DYNAMICS OF GEO-INFORMATICS TO SUPPORT FLOOD MANAGEMENT : experiences in the Netherlands

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ABSTRACT

 upport to flood management as experienced in the Netherlands is both a matter of building up of knowledge, expertise and experience in a long historical context, and, more recently a matter of response to flood (risk) circumstances requiring the support of advanced geo-spatial information technology for adequate and dynamic decision making in case of a (possible) disaster event, managerial and operational. The two matters are explained in detail in this contribution.

Keywords: *disaster management / evacuation / geo-SDSS / information technology / flooding / safety cycle / spatial planning*

ABBREVIATIONS AND NOMENCLATURE

EC/EU, the European Commission as decision making body for the European Union, the current 27 member states; DSS, decision support system; GIS, geographical information systems; IPCC, the international panel of climate change; IRMA, a special EC/EU interregional program of Initiatives with regard to the Rhine and Maas rivers, running from 1996 towards 2004; MDG, Millennium Development Goal; PoldEvac, a project under IRMA which produced a geo-spatial flood and evacuation information and decision support system, trans-nationally, cross-bordering applied to parts of the Netherlands and Germany, from 1997 until 2004 (after 2004, the project has been continued, partly adapted, under different names).

1. INTRODUCTION

The Netherlands is probably the country in the world with the most and extending best practices regarding water management and flood risk protection. It has a past performance of about 2000 years, fighting the sea and the country's at that time extremely dangerous sea arms and inner lakes. This is basic to its current excellence in water knowledge, expertise and worldwide experiences.

Nevertheless, the building up of such knowledge, expertise and experience was and still is a learning process, inside the Netherlands and globally in cooperation with many countries, their decision makers and their water scientists and professionals. That building-up is subject of and related to developments in nature and in society. This includes the reasoning forwarded through United Nation's MDGs (Millennium Development Goals) as a response of decision makers, scientists and professionals. In 'recent' years particularly, efforts of the IPCC (1991, 1992, 2007) are of relatively great importance to understand why globally (and trickled down to locally) the attention paid to flood disaster protection and mitigation is growing on high speed. A wide spreading computerization in and since the eighties of the last century is accompanied by applications to support decision making in various fields. This is true in disaster management and particularly true in flood disaster management. Computerization in flood disaster management in the Netherlands showed a dynamic development in geo-informatics applied to scientific, learning, professional and political information collection and dissemination.
In various Dutch organizations, particularly in universities, already many years ago (Nijkamp 1991), initiatives have been undertaken to investigate the meaning and effects of flooding as a consequence of IPCC forecasted sea water level rise. Two other initiatives have been taken by the Dutch Ministry of Water Management some years later. In 1986/'87, the first, internally, created a simple software system called Disaster ('Ramp'), and the second, externally, submitted to Compuplan Institute in 1989, requested a prototype for flooding and evacuation in a polder area subdivided by compartments.

It would take again some years more, after the 1993 and 1995 (almost-) flooding caused by the huge European Rhine and Maas rivers in the Netherlands and a few other European countries, before a large and comprehensive geo-informatics project, called 'PoldEvac', was organized, co-financed and executed in the course of 1996 until 2004.

Later, due to other catastrophes in the Netherlands, the government decided to provide information regarding hazard and vulnerability risks of a possible disaster threat, relevant to professionals and citizens. This kind of information is primarily geo-spatial, and therefore it is published as safety maps (Hoogewoning 2006; MoI 2007) through the internet and governmental websites. In the meantime, the provision of (flood) safety maps is an obligation in all EU member states according to a High Water directive of the European Commission, ready in 2013, to be followed by flood disaster plans which should be published before 2015. Therefore, in the following, after a few definitions, linked to history, attention will be paid to:

- Flood problems in the Netherlands, faced, recognized and acknowledged, placed in a historical context, explaining the process of knowledge building and sharing, with a Dutch global excellence regarding expertise and experience in water management
- Dutch water expertise and experienced anchored in water knowledge institutes and in operational water boards
- Relevance and framework of the European Union (EU) regarding water and flood protection as a response to serious flood experiences along Rhine and Maas rivers in Europe (1993, 1995)
- Safety cycle as a steering principle in Dutch disaster management
- Geo-informatics for flood disaster decision making, managerial and operational as well
- PoldEvac, development and applications through geo-informatics, a system on flood and evacuation management; concept and software are produced through Compuplan Institute
- Awareness that flood and flood risk are strongly connected with human land use planning and occupancies, leading towards a new policy to give back space (room) to the river, simultaneously an evaluation relevant for understanding that flood problems cannot be solved through technological interventions (alone)
- Safety mapping as source of (flood) disaster information provision and dissemination
- New circumstances, a new Dutch delta policy, Delta Law II, Delta River Plan
- Public awareness, as an effective tool to prevent against and to reduce risks of floods and flooding

Next, a discussion follows on opportunities, advantages, considerations about integration of various disaster relevant tools, and sustainable chances of geo-spatial information and decision support system application to protect against and to reduce of flood (risks). The contribution is completed with some conclusions.

2. MATERIALS AND METHODS

2.1 Definitions

Disaster: a serious disturbance of the general safety, by which life and health of many people, and/or material interests, is under direct risk, and for which a coordinated effort of departments, services, and organizations of various disciplines are required (Dutch Law on Disasters).

Geo-SDSS: geo-spatial decision support system, is a software system, generally conceptualized as a computer aided approach for specific application purposes to provide decision makers with adequate (geo-spatial) information.

2.2 Flood problems in the Netherlands, in historical perspective

A long historical period can be subdivided along a line of dramatic floods and/or flood protection measures and activities. Although the start should be earlier, for our understanding of Dutch flood experiences, the beginning of the middle ages is a reasonable choice.

- **500 - 1500 (A.D.):** The territorial situation prior and during the middle ages, roughly indicated as 500 – 1000 A.D. is a mix of swampy islands and lakes, while probably only a quarter of the current Netherlands was above average sea level. People protected itself against the floods through the construction of e.g., mounds and used (temporarily existing) ridges and dunes. A lot of protection works has been executed by monks from the various monasteries spread across the country.

- **1500 - 1900:** Water management becomes mature. The construction of dikes is accompanied by the creation of polders (defined as inner lands under average sea level), where the water conditions and particular the water level within the polders are controlled and kept in good order. Keeping the water level inside a polder is handled with the aid of wind mills and later-on by hydraulic pumping stations as well. Dangerous lakes are reclaimed and impoldered, and consequently the Netherlands counted increasingly more polder areas. To control the water levels in these polders, special (semi-)governmental bodies came to the fore, called 'hoogheemraadschap', later-on called Water Boards. Originally, the water boards have been created by inhabitants, particularly farmers and land owners, who ruled the control and took more and more water related responsibilities.

- **1900 - 1950:** A large inner sea, connected with the adjacent North Sea, called the 'Zuiderzee' (Southern Sea), caused frequently serious (flash) floods and storm surges. After long technical, scientific and political discussions, accompanied by voluminous studies, the Dutch central government decided to close this inner sea with a barrier dam. As a result the so-called 'Ijsselmeer' (Ijssel Lake). The Netherlands continued inside this lake its re-claiming efforts and impolderd in the course of the time the Northeast polder and Flevoland polder.

- **1950 - 1990:** Shortly after 1950, in 1953, the Netherlands faced a kind of tsunami along its southwestern coast in the Zeeland Province. The province is built-up of islands and peninsulas which are separated by sea branches, with strong tidal forces. The outcome of the flood event was many death, many injured, substantial loss of

land, properties, cattle and infrastructure. That year 1953 is a milestone in the further Dutch experience and building up of water management expertise.

Figure 1: Map of completed Delta Works (I) source Wikipedia, Compatible Licenses

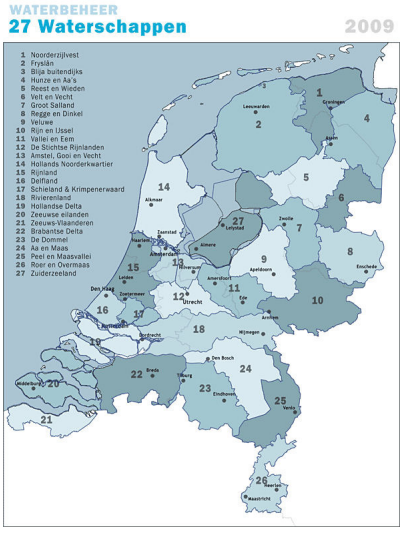

Figure 2: Overview of the current Water Boards in the Netherlands, source Wikipedia, Compatible Licenses

As a result a Delta Law (I) launched huge and radical Delta Works. Finally, these Delta Works closed the majority of the sea branches in the Zeeland Province, except of the Wester Scheldt sea branch which is the outlet of the Belgium Scheldt river and the North sea connection for the Antwerp harbour. Finally, after 50 years, in1997, the works are completed with barrier dams, dikes and a huge, most impressive storm surge barrier dam, built-up by a series of pilar structures and hydraulic devices for water discharge from the hinterlands, and the Maeslantkering.

In this period, a next impoldering in the Ijssel Lake has been considered, called Markerwaard polder, which would simultaneously be seen relevant for the erection of a new airport (to replace or to support the Amsterdam Schiphol airport). Too many societal forces protested, too many negative environmental and ecological expectations came to the fore, scientists produced many critical reports, and with success. The Markerwaard is split from the Ijssel Lake with the aid of a dike dividing the Ijssel Lake mid way. Anyway, the Markerwaard is still a lake.

Although the Dutch government and its Ministry of Water Management in particular spent so much effort, energy, time and attention to the risks from sea water side and land reclaiming efforts, remarkably this period shows a relatively absent attention paid to possible floods caused by rivers, to possible weak quality of the river dikes and to safety of the people, cattle, properties and infrastructure in the adjacent polder areas.

- **1990 - 2005:** In this period a next milestone is set. Major rivers in Europe caused serious floods and where flooding finally did not occur, the risks of floods have anyway been extremely high. The majority of countries along Rhine/Waal and Maas rivers faced flooding in 1993 and 1995. Particularly the February 1995 high water in the

Rhine/Waal river and the accompanying weather conditions necessitated decision makers to expect a dramatic flood disaster in the Dutch polders adjacent to the German border, notably the Greater Maas & Waal polder and the Ooij polder, as a coming reality. Therefore they decided to launch a mass evacuation, of about 250,000 inhabitants, and substantial amounts of cattle and movable properties.
Finally, luckily, flooding of the two polders did not occur and, consequently, people, cattle and other removed issues are returned home in the polders.

Nevertheless, once flooding did not occur, automatically it triggers demands of evaluation of the decision making process, etc. One of the outcomes was the standpoint of the mayors, who are the major decision makers in the crisis team together with the operational decision makers such as regional fire brigade commander, indicating that they had made a choice, acceptable under the risky circumstances, however based on insufficient and more or less absent geo-spatial connected information. They had so to say no sight upon the territorial consequences of that threatening flooding and they had no knowledge about how much time they could wait until the launching of the evacuation intervention. Furthermore, specific data concerning (vulnerable) people in extra risk (elderly, hospitals), required time for the evacuation performance (transportation speed, traffic congestion, accidents to be expected blocking certain evacuation routes), and hazardous, chemical substances stored on land plots and in buildings located in the polder areas (particularly so-called Soweto II extra dangerous substances).

As a result, rivers, river dikes and safety behind these dikes gain rather quickly and durable a huge attention. Furthermore, extensive studies are executed, and substantial development of geo-spatial information and decision support systems for flood management has been initiated, elaborated and trans-nationally applied with the aid of the PoldEvac system (see hereafter the section PoldEvac).

- **2005 - today:** This current stage shows a renewed fast increasing attention for sea flood risks, studying weak spots in the sea barriers, considering consequences of IPCC research efforts and outcomes regarding climate change. Consequently, the Dutch national government decided the compilation and production of a new dedicated law, notably the second Delta Law (II).
  Efforts in line with the PoldEvac system have been continued and extended in various ways: flood films are produced for more municipalities in the Gelderland Province (Viking project), also other provinces are executing flood film simulations, at national level the national flood information system (HIS) is intensified although as an aggregated approach, transnational efforts are mainly directed towards a system that primarily focuses upon communication between disaster management and operational staff (Fliwas). It is, moreover, a period in which huge exercises are planned and executed, followed by extensive evaluation research. This research meant to study what did go wrong during the exercises and why, with the purpose to improve next exercises and, moreover, to be better prepared in case of real flood problems.

  Public risk information is provided through the internet. Provincial websites show safety maps, amongst others regarding flood risks. It is, to complete this historical overview, also a period facing another serious water and therewith flooding problem, notably more frequent, more intensive, more serious rainstorms (probably as a consequence of climate change).

The Netherlands is situated behind dunes, dikes and barriers, it is a country for two-thirds below sea level, centuries already fighting against water from the sea and from large rivers within its delta area. Consequently the Netherlands has gained an enormous expertise and experience, to fight against high water, to create and construct protection barriers and artifacts, and to cooperate with water for trading, economy, environment, traffic and potable water production. (Flood) disaster management is (theoretically) executed according to the Safety Cycle approach.

2.3 Dutch water institutes and operational water boards

It is therefore understandable that in the course of the time, several water knowledge institutes have been created, e.g. Coastal Zone Management (CZM, Ministry of Water Management), Delft Hydraulics (WL), Deltares, UNESCO-IHE, Applied Scientific Research Institute (TNO), university institutes, and recently IMARES and others (for coastal ecology).

During the history, as mentioned already, initiatives through farmers in particular, several water boards have been established, connected to polder and coastal areas. They took the responsibilities and decision making regarding water level maintenance, water purification, keeping polder dikes in good order, etc. These boards developed into governmental agencies with the operational duties as their task, while political decision making was a matter of central and provincial authorities. Currently (since 2009), the Netherlands counts 27 Water Boards, nowadays as much as possible connected with the distinguished watershed areas. The Water Boards consist of an executive Board and an elected water board 'parliament'. The latter one controls the executive and financial workings of the Boards and their staffs.

2.4 European policy and decision making on flood protection

Flood disaster management is increasingly a matter of attention everywhere in the world, getting attention from international bodies as United Nations (UNCED, Agenda 21), International Panel on Climatic Change, Kyoto Summit on reducing CO2 to avoid further greenhouse effects such as sea level raise.

In Europe, following the 1993 and especially the 1995 floods caused by the major European rivers Maas and Rhine (/Waal), and later-on in 2000 by the Elbe river, serious and extensive attention has been and will be paid to prevention and mitigation of flooding of European territories adjacent to those major rivers. This is particularly true for cross-bordering rivers.

During the time, experiencing the floods, it became obvious that policy making on country level, on European level and on a (combined) level would be the only solution to achieve sustainable improvements and results, protecting people, (cattle) animals, infrastructure, properties and economic functions. The European Commission formulated an umbrella framework report with directives applicable to the whole union's territory, addressed the watershed areas within the European Union's extent, published directives on flood reduction and water quality, and initiated large-scale projects (with the necessary co-financial resources) through interregional co-operations between European member state countries. One of these European countries is since human memory in 'water business', i.e. the Netherlands.

2.5 Safety cycle

An obvious result of the evaluation of decision making during the 1995 flooding emphatically shows that decision makers, population and stakeholders need extensive information, particularly geo-spatial information on flooding and evacuation. Provision of that information can be streamlined through a geo-spatial decision support system, integrated in the so-called Safety Cycle approach. This fits in the overall Dutch national government's efforts of sophisticated disaster management. The cycle consists of: (1) ***Pro-action*** [Learning and avoid, Delta Law I and II, Geo-SDSS for flood protection and mitigation, managerial and operational as well, Spatial plan design (and enforcement), Development of disaster plan, Land use planning to redirect land use and to reduce risks, Development of disaster fighting plans safety map productions (internet/website accessible)], (2) ***Prevention*** [Planning and measurements preparation: information available to be prepared concerning simulation, outcomes, training, equipment, information ready for activation, Improvement of dykes and storm flood barriers, Improvement of road network, partly available as compartment support, Development and/or implementation of an adequate communication system, both hardware, software and humanware, Where applicable execution of readjustment or swap of land occupancies where required, Move of vulnerable objects out of the risk zones, Establishment of evacuation routes,], (3) ***Preparation*** [Training (large scale), Awareness raising, Tools availability and (re-)check, Fixation of evacuation routing with indication labels, Safe spots development (e.g., mounds), Mapping and provision of geo-information to crisis team and decision makers], (4) ***Repression, response*** [People, data, equipment, etc. in good order can be applied, system simulation adaptations, Activation of crisis team for decision making, (flood) disaster fighting, Evacuation, Continuation workings in the polder area, e.g., pumping for drainage and keeping the water level stable in not yet inundated polder, Disconnection of sewage system, Handling of hazardous, chemical substances, Removal of special groups of inhabitants, Removal of cattle and other, Adaptation of geo-information through re-consideration and re-simulation efforts, based upon more recent and more accurate disaster event data], and, (5) ***After care, recovery, reconstruction*** [information who is where and return to pro-action, Repatriation of inhabitants back to their houses in the polder area, Return handlings of cattle and other, Evaluation of the flood disaster, Decision making to improve flood disaster management, Execution of related research, Back to business as usual (and to pro-action stage)].

2.6 geo-Informatics for flood decision making

The development of advanced geo-information technological, computer aided, systems has a relatively short history. It is from professional and scientific standpoint relevant to consider preparatory initiatives and (prototype, conceptual) prior to the two serious European / Dutch flooding events.

2.6.1 Knowledge development prior to river flood circumstances 1993/1995

Efforts on information provisions to decision makers, professionals and general public have a history, going through initial steps, prototyping and real-world applications (van der Meulen, 1995). The reasoning to consider scientific and professional preference for a comprehensive and integrated, also interactive and website accessible, system relates to concept developments during time. That process includes (organization: research and software development, years):

- UNDRO (1991): software prototype contributions to the training and information handbook on disasters for the UN Disaster Decade (1987-‘88)

- UNESCO-IHP: contribution to two coastal zone management conferences, Hamburg, Bangkok (1989-‘91)

Aware of the above explained prototypes and concept developments, the Advisory Committee to the Dutch Minister of Traffic and Water Management requested Compuplan Institute to develop a prototype geo-SDSS software program in which flooding of a fictitious polder area with several compartments is handled (1989/’90). The prototype is called “DamSim”, damage simulator.

Conceptually, DamSim shows, simultaneously, a flooding process and en evacuation process. Visualized on the computer screen, at the right hand side, the polder area is displayed with the aid of height contour lines and is subdivided into compartments. Compartment boundaries are (elevated) roads and evacuation road network as well. Evacuation from the compartment areas occurs through movements to the road junctions. At the left hand side, the polder area is built up with pixels, representing average amounts of objects to be evacuated, e.g., inhabitants or cattle.

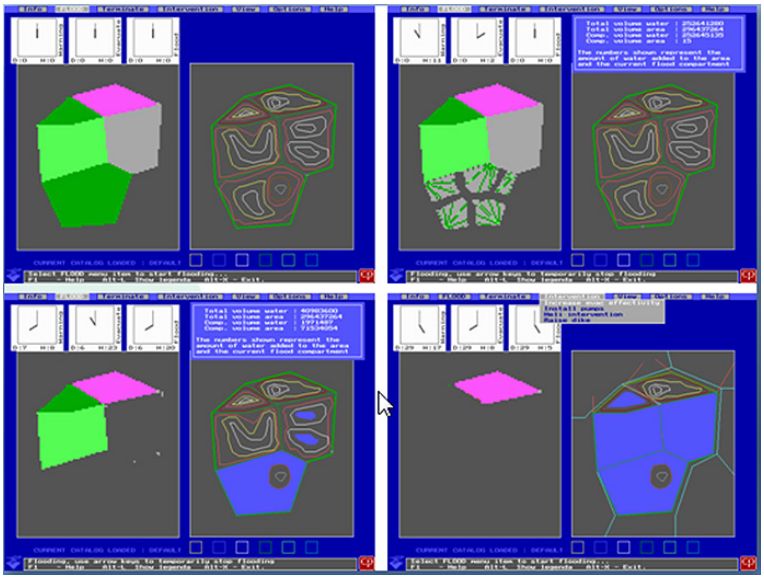

Figure 3: Examples of the progress of flooding (left sides) in combination with (preventive) evacuation of objects (e.g., inhabitants, cattle) applied to a fictitious polder, displayed by height contour lines, and, subdivided into compartments by a road network

The flooding concept is simplified to a bath top model (for the prototype purpose useful, but in reality not correct). Nevertheless, DamSim underlines the relevance of preventive evacuation in case of an expected flooding, and, moreover, it shows the relevance of compartments, a matter of scientific and professional importance as an option to subdivide certain polder areas to reduce flood disaster risks.

2.6.2 PoldEvac

Results of 1995 Rhine river flood risks are:

- Areas under serious flood risks particularly Greater Maas and Waal polder and Ooij polder, about 250,000 inhabitants, polder is completely evacuated. But, afterwards, it is obvious, evacuation has not been necessary, the dykes showed to be strong enough. The expected flooding did not occur.

- Decision makers (particularly mayors of the involved municipalities in these polders) decided that (a) the execution of evaluative research was obligatory, and, (b), sufficient and more adequate (geo-) information is required to get a better insight concerning risks and how to react when a possible next disaster circumstance would appear. In other words, they wanted improved information and emphasized a demand for geo-spatial information.

- EU launched the Interreg II C program with a special IRMA action. This initiative is directed to transnational, cross-bordering Rhine-Maas activities.

- Within the IRMA framework, a proposal for a huge geo-spatial information and decision support system has been compiled, submitted and accepted. The proposal's purpose was to inform, to reduce effects, to avoid flooding, to protect inhabitants, cattle and properties, with special attention to be paid to evacuation opportunities, hazardous chemical substances and land use planning. The project runned from about 1996/'97 until 2003, finally in April 2004 in Dusseldorf completed and through the EC honoured with a best practice award.

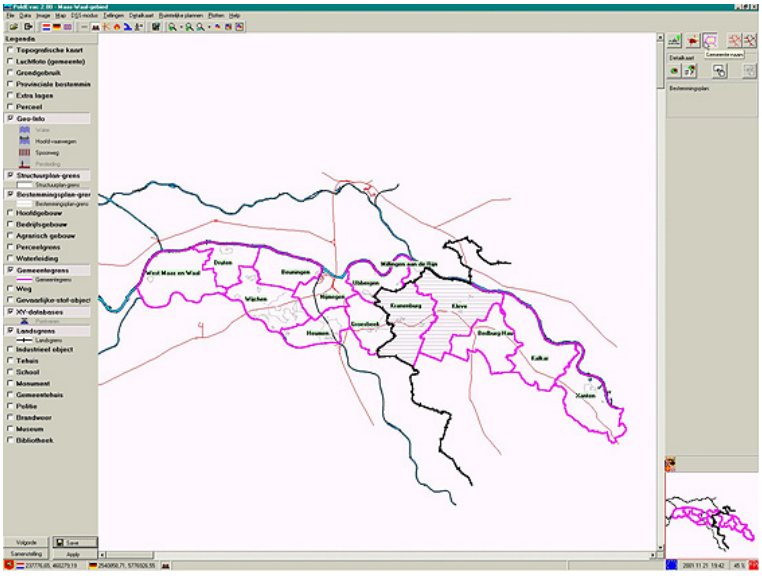

Figure 4: PoldEvac application: Dutch and German regional overview of involved municipalities

At the right moment, so-to-say, the European Commission (EC) specified a part of the Interreg II C transnational program (1996-2004) for IRMA, international Rhine Maas Activities, as a response on the 1995 floods and extreme flood risks along the rivers Rhine/Waal and Maas. The EC included therewith two watersheds, relevant to France, Germany, Belgium, Luxembourg and the Netherlands, and to Switzerland in association as well.

For Rhine/Waal flood risk circumstances, the IRMA program suited wonderfully to a transnational, cross-bordering project. A project proposal had already been compiled for the two Dutch polders Maas & Waal and Ooij, in early 1996. In the course of 1997 the proposal has been extended through the inclusion of the German Duffelt polder, located in the the German Kreis-regions Kleve and Wesel, adjacent to the Dutch-German boundary. That is, at that moment, the project incorporated 9 Dutch municipalities and 3 German municipalities. In the Netherlands including: Nijmegen, West Maas en Waal, Beuningen, Druten, Wijchen, Beek-Ubbergen, Groesbeek, Heumen and Millingen aan de Rijn , and in Germany in the 'Bundesland' Northrhine-Westfalia including: Kranenburg, Kleve and Xanten.

Flood disaster management in the Netherlands is a matter of decision making through the mayors and for the operational fighting management in the hands of the regional fire brigade commander, while in Germany it is a matter of the Kreis-regional authorities, represented by the 'Landrat', the Kreis-commissioner.

The major objectives of PoldEvac (van der Meulen, 2002, 2005) have been specified as follows:

- Collection of knowledge concerning (geo-spatial) information demanded for decision making under (flooding) risk circumstances.
- Provision of insight in the time-tempo flood process in case of a dike breach and a consequent polder flooding. This insight is relevant for all distinguished flood films. Flood films are flooding scenarios simulated to happen along the Rhine, Waal and Maas rivers.
- Delivery of an overview of the consequences of each of the polder flooding scenarios worked out.
- Production of information regarding land use planning and regulations.
- Raising of awareness regarding risks by dangerous, hazardous substances present in the (possible flooding) polder areas for environmental and operational disaster reduction workers.

To adequately execute such a project, a strong and effective project coordination (Commander of the Regional Fire Brigade of the Nijmegen Region') and general project management (executive chairman of the Compuplan Institute) has been assigned. They invited and organized an excellent project team that consisted of: Dutch Research institute Paul Bockholts, German Sociological Disaster Research institute University of Kiel, Hydraulic Laboratory Institute Delft.

Politically and administratively the project has been supported through a widely composed (governmental) number of organizations and agencies, notably: German Country Agency for Water Management, German Country Agency for Geo Information, German Regional State Government in Dusseldorf, German Country Agency for Environment, Netherlands Ministry of Water Management, Netherlands Ministry of Spatial Planning, Department of Crisis Management, Netherlands Ministry of Environment, Ministry of Interior, Department of Fire fighting and disaster management, Province of Gelderland, Department of Water, Dutch municipalities 9, German municipalities 3, Water board Great Maas and Waal. Subparts of the whole project concern: (1) Research, (2) Flood films, (3) PoldEvac system, (4) Seminars, (5) Conference, (6) Closing conference (Dusseldorf April 2004), (7) Animation Mr. Pol de Vac, (8) Training proposal and (9) Internet (www.compuplan.nl).

The PoldEvac modules, together a complete geo-spatial information and decision support system (geo-SDSS) for flood risk management, embrace (van der Meulen 2002):

- **Areal description:** Levels (large scale, micro scale), Vector, grids, pixel, picture/photos, air photos, Kinds: Land use of the Netherlands, cadastre, large scale map of the Netherlands, height maps, water maps, road maps, sewage maps, tap water maps, Municipalities: land use maps, spatial statistics on population, cattle, retired persons houses, hospitals, elderly treatment houses, property (value) data, together with attribute databases;

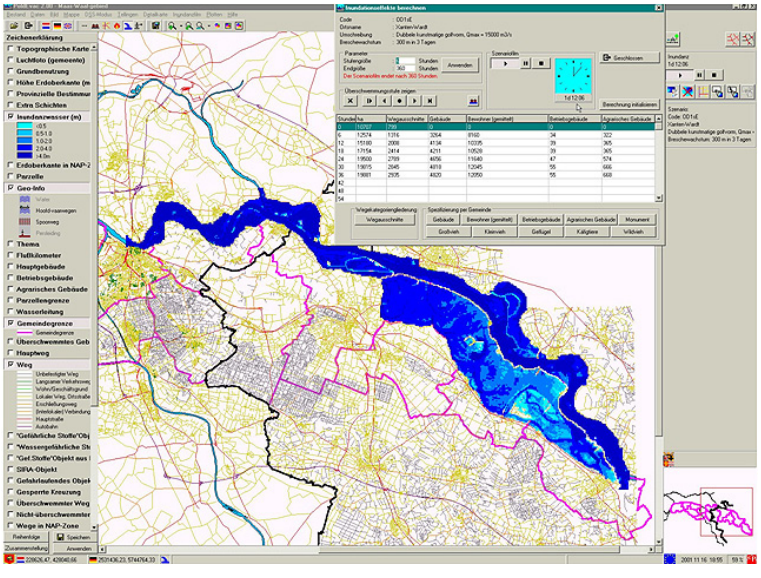

Figure 5: PoldEvac application: Dike breach near German Xanten causing flooding, monitored in time blocks of 6 hours, registering areal extent in hectares, number of hit road segments, buildings, population, agricultural sites, and involved cattle, in case not evacuated preventively; user interfaces are in Dutch, English and German, currently in German language

- **Flooding:** River water characteristics: water level(s), speed, volume, waves, Historical records of river dike breaches, locations and events, flood dynamics calculated through Delft-FLS 2-dimensional flood software (Mierlo 2001), Flood scenarios, flood films, in time-tempo context extension and stream speed, Hazard and vulnerability monitor;

- **Road network:** Roads, road segments, junction, Bridges, ferries, Traffic circulator;

- **Save transport and traffic monitoring:** Shortest and safe evacuation routes (bridging paths), Optimal warning routes (round trips), Save disaster fighting routes, Known disaster area exits;

- **Rivers, canals and networks:** Sluices, locations and attribute data, Connections between rivers;

- **Evacuation:** Road network assigned and selected to be used for evacuation purposes, Area exits (leaving the risk area), Shortest time/distance (road network related) areas calculated out of the available exit location of the polder evacuation area, Municipal or time block area assignments to the evacuation network specified, Evacuation movement processes on the evacuation road network in direct connection with time-tempo flooding scenarios or flood films, Relation between flooding and evacuation based upon a dry-feet leave approach, Capacity oriented approach for the evacuation process over the evacuation road network, Traffic flow monitor for the handling of (temporary) traffic barriers caused by e.g., accidents and the ascertainment of a consequent re-evacuation flow pattern, Evacuation options to steer preparation and repression processes, Connections with the simulated flood scenarios;

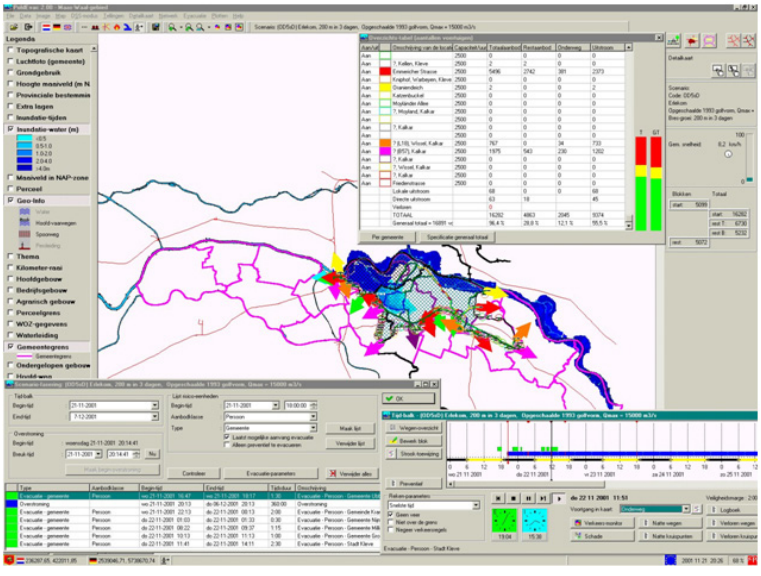

Figure 6: PoldEvac application: Dike breach of Rhine/Waal river near Erlekom, preventive evacuation preceded breach event and consequent flooding, showing the speed and stream out of evacuation vehicles along exits in the upper table, while the flood/evacuation details are displayed according simulation calculations, in time-tempo

- **Land use planning: (NL.):** detailed, specific land use plans, (GE.): structure and building plans;

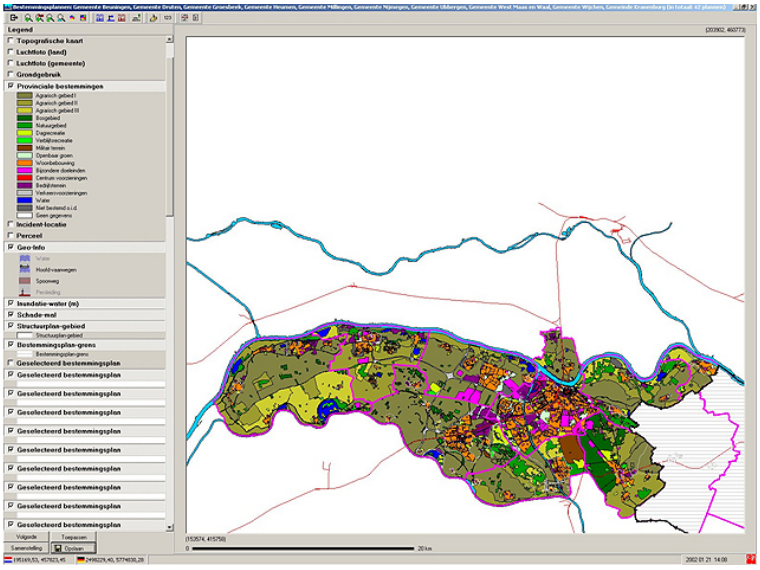

Figure 7: PoldEvac application: Land use plans for all municipalities in the Maas & Waal Polder, displayed in an aggregated way

- **Fire/additional disaster management:** 'a disaster never comes alone' credo: although the topic relates to water (floods), expected fires are incorporated, also other emergency occasions occur, hazardous chemicals, Fire fighting informator, Necessary information regarding water network and sewage system;

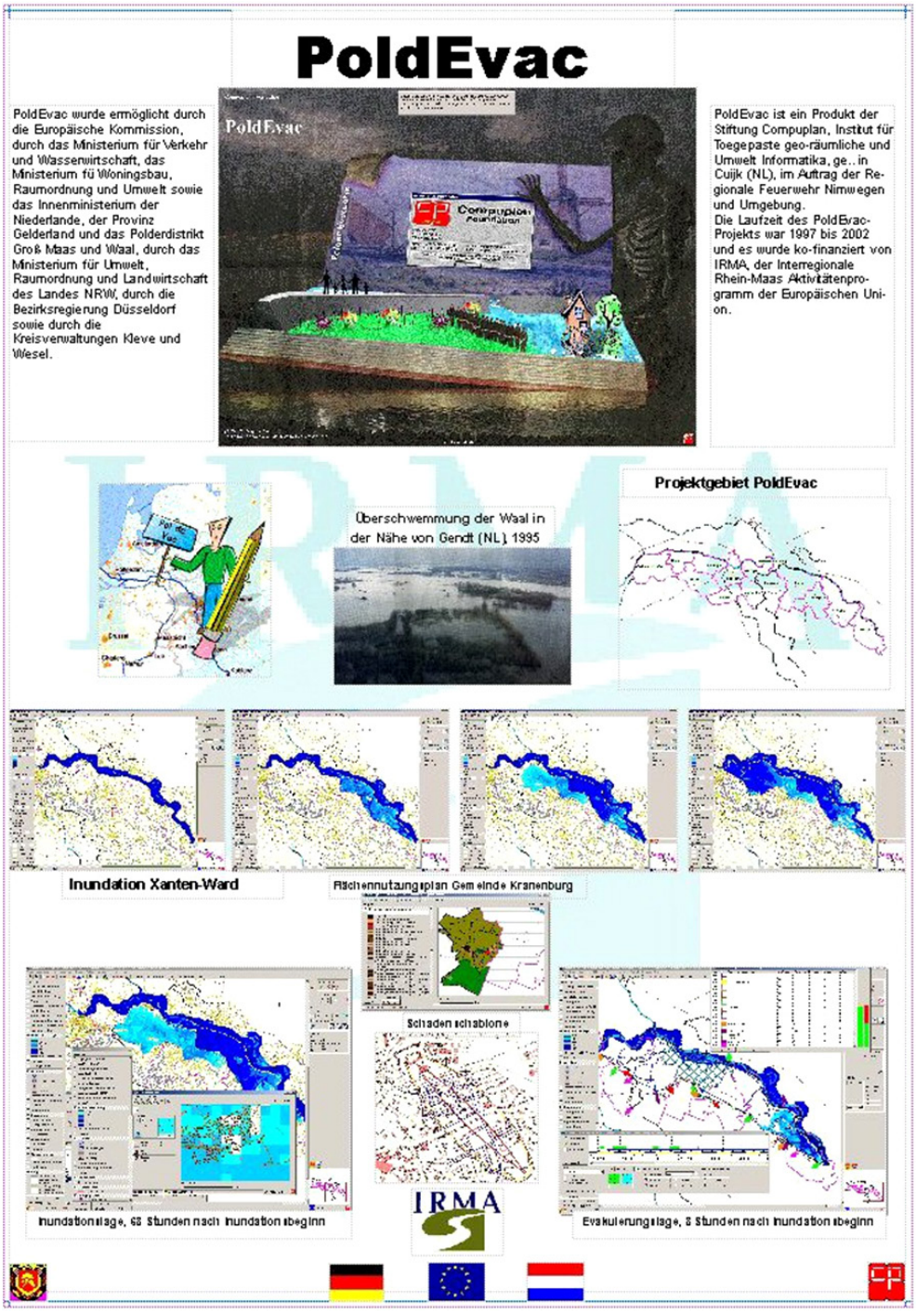

Figure 8: PoldEvac application: Poster with an overview of a flood, time-tempo flooding film, using the PoldEvac system, applied to the Dutch-German cross-bordering Duffelt region, with a Rhine dike breach at Xanten-Wesel

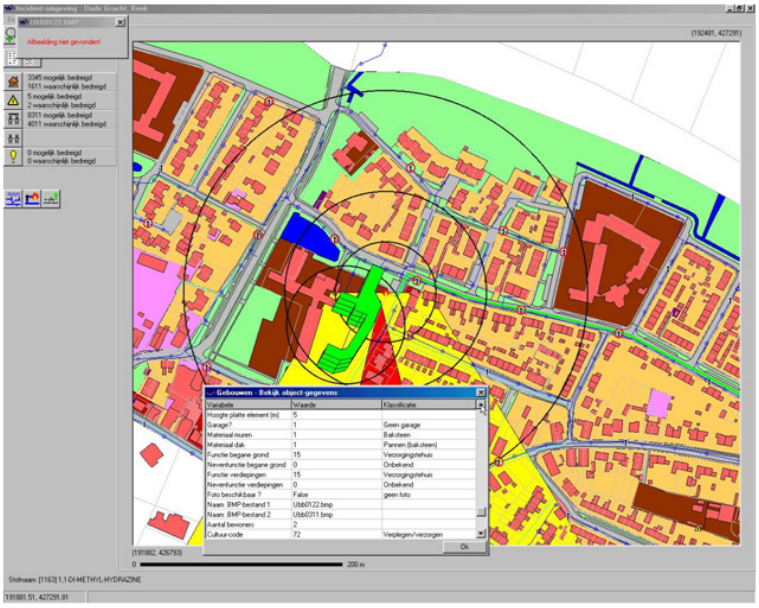

Figure 9: PoldEvac application: Explosion/emission of chemical substances from a source location, showing the geo-spatial extension of its effect, in combination with connected data concerning buildings, people, etc. under threat of lethal victims and/or injuries; the in 3-D displayed building concerns a elderly treatment and service home

- **Chemicals, hazardous implications:** Chemical land and building occupancies, Hazardous (emission, explosion) effects informator, Incident simulator.

2.7 Safety mapping

From (Dutch) government side [IPO 2007], safety maps are explained in at least two ways, notably: (1) kind of relational information provided, and (2) target group addressed. As kinds of information are mentioned: potential flood area, flood barrier failure chance, flooding progress in case of a failure (calculations based upon high water level, terrain qualities and circumstances; de facto, the same factors as applied in the PoldEvac flooding scenarios) with worst case considerations, effects of the flooding, flood risk (result of chance times effects), insurance, and evacuation advices. For each, maps are produced and accessible, mainly through provincial websites. Target groups are both professionals and general public (inhabitants, industries).

A comparable way of working is found in the Excimap handbook on flood mapping in Europe [Alphen 2009, de Moel 2009, Alpen 2007, Martini 2007]. In one of its directives in 2004 also the European Commission dictates the production of flood maps, to be ready in each member state prior to 2014, and consequent flood risk management plans prior to 2016.

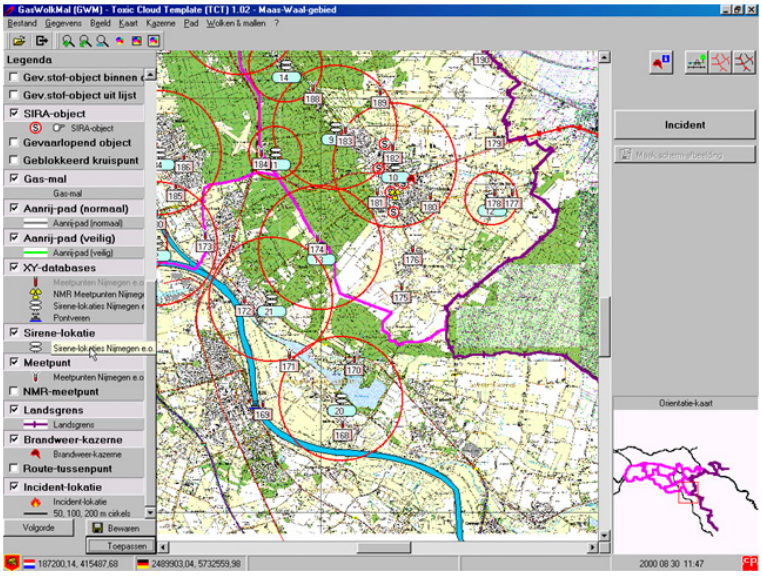

Figure 10: PoldEvac application: Citizens are warned in case of a catastrophe by the sounds of sirens; the image shows several sirens (small and larger type) with the areal extension of the sound they produce

2.8 Public awareness

Public awareness embraces at least two dimensions. The first concerns education, information dissemination, being aware of the risks, and participation in evacuation exercises as preparation in case of a disastrous event. Such public awareness activities should be permanent, frequently repeated.

The second dimension concerns early warning and the availability of public warning devices. Information and communication vehicles of recent technology such as mobile phones may become useful vehicles to early warn and reach as much as possible persons at risk. Since many years the Netherlands possesses a unique system to warn, notably a siren system covering (almost) all housing areas.

The system runs every first Monday each month for testing purposes. For disaster fighting purposes the areal extensions of the various sirens are included in the integrated PoldEvac system.

3. RESULTS AND DISCUSSION

Being informed more adequately, the pro-active responsive of the Dutch government towards the future was twofold, one in concern with geo-informatics and one that focused upon advanced policy making, although soundly based upon geo-spatial information on high water risk, climate change, land subsidence, the quality and strength of storm surge barriers and dikes, and evaluations of land use developments and civil engineering/hydraulic efforts in historic perspective.

3.1 Geo-Informatics

Once the PoldEvac project was completed, also awarded, it became time to consider the success of the project, the usefulness of the geo-spatial systems approach, and continuation of the effects, nationally and trans-nationally.

After all kinds of discussions and decision making, the final choice was continuation, into new, possible project(s).

The initiatives in the Netherlands (PoldEvac follow-ups) are Viking with mainly flood films in the Province of Gelderland, and Fliwas, flood information and warning system, which is particularly developed for communication purposes. The advantages and challenges of a geo-spatial information and decision support system for flood protection and mitigation are manifold (van der Meulen, 2009).

3.2 Future's flood safety, sustainability policies

The Dutch government (and later as said the European Commission as well) published policy reports on returning space to the rivers (Project organization Room for the River, 2007). More recently, municipalities started to compile visions for the future. The Dutch municipality Renkum was one of the first who formulated an integrated water vision for its territory, water system approach. In May 2007 the Cabinet of the Dutch government produced a water vision for the country, as a stepping-stone towards a National Water Plan to be published in the course of 2008. Moreover, this Memo provides leading and steering directives for new spatial activities, design, research and innovations, and therewith for the availability for financial means and support.

> *The central government realizes in this way its key objectives: strengthening of the international competitive position of the Netherlands, promotion of strong cities and a vital countryside, the security and development of important (inter) national values and the security of safety.*

Space for the River became also a policy of the European Commission, fixed in its EU High Water Directive. This directive says that in principle water problems may not be shifted off to other stream-down countries. In other words, solidarity is the key word in European water management.

In May 2007, the Dutch Cabinet produced a report called "Nederland veroveren op de toekomst" ("Conquering the Netherlands for the future") in which it provides a vision on water. The report has 5 water topics:

- 1. climate neutrality as joint effort
- 2. stronger economy with water
- 3. durable living with water
- 4. world wide provision of water knowledge
- 5. renewed recognition of living with water

The Water Vision of the Dutch government's Cabinet has a special chapter on "Netherlands supports world wide with water knowledge", (chapter 5), stating: "international solidarity" for countries in development. The Dutch Cabinet wants to deliver a substantial contribution to the so-called Millennium Development Goals (MDGs), particularly to MDG-7 with a central focus upon (amongst others) climate change and water.

The Dutch Cabinet is aware about vulnerabilities for flooding and increasing flood problems. According to the Dutch Cabinet, regional and local government representatives should be (more) aware of the emphatic meaning of water as a determining factor for spatial planning, design and regulation. Therefore, it introduced the concept of Spatial Quality as a basic ingredient for planning and design in the future.

In the renewed Dutch Law on Town and Country Planning (effective, 2008), local authorities are obliged to devote a special section on water, and, in the future, to include a Water Test, the research results of the effectiveness of water (planned/brought into) within each new local spatial plan (comprehensive and particularly in specific plans).

Aware of possible consequences of sea level rise as forecasted through IPCC studies, the Dutch national government launched a new Delta Law in the course of 2008. This law making has thoroughly been prepared. First, the weak spots along the North Sea coast were subject of study in some parts of the provinces Zeeland and North-Holland, during several years (2002-2006). Second, a special Committee has been installed by the Dutch Minister of Water Management to study flood risks in the coming 50 years.

4. CONCLUSION

The traditional water connected Dutch credo louds `Luctor et Emergo´, translated from ancient Latin language it says 'Ik worstel en kom boven', or in English 'I wrestle and rise'. During a long history, the Netherlands was building up water (management and technological) knowledge, expertise and experience. It is obvious that in an era of computerization, increased attention is paid to GIS, geo/informatics and (in particular to disaster oriented) geo-SDSS, to support decision making, managerial and operational as well.

Flood disaster risks and events in the Netherlands and in various surrounding European countries in the course of the ninetieth of the previous century were for many governments and for the European Commission obvious reason to encourage the execution of extensive projects focusing on protection against and mitigation of the effects of flood (risks). One of the projects focused primarily upon the usage of advanced (geo-) information technology and the development of such a geo -SDSS for disaster management, transnational, cross/bordering, Dutch-German, comprehensive and integrated. That system, called PoldEvac , was a clear response to the demands uttered by the various involved mayors, together tha management part of the crisis team to fight the flood disaster. PoldEvac as a comprehensive and integrated (geo-) system approach is, moreover, relevant to all stages of the safety cycle, the leading approach of disaster fighters and management.

A historical overview of development and applications of disaster management is scientifically of interest. What can be observed is a difference of approach. Safety maps are static representations of possible dangers in case of calamities, instead of a dynamic ('real time')

system approach. From a perspective of safety, a scientific discussion is relevant about preference and where to put emphasis upon. Emphasis could be a matter of both development, quality of system's application outcomes, and information delivery and communication towards involved professionals and civilians. In line with the PoldEvac experiences a number of adaptations and additions have been formulated, notably:

- Extensive training and capacity strengthening of professionals and decision makers involved with the available geo-informatics system(s);
- Extensive operational training simulating disaster events, with comprehensive monitoring and evaluation;
- Emphasis upon GIS for flood simulation and evacuation (instead of integration, although in the meantime after a few years a revival of integration came to the fore again);
- Extensive attention to pay to communication, administrative protocol procedures, etc.;
- Extra interest came to the fore to estimate financial-economic damage cause by flood (possible) events;
- Furthering an enhancement of flood disaster geo-informatics system applications to more and preferably all regions in the Netherlands (replication demand).

Dutch excellence in water management related knowledge, expertise and experience is an obvious consequence of the territorial development as a delta area through about 2000 years. To live in this delta area, and to survive the threats of water coming from the sea, lakes and main rivers, a technical effort in combination with a huge social (human) effort was durable necessary. Building and maintaining dikes and barriers, inclusively mounds and artificial hydraulic works (sluice, flood barrier), were necessary. They required knowledge and sophisticated design. Behind the dikes, the majority of the land in the Netherlands is under average (sea) water level, the polder areas, where inner polder water level should artificially be maintained with the aid of (amongst others) the famous Dutch (wind) mills and pumping systems as well.

Keeping dikes and inner water levels in good order requires an effective (human) organization. Already during the middle ages (500 – 1500 A.D.), inhabitants gather to take responsibilities and to arrange and execute the necessary workings, notably 'Water boards', elected governmental bodies, paid through government and inhabitants (farmers, land owners, inhabitants).

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