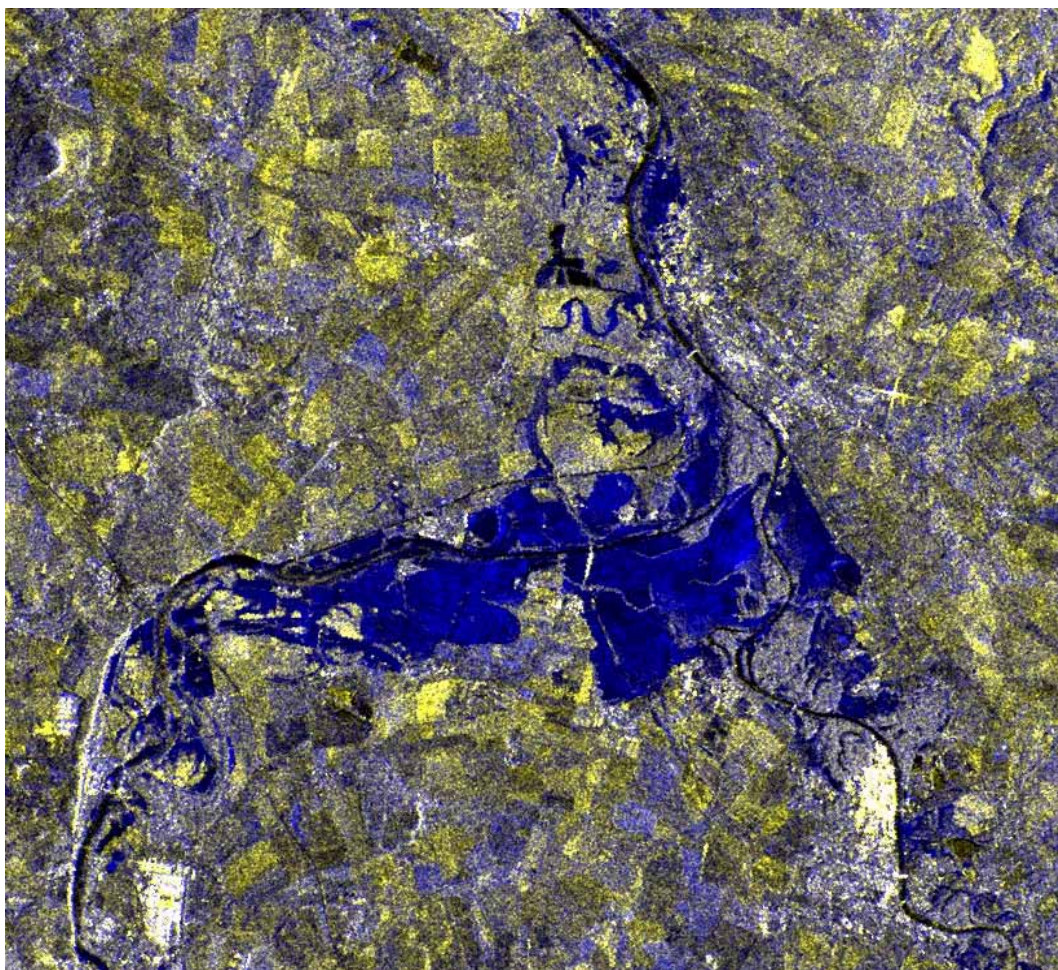


Figure 3-6. ERS-2 SAR multitemporal image, north of Prague. Flooded areas near the river are shown in blue colour tones. The image is based on ERS-2 data acquired 16 August 1998 and 13 August 2002.

(from http://earth.esrin.esa.it/ew/floods/northern_europe_02/)

3.1.3 Light Detection And Ranging (LIDAR) technology

One of the best and most recent techniques to obtain very accurate elevation with cm-dm accuracy is by airborne LIDAR systems. The system emits laser pulses toward the ground and measures the return time - from this the range is calculated. Combined with high precision GPS and orientation information of the aircraft the ground coordinates for each laser pulse can be determined which generates the elevation model. Since LIDAR can penetrate any hole in a canopy, it is possible to provide terrain data in vegetated areas. LIDAR is the only remote sensing method that will do this (Younan et al, 2001). Although in very dense forest it is difficult to penetrate beneath the canopy.

It is often convenient and economically advantageous to complement the LIDAR survey with simultaneously taken aerial photographs. Figure 3-7 shows 2 m elevation curves from LIDAR superimposed on an aerial photograph acquired at the same time.



Figure 3-7. 2 m elevation curves from LIDAR superimposed on a co-registered aerial photograph.

Aerial laser scanning (ALS) can also assist in power line managements by mapping the exact location and height of towers and power lines Figure 3-8.

The 3-D ALS data provides engineers with an improved understanding of the real field situation. Using this data it is also possible to map wire sag. ALS provides a faster survey than a ground based and it also provides detailed

information on the situation in the power line corridor. Obstacles and vegetation along the corridor can be detected. ALS in combination with GIS provides a convenient tool for documentation, updating, planning and analysis.

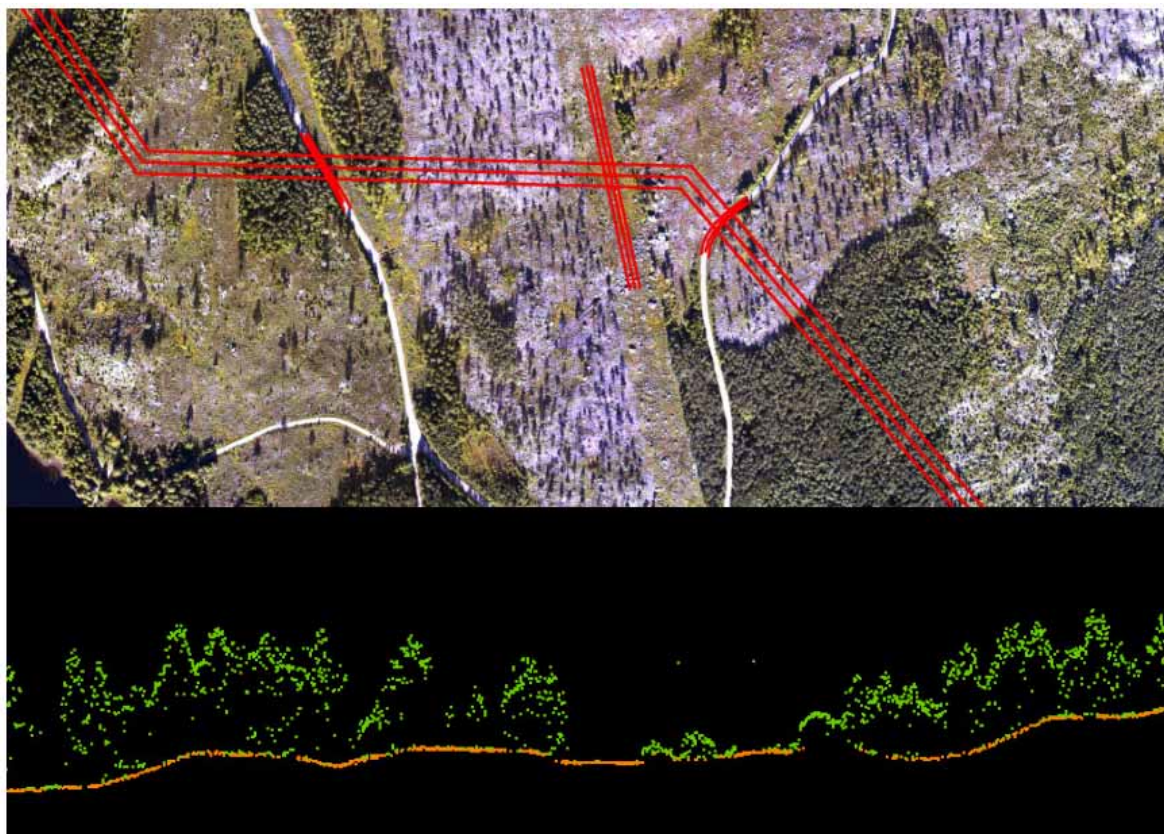


Figure 3-8. Upper) Overhead power lines superimposed on a co-registered aerial photograph. Lower) Laser data showing intersection of classified forest and ground level.

ALS produces data faster and often more cost-effective compared to conventional methods. The information from ALS can be integrated with GIS and used as detailed maps showing asset locations and the exact position of the power lines. Another advantage is the ability to map the actual state of the forest. This leads to a more proactive forest management program that focuses its efforts on where they are necessary and reduce the number of ad hoc work.

Another interesting technique is ground-based LIDAR scanning. With this, terrain models with sub-centimetre accuracy can be created very fast. The system also measures the strength of the laser pulse that is emitted and reflected by the objects, each signal intensity value can be converted into grey-values and generate a LIDAR photograph (Figure 3-9).

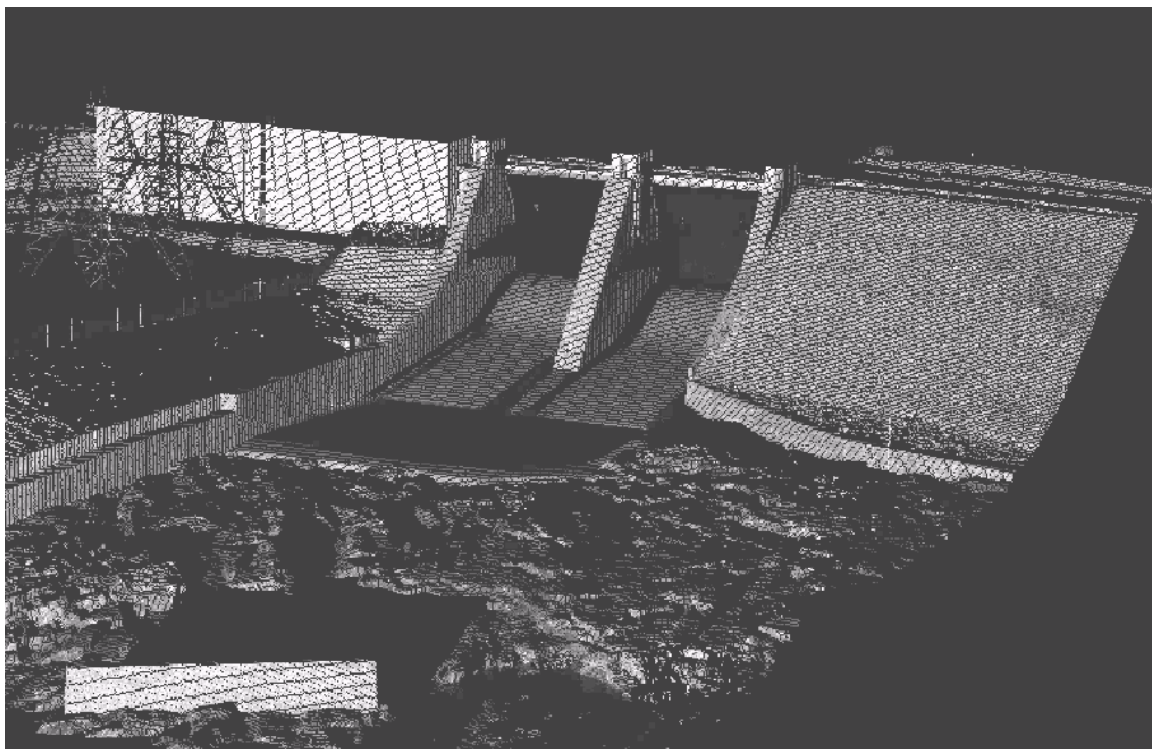


Figure 3-9. Elevation model and LIDAR photo derived from ground-based LIDAR scanning.

Today it is also possible to use airborne LIDAR technology to simultaneously map land (topography) and shallow water (bathymetry). Green laser (532 nm) is used for bathymetry and Near-IR laser (1064 nm) for land. The principle for airborne LIDAR Bathymetry (ALB) is illustrated in Figure 3-10. The major limiting factor for ALB is the water clarity. A rough estimation is penetration throughout the water between 2 – 3 times the Secchi depths (Secchi – a clarity measure, when a standard black and white disc under the water is no longer visible for the human eye).

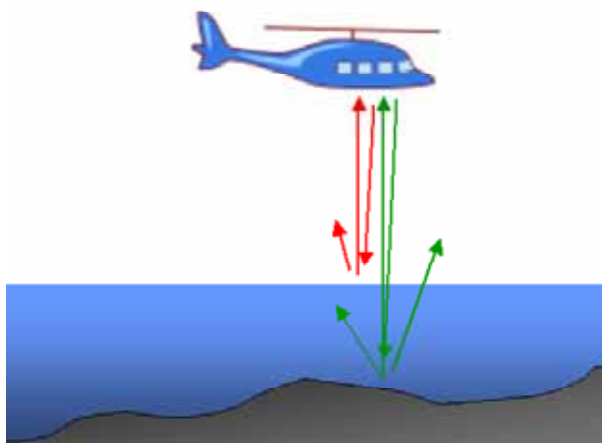


Figure 3-10. Airborne LIDAR Bathymetry (ALB) using green (523 nm) and Near-IR laser (1064 nm) pulses.

3.1.4 Aerial photographs

Aerial photographs are excellent tools for risk management and emergency planning. The photographs contribute with detailed information on the vegetation, land use, roads, bridges, single houses, etc. It is also convenient to produce digital elevation models based on the images. Figure 3-11 shows products based on panchromatic aerial photographs.

Today, the aerial photographs are still the most common background and planning information source, but the last decades the use of high-resolution satellite data has increased a lot. The conventional aerial photographs provide important information base on what happened, the damage extent and in planning when locating vulnerably structures, safe zones, etc.



Figure 3-11. Products based on panchromatic aerial photographs.

3.1.5 Airborne Video systems

Many energy companies use a cost-effective video surveillance and still images from helicopter. The video system collects and stores data automatically for subsequent analysis and evaluation in the office. Manned helicopters with an automatic video system often have these components:

- GPS and GIS
- Video camera
- Still camera
- Thermal sensor

Today many electrical companies routinely examine their overhead transmission and distribution lines by airborne survey. The systems can easily be used in many other applications; it is especially convenient to utilize it on linear features (gas or oil pipeline, rivers, flooding, roads, fences). The images and the derived information can be used for planning, documentation and communication with authorities. Below in Figure 3-12 illustrate a concept on how to use a video system for management of potential floating debris.

Floating debris - identify risk and take action

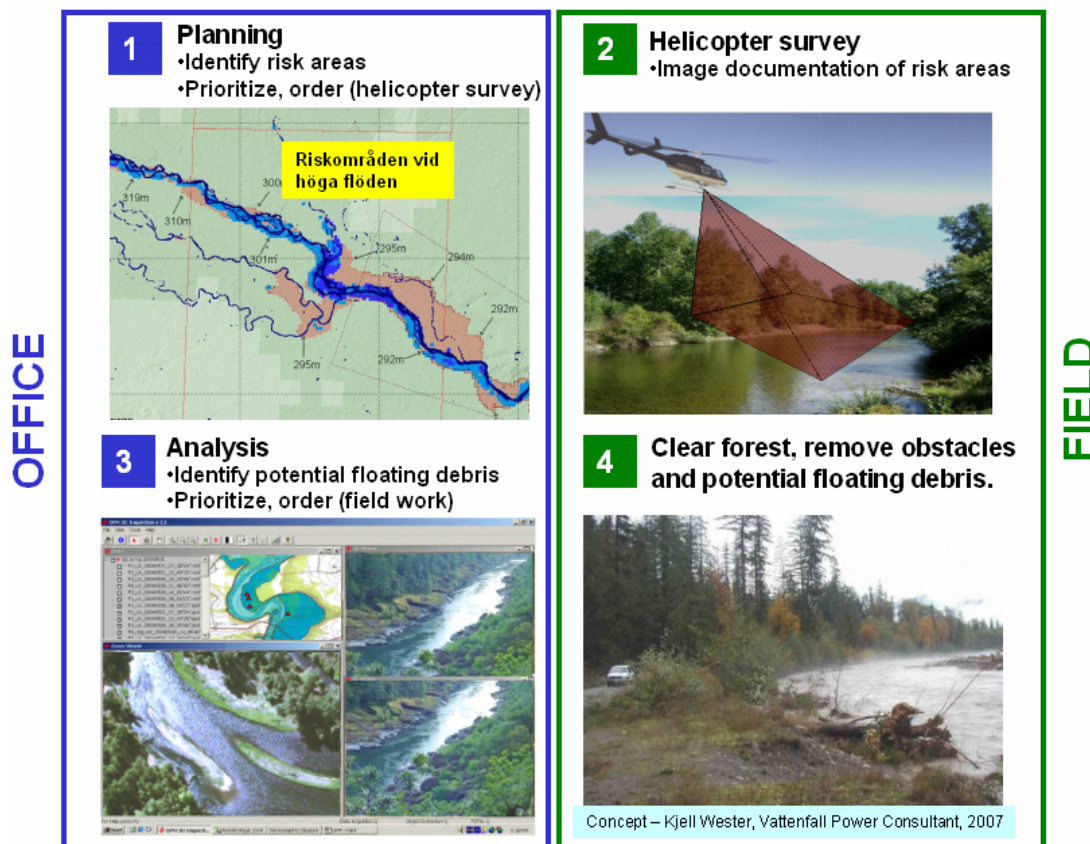


Figure 3-12. Concept for management of floating debris using an airborne Video System.

4 Flood modelling – remote sensing

Flood modelling requires calibration and validation data, boundary conditions, topographic information and hydrological data. Remote sensing data can significantly contribute to flood risk assessment as background information and in the prevention phase with mapping of vegetation and land use.

4.1 Hydraulic modelling

Hydraulic modelling of the river systems, using computers, is a powerful tool in river engineering. Modelling is used for understanding the behaviour of rivers and forecasting the consequences of a dam break or flooding. The value of the results is depending on the quality of the hydrological data, the accuracy of the elevation model and the bathymetry.

4.2 Elevation data

Elevation data is an essential component in flood risk assessment. The elevation data can be obtained from various sources depending on the detail needed for the floodplain and the river channel. A geometric resolution of 5 to 10 meter and a vertical accuracy of 0.5 to 2 meter are sufficient for most regional risk assessment. Elevation data is also needed for determination and delineation of watershed and sub-basin boundaries.

4.3 Satellite based classification

The roughness of the surface will significantly affect the hydraulic modelling result since it controls the overland and the floodplain flow velocity. Using satellite image data vegetation types and land cover can be classified. The land cover can then be converted to Manning's roughness coefficients and used to improve result of the flood modelling. Vegetation cover management is one of the most efficient methods of reducing the consequences of a flooding event (Smith and Ward, 1998). Vegetation cover reduces soil erosion and flooding by detention of rainfall by interception and increased infiltration. Vegetation also reduces the surface runoff by enhanced evaporation and evapotranspiration. One of the most effective land covers to reduce soil erosion is trees. Peak discharges from snowmelt may also increase after forest cutting (Smith and Ward, 1998).

4.2 GIS environment

The modelling result needs to be analysed, presented and visualised. GIS is a convenient tool for this. Centralized access to geographical data benefits workers in the office and in the field. GIS offers a method of quickly accessing information and producing maps. With GIS it is possible to collect, organise, process, analyse, present and visualise geographically referenced information.

5 Flooding, emergency - Related projects and initiatives

ANFAS - Data Fusion for Flood Analysis and Decision Support (homepage: www.ercim.org/anfas/). The overall objective of the project is to develop a simulation and prevention tool to limit flood damage, integrating remote sensing techniques (optical radar, radar interferometry, optical data), GIS and hydraulic modelling. ANFAS was a three-year project January 2000 – December 2002 financed by European Commission IST Programme, the EuroChinese Ministry of Science and Technology, and the World Bank.

CADAM – Concerted Action on Dam Break Modelling (homepage: <http://www.hrwallingford.co.uk/projects/CADAM/CADAM/>). CADAM was a two year project February 1998 – 2000 financed by EU (home: <http://www.hrwallingford.co.uk/projects/CADAM/CADAM/>). Concerted action programme looking at European approaches to dam break modelling, including breach formation, flood propagation, sediment movement and risk analysis.

FLOOD RELIEF – A real-time decision support system integrating hydrological, meteorological and radar technologies. The project is financed by the European Commission under the Fifth Framework Programme. (home: <http://projects.dhi.dk/floodrelief/index2.asp>)

IMPACT - Investigation of Extreme Flood Processes & Uncertainty (homepage: www.samui.co.uk/impact-project/). The project focus on the assessment and reduction of risks from extreme flooding caused by natural events or the failure of dams and flood defence structures. The three-year (December 2001 – November 2004) IMPACT comprises five work packages investigating breach formation, flood propagation, sediment movement, process uncertainty and geophysics/field data. A lot of reports and valuable publications can be accessed from the homepage. The European Commission under the 5th Framework Research Programme funded IMPACT project.

- Pilot Ljusnan - Pilot Project for Development of Emergency Preparedness Planning due to Dam Break (2002-2005). The Swedish power companies through Elforsk AB and the dam safety regulators through Svenska Kraftnät have jointly sponsored this pilot project. Vattenfall Power Consultant (former SwedPower) has been project leader and has developed the necessary system for hydraulic calculations and mapping of flooding. This has required state-of-the-art competence in Geographical Information System (GIS), digital photogrammetry, hydraulic modelling and dam engineering. The aim was to carry out a pilot project including a complete example on EPP, which is to serve as a basis for development of EPP due to dam break. Also, the project includes discussions on responsibilities for emergencies at facilities according to the legislation for Public Safety Management and other dams. The system developed in this pilot project will be used in the future for other rivers in Sweden.
- RESCDAM - Development of rescue actions based on dam-break flood analysis (<http://www.environment.fi/print.asp?contentid=69912&clan=EN>). The main aim of the two-year project (June 1999 – March 2001. was to develop dam safety in terms of dam break analysis, risk analysis and emergency planning. The European Commission, the Finnish Ministry of Agriculture and Forestry, the Finnish Ministry of the Interior, the West Finland Regional Environment Centre and the Finnish Environment Institute, financed the project.
- RIPARIUS - Risk of inundation - planning and response interactive user system (homepage: www.nwl.ac.uk/ih/riparius/). The original objectives of the project were to identify the different approaches to flood risk assessment, encouraging interdisciplinary communication and communication within the EU with aims towards defining best practices and unification of methodologies. RIPARIUS was a two-year project July 1998 – May 2000, financed by the European Commission, Directorate General Information Society Technologies Programme.

Riverside Technology Inc. in Colorado (homepage: www.riverside.com) has developed an interactive flood inundation mapping system (Figure 5-1). The Web-based system use real-time streamflow forecasts and instrumentation, data communications and database management systems, systems integration, geographic information systems (GIS) and remote sensing techniques.

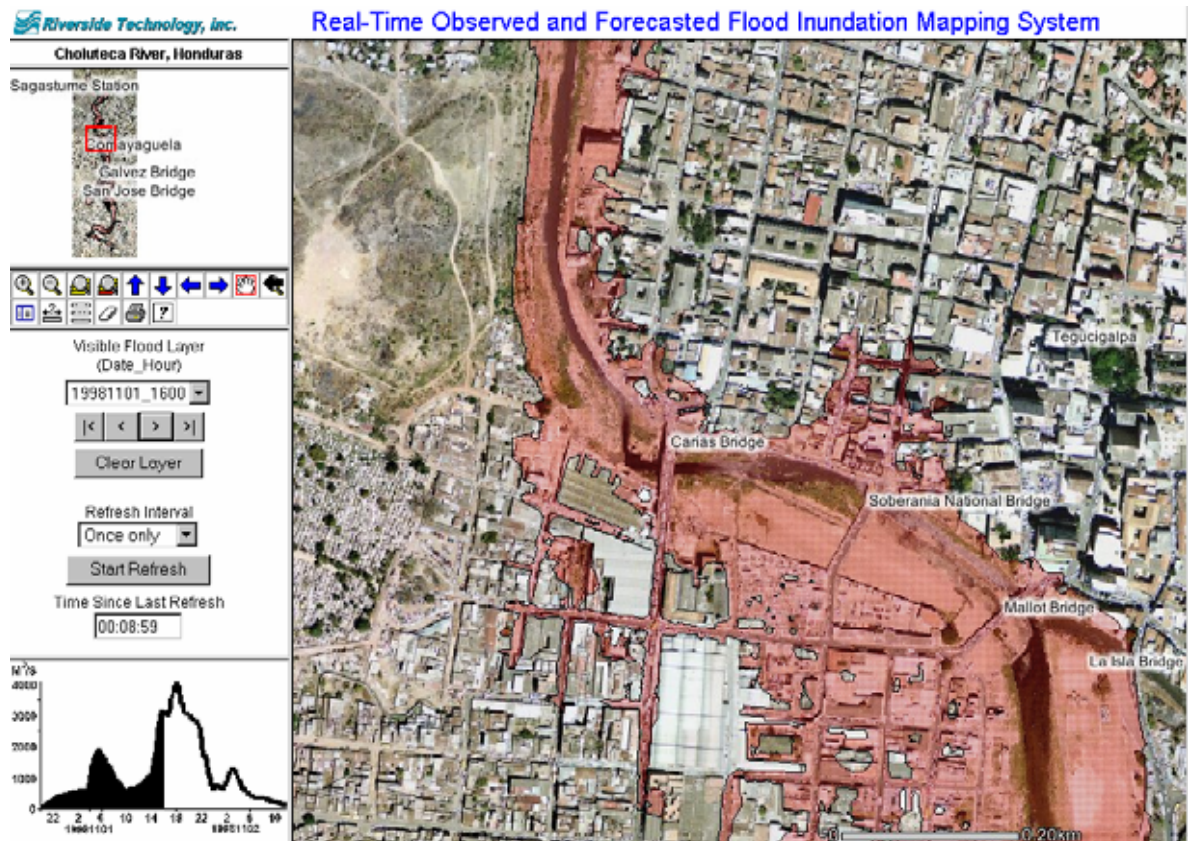


Figure 5-1. Real-time flood inundation mapping system.
(from www.riverside.com)

THMP - The Texas Hazard Mitigation Package (THMP). The THMP is a free web-based GIS data distribution tool (www.thmp.info) aimed for hazard analysis in Texas. State and local hazard mitigation planners and emergency managers in identifying risk areas, natural hazards and vulnerabilities can use the system (Figure 5-2).

The main functions is to:

- Historical hazard occurrences by the event location or summarized by county,

- Hazard risk areas and other detailed geographic data relative to hazards
- Vulnerable population and property value areas to particular hazards
- Download any data to perform detailed quantification of impact on other mapping/GIS systems

Hazards: Weather-related

Hurricanes & Tropical Storms
Tornadoes
Floods
Other Storms
Outdoor fires
Extreme Temperatures
Coastal Erosion

Hazards: Non Weather-related

Earthquakes
Hazardous Materials
Subsidence

As background data THMP use following base maps:

- Administrative Boundaries
- Transportation
- Hydrography
- Landscape
- Weather-base data

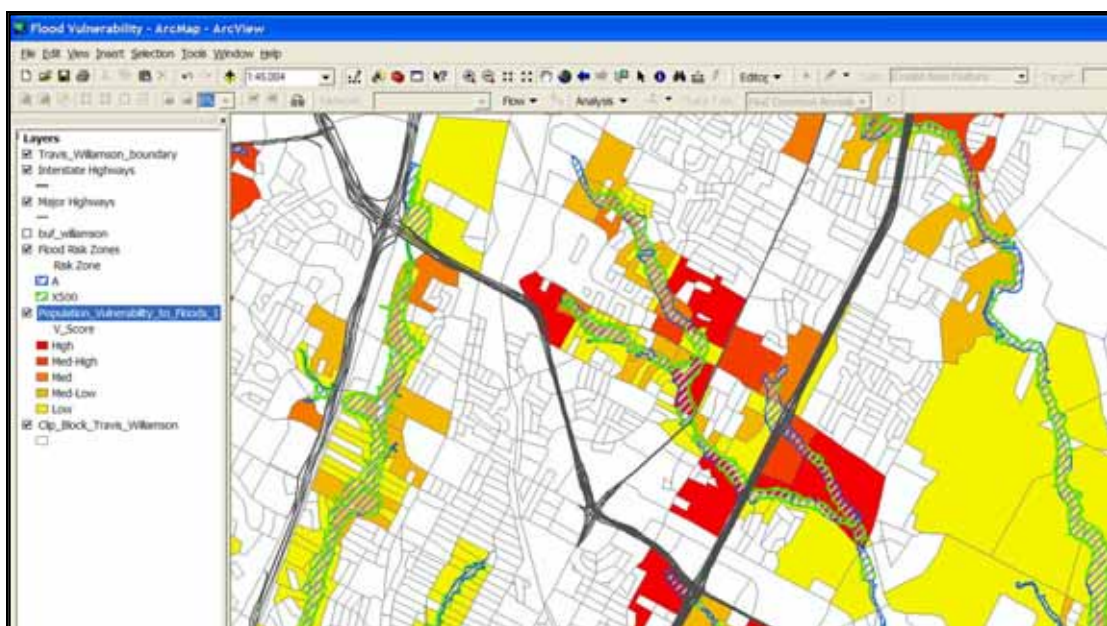


Figure 5-2. Map showing population vulnerability to floods (from THMP).

5.1 Internet solutions – Global perspective

One of the most promising global Internet solutions is the MODIS Rapid Response System. The main aim of the MODIS system is to supply daily satellite images of the Earth's landmasses in near real time (Figure 5-3). The emphasis is on MODIS satellite data with 250 m resolution in colour.

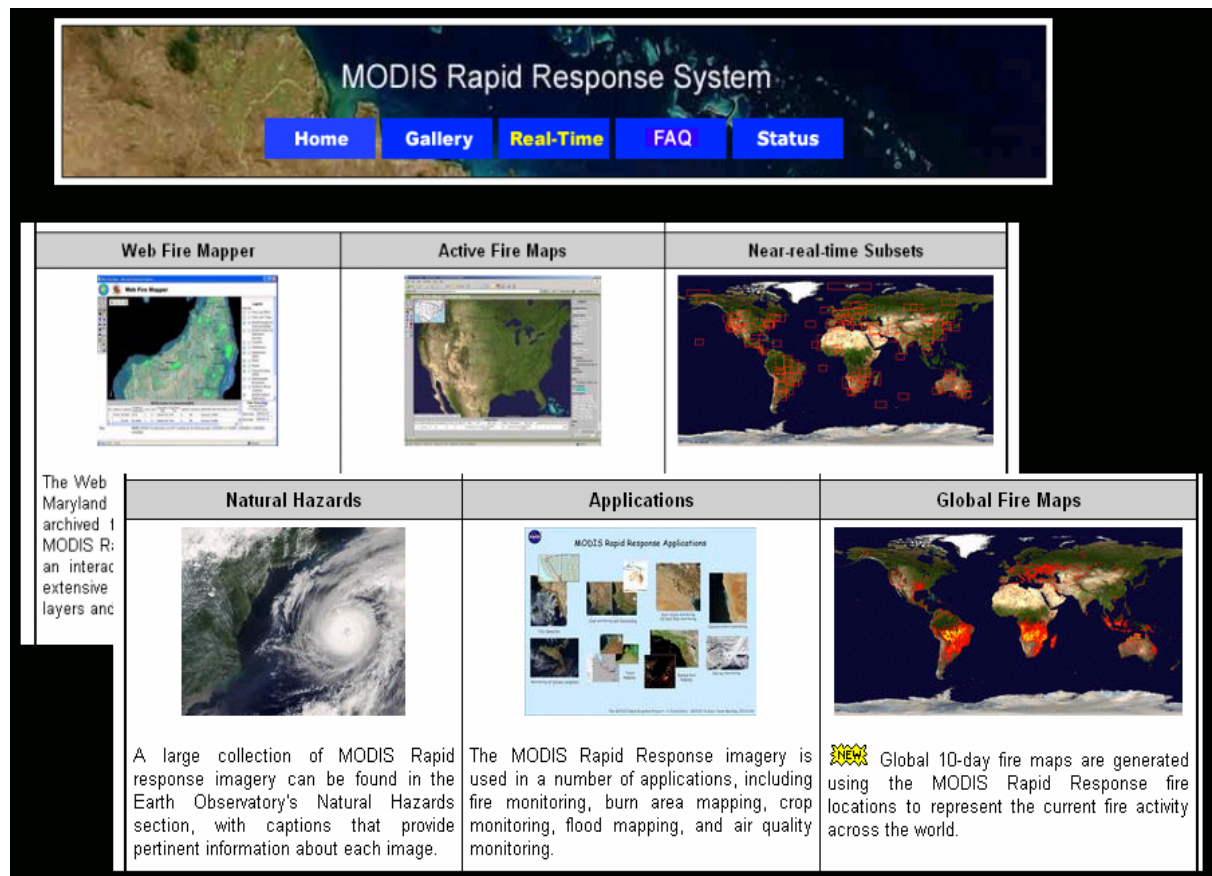


Figure 5-3. MODIS Rapid Response System with free access to MODIS satellite images in near real-time and image galleries for different applications (<http://rapidfire.sci.gsfc.nasa.gov/>).

Another promising site (<http://www.dartmouth.edu/%7efloods/>), focused on flooding, is hosted and developed at the Dartmouth Flood Observatory (Figure 5-4 and Figure 5-5).

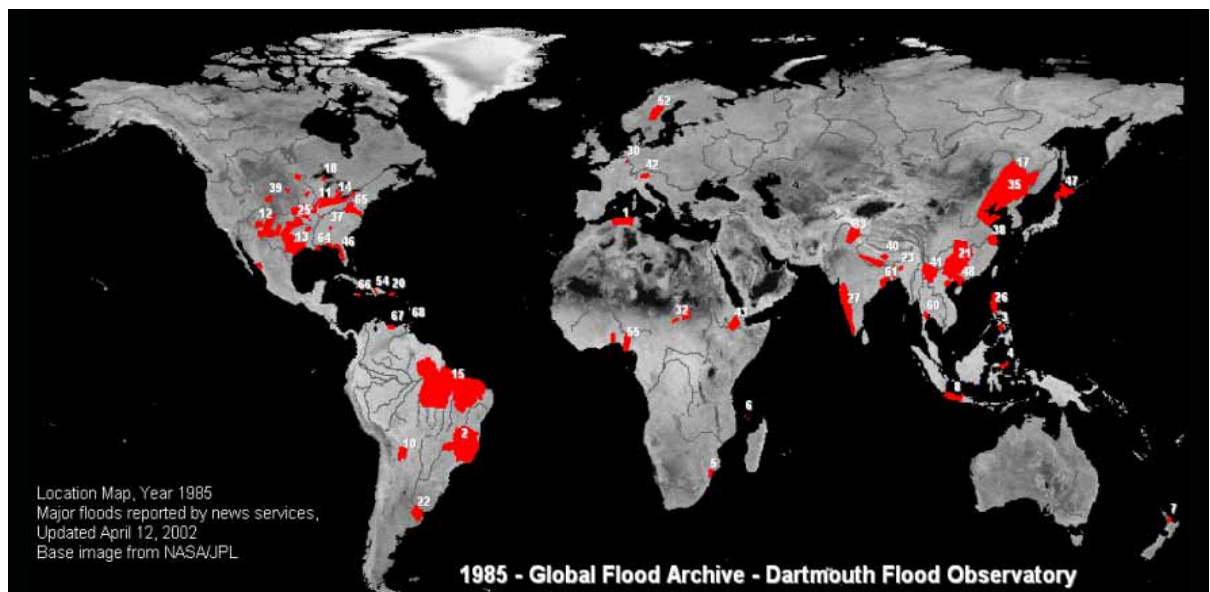


Figure 5-4. Global Flood Archive developed by the Dartmond Flood Observatory.

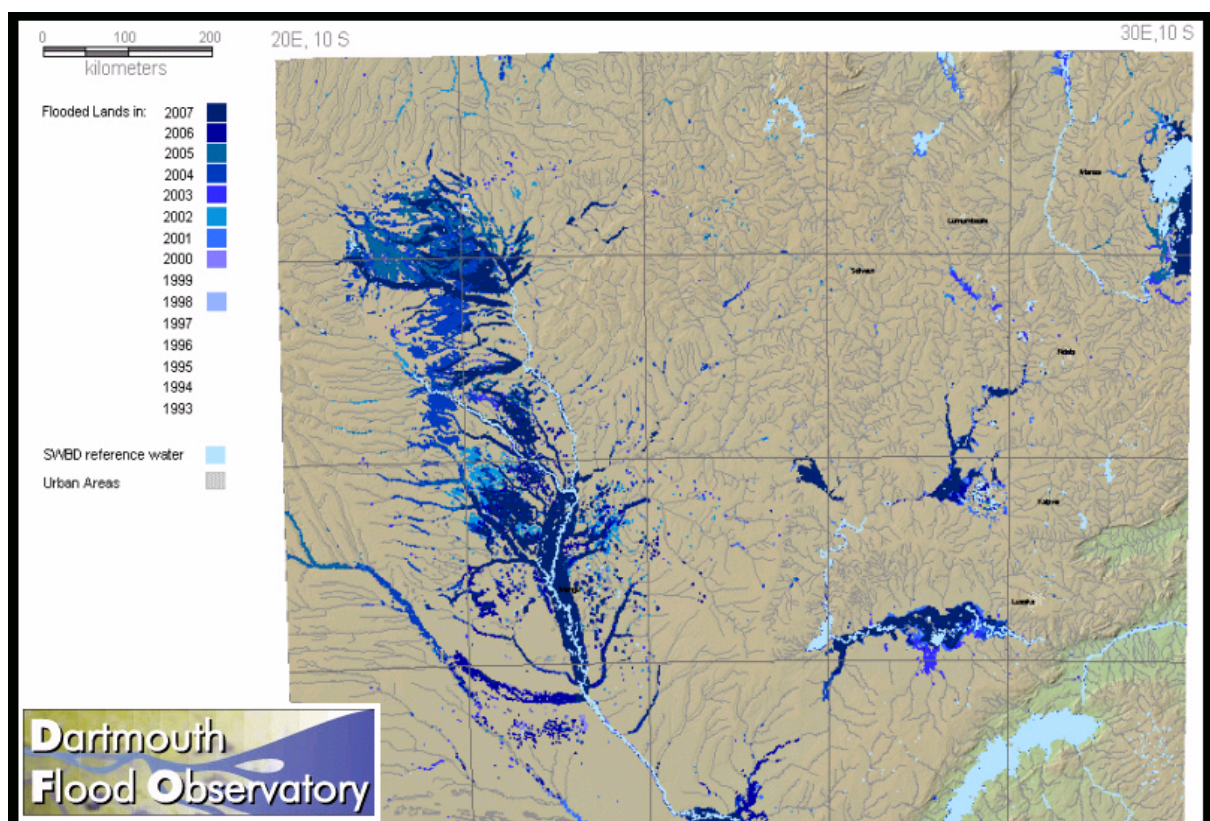


Figure 5-5. Detail over flooded area, from the Global Flood Archive (see Figure 5-4).

The NASA Earth Observatory have created an Internet site (Figure 5-6) showing natural hazards (<http://earthobservatory.nasa.gov/NaturalHazards>).

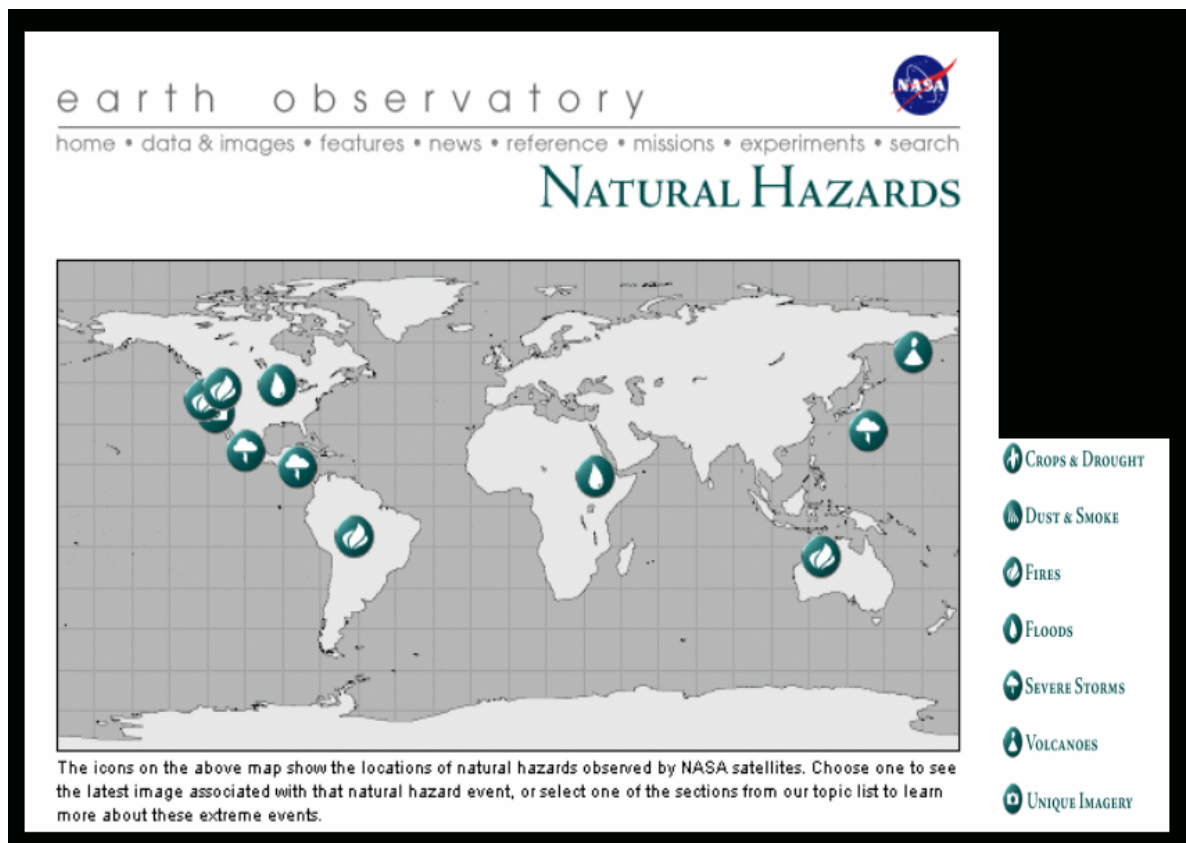


Figure 5-6. NASA Internet site for natural hazards.
(from <http://earthobservatory.nasa.gov/NaturalHazards>)

6 Discussion

High quality and up-to-date information is essential for dam safety, risk assessment, consequence analysis, inundation mapping, emergency planning, etc. Today, available maps are often too old, and do not reflect the existing situation. In addition, they are not produced with emergency planning and dam safety in mind.

The last five years, very high resolution satellite imagery together with other digital geographically based data have modernized and improved the way disaster relief and emergency relief groups make decisions before, during and after natural and man-made disasters. Optical high-resolution satellite images in a GIS system can provide cartographic background information to planners and decision makers.

The contribution of satellite data for inundation mapping can be divided into two main fields:

- Provide cartographic background information to the planners and decision makers with up-to-date images and land cover mapping.
- Provide information about the watershed vegetation cover, land use, soil moisture, topography, etc to hydraulic modelling or parameter tuning.

The modern flood risk management approach are often based on satellite images, GPS, digital elevation models, hydraulic modelling integrated in a GIS.

The major trends are:

- Increased importance of detailed satellite imagery, aerial photographs, laser, radar.
- Demand for up-to-date maps with high quality.
- Application of new field based technologies.
- Increased importance for 3-D data.
- Techniques for conversion and updating of data.

Flooding is relatively easy to map and monitor with satellite SAR data. The main advantage of SAR images is their capability of obtaining information at night and through clouds. SAR is often the only available tool to monitor flood events during bad weather conditions.

One of the best and most recent techniques to obtain very accurate elevation data with cm-dm accuracy is by airborne LIDAR systems. Since LIDAR can penetrate any hole in a canopy, it is possible to provide terrain data in vegetated areas. LIDAR is the only remote sensing method that will do this.

It is often convenient and economically advantageous to complement the LIDAR survey with simultaneously taken aerial photographs. Today it is also possible to use airborne LIDAR technology to simultaneously map land (topography) and shallow water (bathymetry).

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