

## LOCAL FLOOD MITIGATION PLAN FOR A VILLAGE: THE ROLE OF GIS

### LOKALNY PLAN OGRANICZANIA SKUTKÓW POWODZI DLA MAŁEJ MIEJSCOWOŚCI: ROLA GIS

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### Introduction

Modern trends in flood protection are associated with a new approach to natural hazards, characterized by acceptance of the impossibility of eliminating hazards to persons and their property. Thus, it is assumed that this risk should be at a reasonable level, and that potentially endangered persons should be aware of this fact. Consequently, emphasis is laid on flood preparedness, including flood risk management plans based on flood hazard and risk maps. Such plans for a flood basin will shortly be required in the countries of the European Union, based on a directive on the assessment and management of flood risks (Directive 2007/60/EC, 2007).

Plans for large areas based on a catchment area approach will not solve many local problems; thus, on a microscale, there remains a need to prepare such plans for flood-prone towns. The planning process, independent of the size of the area for which it is being conducted, requires collaboration and exchange of information among various institutions, as well as direct or indirect participation in the planning process on the part of the community at risk for flooding. The need for information exchange, as well as for dialogue with inhabitants and users of hazard areas, gives rise to a challenge for the tools side of the endeavor as well. In the present article, we describe an example of flood mitigation plan preparation for a small town, focusing on presentation of the possibilities for utilization of geographical information systems in the planning process.

## **Flood Hazard in the Village of Gorzanów – Diagnosis of Problems**

### **Description of Gorzanów and Historic Floods**

Gorzanów is a village located in southwestern Poland, in the Kłodzko Valley. The Kłodzko Valley, located at 350–450 meters above sea level, is surrounded by the mountains, up to 1400 m a.s.l., with steep slopes. Those topographic conditions and thick river network result in fast runoff concentration and in consequences high flash flood hazard. Through Gorzanów flows the Nysa Kłodzka River, one of the main left-bank tributaries of the Odra. A significant part of the village, including the center, is located on low-lying terrain by the river; and the rest, on the slope of the river valley. Also belonging to the river network in the town and its environs are small streams draining the surrounding fields, as well as an artificial mill stream running through the center of the village, presently almost always dry and overgrown. The village has existed at least since 1341, when it was mentioned for the first time in historical sources under the name of Arnoldi Villa. Surviving in the village are several historic buildings – among others, the parish church of St. Mary Magdalene, as well as the ruins of a Renaissance palace, together with an expansive park. Since the 19<sup>th</sup> century, local mineral water sources have been utilized (<http://tmg.gorzanow.prv.pl/>) In the village, there are ca. 200 residential homes, inhabited by a little over 1000 persons, of which 10–15% live off the land, and 30–40% work at firms in the local or surrounding area. A significant proportion of Gorzanów's inhabitants is represented by older persons (retired, disabled). For such a village, a relatively large number of unions and associations are active here. Among the most active are: the Village Council, the Village Homemakers' Circle, the Zamek Sports Club, the Society of Friends of Gorzanów.

A survey conducted among the inhabitants shows that the population arrived in the area after World War II (Erlich et al., 2002). From that time up until 1997, there were no floods in this place, although according to historic sources, floods had invaded the Kłodzko Valley multiple times. Among the nearly seventy documented floods, mentioned by Polish, German and Czech chroniclers already since the 10th Century, the largest are those from 1310, 1598, 1783, 1854, 1883, 1903, 1938, 1997 and 1998.

The flood in 1997 was the largest one still remembered by people here, and the largest in the preceding hundred years. In the night between Sunday and Monday 6–7 July 1997, the center of the village, as well as its side streets, together with the buildings located on them, found themselves under water (Olczyk, 2004). On the afternoon of 7 July 1997, there occurred a second flood wave, larger than the previous one. The damage was considerable: 81 private residential homes (including 1 completely destroyed); 100 farm buildings (including 3 completely destroyed); flooded communal buildings – culture club, post office, Volunteer Fire Brigade building; 2 communal residential buildings, a mineral water bottling plant, a waffle production factory, the mill, 2 shops. Found under water were 135 ha of agricultural lands belonging to 70 farmers. Damaged or destroyed were: 3000 m<sup>2</sup> of county roads, 47 200 m<sup>2</sup> of municipal roads, 15 000 m<sup>2</sup> of agricultural transport roads; 1 bridge and 1 auto-footbridge collapsed, and 2 bridges were damaged. Also destroyed were elements of infrastructure: telecommunications, power, gas lines; water, sewage networks; lighting. All told, losses were estimated at ca. 13.2 million PLN, i.e. ca. 3.6 million EUR. The flood made local authorities and inhabitants aware of both the magnitude of the flood hazard and the need for better preparedness for future events.

### Local Flood Mitigation Plan

In Poland, there is no obligation or tradition of preparing plans associated with hazard mitigation for individual towns (unless it is an urban municipality). Plans are prepared at the municipal level, but are oriented not towards flood prevention or preparedness, but towards flood response. Additionally, municipalities cover areas in which often several or even over a dozen towns are located. Thus, these plans are of general character; they are not normally dedicated to individual towns, nor are they perceived by inhabitants as plans prepared for their safety. So the need arises to answer the question of how a flood mitigation plan for a small town should look.

An attempt to prepare such a plan was undertaken on the initiative of IMGW Kraków and carried out jointly with Regional Water Management Board (RZGW) Wrocław, the Kłodzko County Government Office and the Bystrzyca Kłodzka Municipal Government Office (Global Water Partnership-Poland, 2006). All of these institutions were interested in gaining experience in the area of planning on such a small scale, and in utilizing these experiences in other places. The plan for Gorzanów was prepared according to a scheme:

- Identification of problems;
- Determination of action goals;
- Selection of methods for achievement of goals;
- Establishment of principles for their realization, including a financing and implementation plan.

An advantage of preparing a plan on such a small scale is ease of access to local information, ease of verifying assessments and proposed variants. However, it does require involvement in the planning process on the part of representatives of local authorities, representatives of the local community and inhabitants. For the preparation of the plan, a planning group was set up, which was comprised of the village administrator of Gorzanów, a representative of the Kłodzko County Government Office and of the Bystrzyca Kłodzka City and Municipal Government Office, representatives of the local community (priest, Volunteer Fire Brigade, Village Homemakers' Circle, Society of Friends of Gorzanów). This team held a series of meetings, during which were discussed both the causes of flood losses, and ways of eliminating or at least minimizing them.

The fundamental task permitting preparation of the plan was to diagnose the most important factors which could influence the magnitude of flood losses in Gorzanów. Several methods of action were used, which were meant to facilitate establishment of problems requiring solution. Among them were:

- Analyses of materials concerning the flood hazard in the village of Gorzanów, the 1997 flood process, and proposed actions intended to mitigate the hazard;
- Survey research conducted among Gorzanów inhabitants affected by the flood;
- Conversations conducted both with inhabitants and with local services and forces (mainly with members of the Volunteer Fire Brigade);
- Discussions within the team involved in preparing the flood response plan.

As a result of this work, the following problems requiring solution were identified:

- Insufficient maintenance of the Nysa Kłodzka river bed (bank erosion, silting of some segments);
- Impeded water flow in beds of Nysa Kłodzka tributaries (Gorzelniany stream and mill stream);

- Bad condition of drainage ditches and some hydro-technical structures (impeded water flow in drainage ditches, missing levee segments, improperly functioning weir);
- Ineffective inhabitant warning and response system (inhabitants warned too late or not at all);
- Low inhabitant knowledge level in the area of flood prevention and preparedness (lack of evacuation points in the town, weak inhabitant knowledge concerning how to prepare the home and family in case of a flood);
- Improperly organized distribution of aid after a flood (aid not fairly distributed).

The analyses carried out provide an initial picture of the problems that occurred during the 1997 flood and directly thereafter. Some of them were a consequence of insufficient financing of institutions administrating the rivers; some of them resulted from lack of experience; others were caused by traditional ways of thinking about flood mitigation methods. Regardless, however, of the causes, removing or at least minimizing them will have a vital influence on the effects of future floods.

Further work focused on problems of flood warning and response, as well as on raising inhabitant awareness levels. Utilization of GIS for their solution is the subject of the subsequent portion of this article.

## **The Role of GIS in Planning Work for Gorzanów**

### **Digital Flood Hazard Map for the Village of Gorzanów**

During analysis of source materials and field research, certain information resources were gathered, illustrating the flood hazard in the village of Gorzanów with spatial reference for this information on analog (paper) maps. Also obtained were data in digital form. On this basis, a digital map was prepared, encompassing the area within the administrative boundaries of the village of Gorzanów. The basic source of spatial data in digital form were data obtained from the County Center for Geodesic and Cartographic Documentation (PODGiK) in Kłodzko, coming from land and building records. The most important information from this data source were the borders of land plots and outlines of buildings in PUWG 65 projection (one of the standards projection in use in Poland).

An array of detailed information on the flood process in 1997 was collected by surveying inhabitants and members of the Volunteer Fire Brigade who took part in the disaster aid action at the time. This information was entered onto the sheets of a paper records map at 1:2 000 scale and in PUWG 1965 projection.

Additional map source material – valuable for our work – were paper maps at 1:10 000 scale in PUWG 1942 projection, with indicated potential inundation extents of probability 10% (the so-called 10-year flood) and 1% (the so-called 100-year flood), on commission from the RZGW in Wrocław, the Wrocław Regional Development Agency (Zalewski et al., 2004). These maps contained, beyond this, the historic flood line from 1997, determined on the basis of hydraulic modeling. These maps were obtained thanks to the kindness of RZGW Wrocław.

Such non-uniform source material had to be processed: above all, numerical data had to be converted to appropriate formats, digital forms had to be obtained from analog materials, all data had to be imported into the same coordinate system, and differences had to be worked out.

Numerical data in DXF format were converted to ESRI shape format. It was necessary to select the material, as well as divide it into information layers concerning selected classes

of objects. A portion of the data remained in the form of a 'spaghetti layer'. Buildings and infrastructure elements of particular significance in the area were transformed into object form. Geometric information about buildings was supplemented with attribute information referring to inundation depth, coming from the survey interview. On the basis of land plot borders, the layer of rivers within the bounds of the town was supplemented. This was important in that some of the smaller streams (drainage ditches) create a flood hazard.

Paper maps were scanned, rectified and recorded in the GIS system. On account of the fact that the majority of the map data was in PUWG 1965 projection, this coordinate system was adopted as the foundation for further work. Thus-prepared raster data were the basis for digitization of the screen line: inundation extents, flood and bank erosion routes. During this work, simultaneously, inundation lines were corrected, taking into account inconsistencies between the analog and digital records maps. Certain inaccuracies in data matching resulted from the scale difference in the source data. Finally, considered as reference data were numerical data concerning land and building records, since they were the most credible, precise and reasonably up-to-date.

Finally, as a result of this work, a spatial database was built, encompassing the area within the administrative boundaries of Gorzanów, with a small amount of adjacent terrain. It is comprised of layers in ESRI shape format, as well as raster underlays in TIFF format with georeferences. As has already been mentioned, these data are in PUWG 1965 projection. The detailed content of the resource is:

- Infrastructure data, including:
  - Building information, containing outlines of buildings and points with assigned information concerning the building category (residential, farm, infrastructure) and number of stories;
  - Selected roads and streets within the village;
  - Selected more important structures within the boundaries of Gorzanów: culture club, water reservoir, pumping station, transformer, gas station, park, church, castle, cemetery, mineral water bottling plant, mill, post office, shop and GS warehouse; as well as drainpipes, weirs, bridges, railroad tracks;
- Flood hazard information:
  - Rivers and streams within the boundaries of Gorzanów;
  - Predicted inundation extents for floods of 10% and 1% probability, as well as the historic inundation from the 1997 flood, obtained as the result of hydraulic modeling;
  - Inundation and path of 1997 flood, supplemented with bank erosion segments obtained from field survey;
  - Information about the maximum depth of water during the 1997 flood, or information about water in the courtyard or basement (for parts of buildings located in the inundation zone);
- Information associated with flood warning and response:
  - Evacuation points and routes;
  - Places of residence of volunteer flood wardens;
- Additional information including:
  - Borders of land plots (layer is not divided into objects);
  - Kilometrage points for the Nysa Kłodzka within the boundaries of Gorzanów, from km 140 + 100 to km 145 + 300;
  - Administrative boundaries of the town.

Aside from the vector layers described above, the resource collected contains raster source data including:

- Records map sheets of Gorzanów at 1:2000 scale, with inundation extents, comments, etc. entered by Volunteer Fire Brigade firefighters;
- Map sheets scanned from inundation extent maps prepared by Wrocław Regional Development Agency on commission from RZGW (sheets at scale of 1:5000, enlarged from a 1:10 000 map).

The above resource was transmitted to the Department of Crisis Management in the municipality of Bystrzyca Kłodzka, together with ESRI's free map browser ArcExplorer, enabling browsing and simple queries to collected data. In the subsequent portion of this article, we describe its utilization in planning work.

### **Utilization of the map in work on the local flood hazard plan**

The manner adopted for execution of the plan assumed active participation of the local community in the process of its preparation. Representatives of the Gorzanów community participated in the work of the planning team; the results of its work were consulted/discussed with local leaders and presented to inhabitants.

The IMGW team coordinating planning work faced the problem of selecting tools solutions which would permit effective support of the information collection and exchange process, as well as discussion within the planning team. In the initial work phase, it was determined that the map could have a very positive, stimulating influence on discussions concerning local flood protection problems. On the other hand, the limitations of traditional maps, associated with predefined scales, areas covered and map content, were revealed. Based on these experiences, it was decided that a tool permitting *ad hoc* preparation of paper/traditional maps of scale and information scope adapted to specific needs would be potentially very helpful in planning work. GIS meets these requirements well; thus, in the planning work, GIS tools from the firm ESRI were utilized. They permit materials available in digital form to be integrated, and then supplemented on the basis of Gorzanów inhabitants' and local Volunteer Fire Brigade firefighters' knowledge.

As has already been mentioned, a portion of the materials was obtained by way of field interviews conducted by firefighters from the local Volunteer Fire Brigade and members of the planning team. In this manner, the inundation extent from the 1997 flood and the inundation depth of individual homes was determined. On the basis of this information the so-called flood path was determined, i.e. the area in which inundation depth and water flow velocity create a threat to the life of persons finding themselves in that area. This information indicated on paper maps was processed into digital form, which permitted verification of the materials collected. From comparison of inundation extents for the July 1997 flood, we can see that the inundation extents determined on the basis of results from hydraulic modeling differ considerably from those prepared on the basis of on-site visitation (Fig. 1). This is not surprising. Modeling results always differ from reality; and beyond this, the degree of analytical detail – if only the map scales utilized in each case – was essentially different here. Beyond this, the Volunteer Fire Brigade did not limit itself to the effects of a flood wave on the Nysa Kłodzka, but also included its small tributaries, places without drainage, etc. The results of the comparison confirmed planners in the conviction that in microscale analyses, as in the case of Gorzanów, a detailed community interview is key in diagnosing hazards. The inundation extent obtained as





**Figure 1.** Gorzanów center – Comparison of inundation extents from field surveys and hydraulic modelling, for 1997 flood

the result of surveying inhabitants appears to be credible, because the period which has elapsed since the flood is not too long. Thus, after clearing up doubts, the inundation extent determined by the Volunteer Fire Brigade was taken as the basis for work.

On account of the flash flood hazard, an important element of the local flood mitigation plan was the problem of warning inhabitants of impending danger. Work was focused on utilizing and developing the capabilities of the local flood warning system built several years earlier by the County Government in Kłodzko (Madej et al., 2005). It was established that in addition to the already-existing telephone system for warning inhabitants, an attempt would be made to reinforce it with a group of volunteer flood wardens, whose basic function would be to warn neighbours on the basis of information from the County Crisis Management Center. GIS was utilized in the process of determining the list of volunteers as a tool enabling visual analysis of the evenness of distribution of volunteers.

During discussions within the planning team, a plan for evacuating persons and property was also established, and evacuation routes and points were entered on the map. This information was input into the digital resource, after which it was finally agreed upon with representatives of the local community, as well as with persons responsible for crisis management within the boundaries of the municipality.

The planning team met in varying composition of personnel, and the digital map represented an important element documenting their work and organizing information, as well as transmitting information and determinations from meeting to meeting. The map was utilized both in analog (printouts prepared for meetings) and digital form. In this second case, edition and supplementation of information took place straight on the digital material, and the information presented and discussed could then be expanded with the documents linked to the map objects, containing descriptions of the technical condition of structures, suggestions concerning work necessary, photographs, etc.

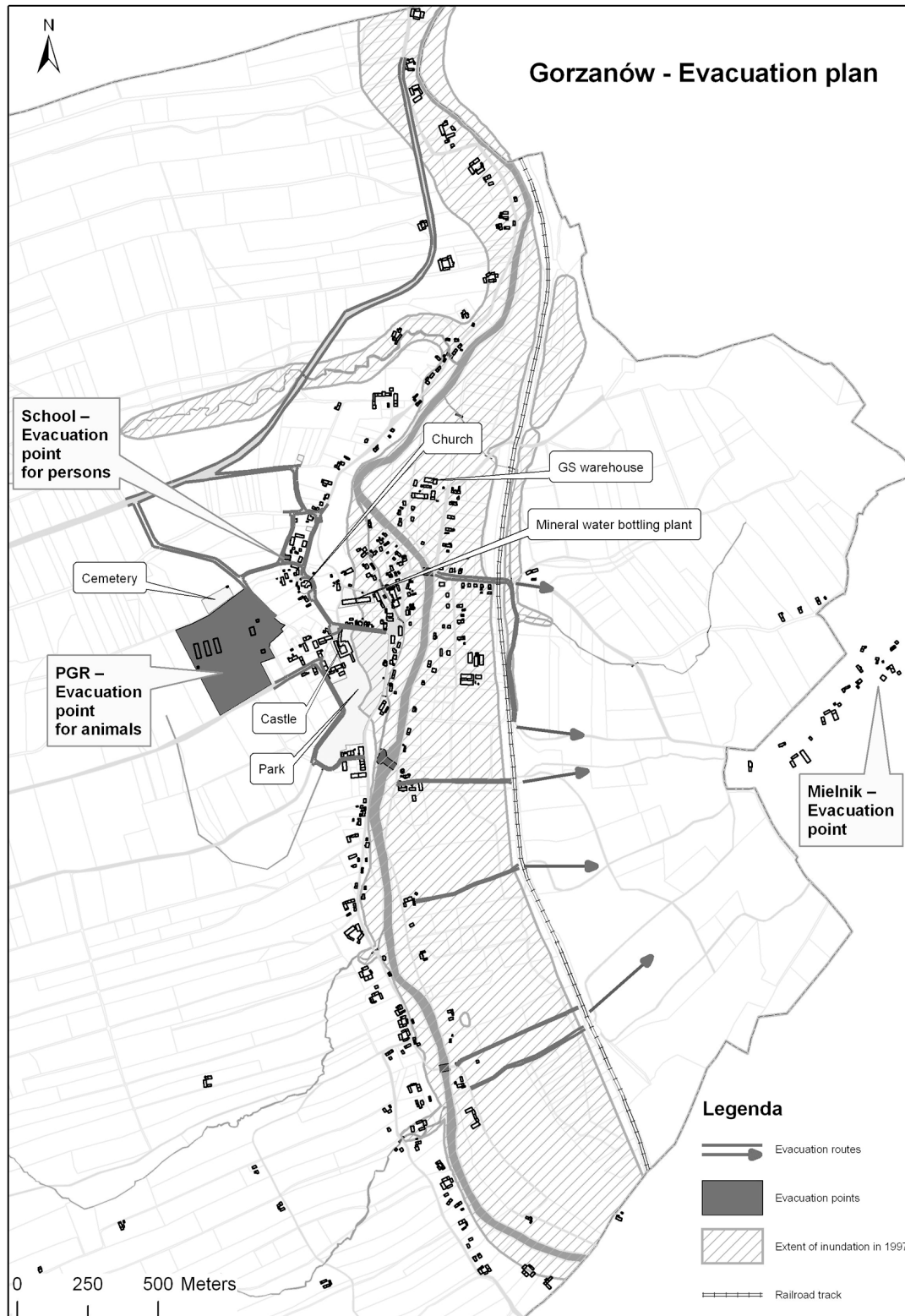
### **Utilization of a digital map for the process of informing and educating inhabitants**

The effectiveness of modern flood mitigation systems is decided in large measure by the degree of awareness and knowledge of the entities involved in their building and exploitation. For present trends in this area assume that obtaining good results from these actions, and especially from flood preparedness, depends on the involvement of all groups which could have any effect on the extent of losses, thus: State and local government administration, commercial sector firms, public institutions and ordinary people. Influencing these entities, in particular risk area inhabitants, is not easy.

An important and effective source of information associated with flooding, enabling action to be taken, can be a risk map containing lines which water could reach in the future and/or which it has reached during past floods. Equally essential is to indicate on the map evacuation points for persons, farm equipment, machines and animals, as well as safe evacuation routes. As part of work on the flood mitigation plan for Gorzanów, maps containing the above information were prepared and printed in A0 format (cf. Fig. 2). These maps are to serve two purposes:

- School education (map prepared on cloth, easy to carry from room to room);
- Maintenance of inhabitant awareness (map on rigid backing, covered with protective lacquer, intended for the culture club in Gorzanów).





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**Figure 2.** Evacuation plan for the Village of Gorzanów

The digital map described above has also been utilized to prepare a flyer on the local flood warning system. The aim of the flyer is to inform inhabitants how they will be warned and who will warn them, as well as how to proceed after receiving a warning. An integral part of the flyer is the evacuation plan for the town.

For educational purposes, local events have been utilized, e.g. a festival organized on St. Florian's Day (St. Florian being the patron saint of firefighters), during which a diagnosis of the sources of flood risk in Gorzanów and propositions for solution of local problems in this area were presented to inhabitants, along with the organization of a family evacuation plan contest. Also utilized was the Internet, with preparation of an information packet for the web pages of the Society of Friends of Gorzanów, a local NGO active for years. In both cases, maps were an important source for transmission of information.

## Summary

GIS turned out to be a good tool not only for integration of data, but also an effective tool for communication among various groups, stimulating information exchange. It was also useful in preparation of informational materials. The analytical capabilities of GIS were not utilized in the example described (aside from simple analyses concerning the number of buildings in the flood zone), which does not mean that these functions of spatial information systems cannot play an important role in planning work.

Integration and presentation of information are the main areas for utilization of GIS in planning work for Gorzanów, and the spatial database represented an important element in the documentation of the work, enabling presentation of the current status of its progress. Especially the presentation function requires emphasis. This function was without doubt the most essential in the case being described, taking into account the participation in the planning process of representatives from the local community, the changing composition of participants in the meetings, and the resulting need for frequent and easy-to-understand presentation of the status of progress on the work. Beyond this, equally importantly, the map – whether in analog or digital form – was a catalyst for discussion and exchange of views among the planning team and at meetings with inhabitants.

The example presented shows the usefulness of spatial information systems for the process of participatory planning, as well as community consultation, which are now a standard element, required by many European directives, of planning work in environmental issues.

## References

- Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, 2007: Official Journal of the European Union L 288/27, 6.11.2007.
- Erlich M. et al., 2002: Analyse de retour d'expérience des inondations (Pologne, Bretagne et Saône) , Retour d'expérience des inondations liées à la crue de l'Oder de 1997 en matière de gestion de la crise, de la post-crise et de la reconstruction, Agence de L'eau Loire-Bretagne, CCTP n° 01S0022 (in French).
- Global Water Partnership-Poland, 2006: Forward integration of flood warning in areas prone to flash floods. Implementation of a Flash Flood Warning System for Inhabitants and Users of Flood Plain Areas in the Kłodzko Valley, Poland ([http://www.apfm.info/pdf/pilot\\_projects/Flash\\_Floods\\_Poland\\_Pilot.pdf](http://www.apfm.info/pdf/pilot_projects/Flash_Floods_Poland_Pilot.pdf)).

- Madej P., Konieczny R., Kruszewski A., Partyka D., 2005: Flood Warnings at the Local Level: Tools and Experiences in Their Implementation. Hřebíček J., Ráček J. (eds.), Proc. of 19th Conference "Informatics for Environmental Protection" Enviroinfo 2005, Brno, September 07-09, 2005, vol. 1, pp.202-206.
- Olczyk A., 2004: Powódź we wsi Gorzanów. Problemy społeczno-prawne, Praca magisterska napisana pod kierunkiem A. Czajowskiego, Uniwersytet Wrocławski, Wydział Nauk Społecznych, Instytut Politologii (in Polish).
- Zalewski J. et al., 2004: Studium ochrony przed powodzią Kotliny Kłodzkiej ze szczególnym uwzględnieniem ochrony miasta Kłodzka, Wrocław (in Polish).

#### **Abstract**

*Article describes the work related to development of the local flood mitigation plan for Gorzanów, village located in the Kłodzko Valley south-west of Poland. Problems of flash flood warning and response are particularly considered. Work carried out is described focusing on the role of the GIS tools in the process of planning activity. Use of GIS in collection, organization and exchange of information between different institutions and within working team is noted. An advantages of using such tools for interactive communication with non professionals in participatory planning is described as a key result. Finally the examples of informational materials used in process of dissemination of information related to flood hazard and response are showed.*

#### **Streszczenie**

*Artykuł opisuje przebieg prac związanych z przygotowaniem lokalnego planu ograniczania skutków powodzi dla Gorzanowa, małej miejscowości położonej w Kotlinie Kłodzkiej w pld.-zach. Polsce. Rozważane są problemy dotyczące ostrzeżeń przed szybkimi powodziami oraz reakcji na nie. Artykuł opisuje rolę narzędzi GIS w procesie planowania. Podkreślono rolę GIS w zbieraniu, przetwarzaniu i wymianie informacji pomiędzy różnymi instytucjami i osobami a zespołem planistycznym. Za kluczową zaletę użycia tej technologii uznano możliwość interaktywnej komunikacji z nieprofesjonalistami w trakcie procesu planowania partycypacyjnego. Pokazano również przykłady materiałów informacyjnych użytych w procesie rozpowszechniania informacji dotyczących zagrożenia powodziowego i planów reagowania na powódź.*

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