GIS Technical Evaluation of the Flood Disaster in Summer 2002 with respect to the City of Dresden on the Basis of Remote Sensing, Laser Scanner and Measurement Data

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KEY WORDS: disaster monitoring, flood analysis, IKonos, laser scanner

ABSTRACT: By the example of the extreme flood of the Elbe river in summer 2002 modern methods of analysing the flood event on the basis of high-resolution satellite data, laser scanner elevation models and terrestrial surveys are presented. For this purpose, an IKONOS satellite image mosaic consisting of 6 partial images, each of them being panchromatic and multispectral images, was computed for the area of Dresden after orthorectification. The flood line was mapped in this image mosaic that had been taken shortly after flood peak. On the basis of a DTM with 1 m grid spacing, deducted from laser scanner data, the position of the water surface level was computed by overlay with the flood line. This method was compared with terrestrial measurements on cross-section profiles of the Elbe at the crest of the flood, and assets and disadvantages were explained. Conclusively, a new flood plain is computed on the basis of the flood event and of hydrologic model computations.

1. INTRODUCTION

The flood catastrophe in Central Europe in August 2002, which brought a number of mountain streams as well as the Vltava, Elbe and Danube Rivers to unprecedented record marks, was a drastic demonstration of the fact that floods represent the most devastating catastrophes for Central Europe’s population, economies and environments. In Saxony alone, twenty people fell victim to the flood of 2002. The total damage caused by the flood is estimated to approx. 10 billion € for the entire territory of Germany and approx. 7 billion Euro for Saxony. The tributaries to the Elbe, i.e. the Gotteluba, Müglitz and Weisseritz Rivers which are coming from the hills of Saxon Switzerland and the Ore Mountains awfully damaged roads, bridges, railway lines and buildings in their mostly narrow valleys. On August 13, the discharge of the Weisseritz River, which empties into the Elbe in Dresden, had a volume of 430 m³/s, thus exceeding the average discharge of the Elbe at the water-level gauge in Dresden (327 m³/s). It inundated large areas of downtown Dresden, including the main railway station and the Zwinger castle, five days prior to the Elbe flood.

The trend to extreme floods is on the increase. Only during the past ten years Germany experienced several “floods of the century” (among them those of the Rhine in 1993 and 1995, the Oder in 1997, the Danube in 1999). Hence, the issue of floods is now coming under the focus of public interest. Floods are natural phenomena that cannot be totally prevented, but their extent and consequences can be influenced with the appropriate land conservation and regional land management policy. Flood protection truly constitutes an interdisciplinary field of action that involves various special sciences, e.g. hydrology, municipal water management, meteorology, and the methodological disciplines of geoinformatics and remote sensing. In this context, planning is the core element in many aspects, starting from the definition of flood plains on the basis of scientifically grounded identification, intervention in land utilisation (which fundamentally affects the risk of floods also in the upstream countries) up to the promotion of an approach related to flood plains (including the co-ordination between the riverside settlements upstream and downstream).

Following an overview of facts pertaining to the August flood, this paper describes specific aspects of image information recording for the management of catastrophes and the updating of geodata on the flood-related situation in the city of Dresden. It also highlights, in greater detail, issues of identifying inundated areas and of computing the water surface level in the event of a flood.

2. FACTS OF THE ELBE FLOOD IN AUGUST 2002

2.1 Meteorological Situation

In the period from 11.08.2002 to 13.08.2002 the weather of large areas of Central Europe was dominated by a huge high-level low whose centre travelled from the Gulf of Genoa toward Hungary. The relevant surface low simultaneously travelled across the eastern Alps to Poland (Vb weather situation). Warm and moist subtropical air coming from the Mediterranean and riding up over the cold air in this high-level low-pressure system generated a very wide stripe of rainfall covering Austria, the Czech Republic, eastern Bavaria, Saxony and Brandenburg. At the reverse side of the low-pressure area a northerly flow occurred, and consequently, the Ore Mountains experienced considerably growing precipitation due to the accumulation of air and orographically caused air lift-up. Unusual heavy rain fell on widespread areas. Rainfall lasted for more than 48 hours with the low-pressure system moving eastward very slowly.

Especially many of the upland sections of the drainage areas of the Elbe tributaries Müglitz and Weisseritz experienced intensive rainfall at that time. For instance, the Zinnwald-Georgenfeld station in the Ore Mountains recorded a 24-hour precipitation column of 312 mm for the period from 7:00 on 12.08.2002 to 7:00 on 13.08.2002, which was the highest one-day precipitation column ever recorded since the beginning of routine monitoring in Germany! In an area of up to 25 km² it comes close to a volume of precipitation considered to be the maximum of what is physically possible. The 72-hour reading of the rain column (11.08. to 13.08.2002) for areas of up to 25 km² in size, makes, with 406 mm, 80 percent of the supposedly highest-possible 72-hour volume of precipitation in the urban area of Zinnwald-Georgenfeld (Table 1).

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2.2 Hydrologic Situation

Due to the long-lasting, abundant rainfall since early August the soil became saturated to a wide extent. Then, the heavy rainfall that covered wide areas generated, from August 8 on, an extraordinarily extreme flood situation in Saxony. Frequently especially smaller streams chose “new” channels: roads, houses, trees, and bridges were swept away, electricity and telephone networks collapsed. Many water-level gauging stations were destroyed. The volume of inflow to water storage reservoirs was much higher than that of their outflow, thus these dams temporarily failed to fulfil their flood protection task.

With this flood event any previous flood peaks were surpassed at the main water-level gauges of the Elbe River in Saxony (Table 2). The Elbe gauge in Schöna reached the 12.02 m mark on August 16, thus exceeding the so far highest level by 2.34 m. In Dresden the water-level of the Elbe crested at 9.40 m the following day, 63 cm above the so far all-time high level recorded in 1845. Estimates by the Bundesanstalt für Gewässerkunde (BfG) give a discharge volume Q of 4,680 m³/s.

A first analysis by the German Federal Institute of Hydrology suggests that the flood of the Weisseritz and Müglitz Rivers was a 1,000-year flood, in some of their courses even a 10,000-year event. Figure 1 shows the flood levels at the gauge in Dresden.

2.3 Comparison with Previous Flood Events

The evaluation of the water levels and the flood line by comparison with previous events gave rise to some surprises (overview of flood levels in Figure 1) as the maximum water level readings for example in Dresden-Pillnitz (kilometre 42.9) and in Dresden-Niederwartha (kilometre 69.7) in August 02 were close to those of the all-time peak recorded in 1845, the gauge in the city centre (kilometre 55.7) however showed 63 cm more than this all-time peak. Apart from special protection designed for the city centre with the aid of sandbag building-up, which drove the water-level higher in this area, this was caused by further interventions in the stream channel (e.g., earth dams in the bank area, channel regulation, enforcements, diversions etc.), but more than that by the sealing and coverage of such areas.

Based on mapped flood lines of the events of 1845 and 1890 detailed research work is still going on so that final results are not yet available. But already now it is fair to say that protective measures were much more successful than those in former times, thanks to new technologies and their wide-scale use. Eventually, all historic information on both the gauged data and the mapped flood plains have to be analysed by taking into consideration the circumstances of their occurrence. In doing so, the problems of the recording of readings under the conditions of a catastrophe that are challenging even nowadays should represent another point of consideration.

3. ANALYSIS OF THE FLOOD SITUATION

With the authors having, in 2001, computed various annual flood lines of the Elbe River in the Rural District of Saxon Switzerland, after the flood catastrophe of 2002 the municipality of the Dresden, Capital of Saxony, ordered the analysis of this flood in relation to the urban area of this city, aiming at laying fundamentals to redefine the flood plain in the city. The flood plain just finally defined in 2000 was based on a 100-year event with a gauge mark of 8.17 m in Dresden, which however was dramatically exceeded in 2002 by a reading of 9.40 m. The order of the municipality included the processing of a high-resolution satellite image taken during the flood, the computation of the water surface level for the crest of the flood, the determination of effect on the inundated area (local flood peak at every point of the inundated area), and the computation of the inundated area for the assumed gauge mark of 9.00 m as a scientific precondition for new flood preventive measures.

3.1 Computation of an IKONOS Satellite Image Mosaic

In large-scale flood events image data are mandatory for catastrophe management and the subsequent analysis to determine the inundated area. These data also form the basis of first damage surveys, the improvement of hydrologic models, and the re-considering of flood plains as the legal basis for interventions in planning activities and building restrictions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Size of region</th>
<th>Precipitation (T = 24 h)</th>
<th>Precipitation (T = 72 h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban area of Zinnwald-Georgenfeld</td>
<td>1 ... 25 km²</td>
<td>350 mm</td>
<td>500 mm</td>
</tr>
<tr>
<td>Area around Zinnwald-Georgenfeld</td>
<td>1,000 km²</td>
<td>300 mm</td>
<td>450 mm</td>
</tr>
<tr>
<td>Part of the “Upper Elbe“ drainage area</td>
<td>5,000 km²</td>
<td>200 mm</td>
<td>275 mm</td>
</tr>
<tr>
<td>“Upper Elbe“ drainage area</td>
<td>12,000 km²</td>
<td>160 mm</td>
<td>250 mm</td>
</tr>
</tbody>
</table>

Table 1. Probably the biggest volumes of precipitation in areas of variable sizes, including the Zinnwald-Georgenfeld station  
(Source: Landesamt für Umwelt und Geologie, 2002)

<table>
<thead>
<tr>
<th>Water-level gauge</th>
<th>Record peak (previous value)</th>
<th>Peak flood 16.-18.08.2002, cm</th>
<th>Difference (2002 – record peak) cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ústí nad Labem (CZ)</td>
<td>1,119</td>
<td>1,185</td>
<td>+ 66</td>
</tr>
<tr>
<td>Schöna</td>
<td>868</td>
<td>1,202</td>
<td>+ 234</td>
</tr>
<tr>
<td>Dresden</td>
<td>877</td>
<td>940</td>
<td>+ 63</td>
</tr>
<tr>
<td>Torgau</td>
<td>863</td>
<td>945</td>
<td>+ 82</td>
</tr>
</tbody>
</table>

Table 2. Comparison of selected flood levels of the Elbe in August 2002 with water levels on previous events  
(Source: Regional Office of Environment and Geology, 2002)
Medium-resolution satellite image data covering wide areas promptly provide an overview of the inundated surfaces. Furthermore, satellite image data allow for very quick georeferencing, thus making them GIS-compatible. Expensive flights over the respective region and a subsequent time- and cost-consuming pre-processing of images (digitalisation and georeferencing) become unnecessary. The German Centre for Remote Sensing Data (German: DFD) of the German Aerospace Centre (German: Deutsches Forschungszentrum für Luft- und Raumfahrt / DLR) placed various medium-resolution satellite image data on the Internet as early as during the flood event (wwwdfd.dlr.de). Table 3 contains a list of the satellite image data, which display the city of Dresden during the flood catastrophe.

Local evaluation of flood events requires image data on scales of 1:5,000 to 1:10,000 which can only be achieved with IKONOS or QuickBird satellite images that have a geometric resolution of 1 m. In 2002, SpaceImaging Europe surveyed the course of the Elbe River in the Dresden region with the IKONOS satellite system during the flood on a speculative basis, i.e., without previous customer order. For the surveyed area six individual image scenes dated 18.08.02 – one day after the peak flood in the city of Dresden - were available, which represent a complete coverage of the inundated areas of the city of Dresden. These images are slightly hazy and approx. 5 % of the area is covered by clouds, but they are suitable for mapping the flood line. Thus, a “1m4m bundle product” (one panchromatic image of 1m and one multispectral image of 4 m surface resolution for each of them) in the “Geo” product form (rectified with an average positional truth of +/-50 m) was provided ordered by the municipality of Dresden. To keep the expenses of the images on the lowest-possible level, the option of image limitation by an irregular polygon in Shape-Format was chosen, which has to be defined in geographic co-ordinates when being ordered. The distributor granted a fifty percent discount in support for the catastrophe management, thus the price was $ 15 per km². The image area (Figure 2 and 3) was limited generously around the Elbe trunk and its tributary Weisseritz.

<table>
<thead>
<tr>
<th>Sensor / Mission</th>
<th>Type / Resolution</th>
<th>Date of image</th>
<th>Content / Relevance to local evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS / TERRA</td>
<td>36 channels / 250 m</td>
<td>23.08.2002</td>
<td>None</td>
</tr>
<tr>
<td>ASAR / ENVISAT</td>
<td>Radar / 30 m</td>
<td>19.08.2002</td>
<td>Very low</td>
</tr>
<tr>
<td>ERS-2 / ESA</td>
<td>Radar / 12.5 m</td>
<td>13.08.2002</td>
<td>Low, Image hardly interpretable</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>Colour / 30 m</td>
<td>20.08.2002</td>
<td>General view, 7 channels: good conditions for classification</td>
</tr>
<tr>
<td>IRS-1C</td>
<td>Colour / 24 m</td>
<td>19.08.2002</td>
<td>Basis for the computation of a water mask by the DLR</td>
</tr>
<tr>
<td>IKONOS-2</td>
<td>Colour / 1 and 4 m</td>
<td>18.08.2002</td>
<td>Very good mapping possibilities</td>
</tr>
</tbody>
</table>

Table 3. List of satellite image data of the urban region of Dresden during the flood of August 2002  
(Source: German Centre for Remote Sensing Data, DFD, as reviewed by the authors)
The image data were delivered in TIFF format and a 16-bit radiometric resolution. They split up into three stripes, each consisting of two non-overlapping partial images. The three image stripes were taken on 18.08.2002 between 10:39 and 10:40 GMT, i.e. 12:39 and 12:40 Central European Summer Time. The geometric resolution of the panchromatic image data ranges from 0.93 to 1.12 m, the radiometric one is 11 Bit. As the data were collected in the course of disaster monitoring, an extreme deviation from the vertical view (Nadir) of 39° and 31°, respectively, has to be tolerated. The mosaic covers an area of approx. 110 km². The informational content of the northern edge of the satellite image mosaic is affected by clouds and haze (see Figure 3). The very bright cloudy spots also have a general negative effect on the image’s histogram (relevant parts of the image are displayed too dark). For the sake of overview evaluation the colour transformation curve was manipulated in a way that generates an image which allows for easy evaluation with respect to the entire area. This can be optimised for partial sections provided that image-processing programmes, e.g. Erdas Imagine or Image Analysis for ArcView, are used.

It turned out to be a problem that the image data, conditioned by speculative recording, were delivered first without “Rational Polynomial Coordinate Information” (RPC), which, however, is a prerequisite to carry out an orthorectification of the image scenes. Therefore, the data had been processed again using European SpacelImaging and then being delivered in RPC files.

Figure 2. Position of the individual IKONOS satellite image scenes in the urban area of Dresden

Georeferencing, image mosaicing and fusion of IKONOS data requires the following working steps:

- Import of all image scenes from TIFF format to IMG format
- Rectification of the 6 panchromatic scenes (PAN)
- Rectification of the 6 multispectral scenes (MS) based on the control points of the associated PAN image scenes
- Mosaic creation of the individual PAN scenes within the three image stripes
- Mosaic creation of the individual MS scenes within the three image stripes
- Computation of 8bit PAN, and/or 8bit MS satellite image mosaics
- Image fusion of the appropriate original PAN and/or MS scenes (unreferenced)
- Rectification of the fusion image scenes based on the PAN rectification models (GMS)
- Mosaic creation of the individual fusion image scenes by image stripes achieving a comprehensive geographical fusion image mosaic (16bit, four-channel, file size approx. 9 GB)
- Computation of an 8bit infrared fusion satellite image mosaic and an 8bit natural-coloured fusion satellite image mosaic (each three-channel, file size each approx. 3.3 GB)
- Image compression with MrSID Geospatial Encoder
Orthorectification based on a laser scanner DGM, on an aerial image mosaic, and partly, on topographical maps was done with an average precision of approx. 0.5-2 pixels (Table 4), whereas with respect to rectification specific importance had been attached to the true positioning at the edge of the flood area. After orthorectification of the panchromatic data, multispectral data sets were rectified with the same transformation parameter. After that, mosaic creation was accom-

Table 4. Survey of the number of control points on the individual references and the rectification errors resulting there from.

<table>
<thead>
<tr>
<th>Scene name</th>
<th>Number of control points</th>
<th>Rectification errors RMS in pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>aerial image Dresden</td>
</tr>
<tr>
<td>po_99524_1_0000000</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>po_99524_2_0000001</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>po_99524_3_0010000</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>po_99524_3_0010001</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>po_99524_4_0020000</td>
<td>34</td>
<td>6</td>
</tr>
<tr>
<td>po_99524_4_0020001</td>
<td>16</td>
<td>11</td>
</tr>
</tbody>
</table>
plished without histogram adjustment of the partial scenes and fusion products were formed from the panchromatic and multispectral image data using the Brovey algorithm. Here, after a colour space transformation into the IHS space (intensity, hue, saturation), the intensity channel is replaced by the panchromatic image and then the image is retransformed. Multispectral IKONOS data are four-channelled: three channels in the visible and one channel in the infrared range. Therefore, a natural colour fusion and an infrared fusion product were computed. Finally, the black-and-white, natural colour and infrared mosaic image products, each with 1 m ground resolution, were computed into different formats (IMG, MrSID, TIFF and JPG).

3.2 Experience with Image Data used for Flood Validation

Images taken at the highest water level are important in the validation of floods based on remote sensing data so as to be able to map flooded areas precisely. Although it is possible to map the water level of areas taken in coloured images shortly after the crest of the flood which were then dried, but normally, this is not exactly enough and mostly not possible over the whole geographical area. During the flood disaster in August 2002 it was extremely difficult to carry out image flights quickly enough. Due to the vast expansion of the disaster and the lot of simultaneous flight requirements of partial areas, companies carrying out image flights could not react within an appropriate time. Thanks to the help of the Federal Army, aerial image data are available for Saxony from a Tornado flight on 17.08.02 done with special tri and pent lense opt.

The advantages of satellite data compared to aerial image data are the large geographical coverage and the comparatively low costs, unless it is required to use high-resolution satellite data (1m ground resolution). However, it is more likely that image data are distorted by atmospheric interferences due to clouds or dust than aerial images, since in the latter case the plane may fly beneath the clouds. In case of disaster monitoring, selection of high-quality image data from a satellite image archive is not possible.

Precise mapping of flood lines from image data is partially difficult. A safe classification of water surfaces based on the strong absorption of infrared rays for clear water is not possible in turbid, muddled water - as it is found in flood situations. However, a CIR colour composite is more suitable to digitalise the water-and-land lines than a natural colour image. In this case, mapping of the flood lines was accomplished by a visual interpretation based on aerial images taken during the Tornado flight on 17.08., i.e., during the highest level of water in Dresden. However, time and expenditure to georeference the Tornado aerial image data were too high, so that mapping was not done by onscreen digitalisation, but by transmission. Thus, the satellite image data are the only georeferenced image data that can be used in the GIS. The IKONOS mosaic dated 18.08.02 can be used for control and correction purposes of the flood peak line (9.40 m) and as basic information of the water-and-land lines at a level of 9 m (the level when the images were taken). The satellite photos proved to be also suitable to validate covered surfaces of the Tornado image data due to the fact that it were angle-shot images.

4. COMPUTATION OF A LASER SCANNER DTM

Digital laser scanner data recorded in November 2000 had been available for the river area. The data had been stored as ASCII table values in the x, y, z format for each of the eight TK-10 map sheets in separate files per map sheet for all elevation measuring points (.all), the elevation measuring points adjusted for buildings and vegetation (.grd), and the stabilisation points (.typ), which are mainly located in the trunk of the river. Thus, a digital terrain model (DTM) and a digital surface model (DSM) could be computed. To do so, the approximately 5-8 million dots per map sheet were read in and then triangulated. After that, a regular dot raster was produced having a resolution of 1 m in GRID format. Finally, the eight single sheets had been mosaiced whereas artefacts had to be registered partially at the cutting edges of the map sheets (pixels with 0 values), since it was not possible to triangulate beyond the map margins. The compilation of all relevant elevation measuring points (approx. 45 million dots) and the following triangulation stretched the software to its limits (ArcInfo as 32Bit application software can address only up to 2.1 Gbyte!). Based on the comprehensive geographical DTM in raster format, a contour shape was produced with spacing of contours of 50 cm after having accomplished a raster filtering process. To compute the vectorisation with a horizontal equivalent spacing of contours of 25 cm exhausted the system's capacity again and was finally given up, also for reasons of obviousness.

4.1 Computation of Water Surface Levels

Computation of water surface levels was done, on the one hand, by use of a mapped water-land line to the flood peak followed by an overlay with the DTM (method A), and on the other hand by use of terrestrial elevation measurements up to the flood peak at selected cross-sections of the river Elbe (method B). The comparison of both approaches produces some interesting results.

4.1.1 Computation of the Water Surface Levels from the Water-Land Line (Method A):

Height values were taken from the DTM recorded along the water-land line at the flood peak in Dresden, so that one height value was available for each point of the water-land line (grid spacing of the DTM: 1 m). A subsequent plausibility check showed that the height values along this line in flow direction do not reduce continuously, which could have been expected normally, but they vary relatively strongly at local points (Figure 4).

The reason for this is obviously minor planimetric deviations of the water level line, which in case of more inclined areas, slopes, retaining walls, and errors in the DTM (wrong morphological filters, e.g., buildings which are not completely eliminated) strongly affect the height values (height deviations of up to 50 cm!). Therefore, an adjustment line (simplified model) was used here (Figure 4). The linearised elevation measu-ring values along the water-land line were used as starting points to triangulate the height values of both banks of the river. Based on this TIN model, a raster with 1m resolution was computed.

4.1.2 Computation of the Water Surface Levels from Terrestrial Elevation Measurements (Method B):

During or shortly after the flood disaster, the Local Office for Waterways and Shipping (WSA) in Dresden determined the high-water's summit height from selected cross-sections along the trunk of the river by means of terrestrial surveying (kilometre 39.5 - 71.0 of the river). In 2001, an echo depth sounding of the Elbe bottom and a height measurement on the banks were carried out for all profile axes of the WSA control system in the city of Dresden (every 100 m). Thus, a height value is available for many cross-sections (although normally measured from one side) for the flood peak of 2002. Heights of cross-sections which were not measured were added by the WSA using linear interpolation.
following the kilometre marking of the river. Due to the homogeneity of the measuring values and their spatial distribution extended depending on the relevant width of the flooded area to compute the water surface levels. After that and due to the fact that peak values could be uniquely allocated, the profile axes over the whole city area, the interpolated height values might be considered as good estimates. Additionally, cross-sections were shortened so that no more overlappings occur (this applies, above all, to the bends of river) and priority is attached to the inflow rather than to the outflow (Figure 5).
Finally, the measured and/or interpolated high-water peak values were allocated to the profile axes (constant value for each axis), and based thereon, a triangulation was accomplished. Water surface levels determined this way were checked on plausibility and are now available in the TIN and the GRID format (1m resolution).

4.1.3 Assessing Both Methods: For method B, the water surface level at terrestrial measuring points has the highest preciseness. With this model, uncertainties may emerge due to the assumption of a constant water level over the whole flood width (which is not exactly true for the strong flow), due to the determination of the length of the profile axes in curvature areas and due to lacking data in-between the terrestrial measuring points. In contrast to thereto, it can be pointed out that method A has a continuously high density of triangulation points. Here, sources of errors are the inaccuracies and uncertainties when mapping the water-land-line (which were reduced by applying the adjustment calculation) as well as lacking triangulation points over the water surface.

To compare the results of both collection methods in terms of areas, the two raster data sets related to the water surface height are subtracted from each other. The mean height difference was 5 cm, the maximum height difference 49 cm. Since major errors were found in the water-land-line mapping when the results had been compared later with the satellite image, the water surface level from the terrestrial height measurements was taken as reference for further working steps (method B).

4.2 Computation of a new Flood Plain

The high-water of August 2002 is now considered as a 150-year to 200-year event. The inundated area in the city was considerably larger than the flood plain documented for a 100-year event (related to a level of 8.17 m). Therefore, the city of Dresden decided to define a new, temporary flood plain for a level of 9.00 m within a short time. Since the intended, two-dimensional hydraulic modelling could not be accomplished within the available time, a decision was taken in favour of the following pragmatic approach:

The flooded area at a level of 9 m should be determined using a combination of the available, hydraulically computed flood model for a 100-year event (HQ100) and of the real flood event of 2002. Summit height values - related to different cross-sections - were accessible for both events. Therefore, the available, hydraulically modelled HQ100 values were converted at first into the equidistant profile axes of the Local Office for Waterways and Shipping (by linear interpolation according to the kilometre marking of the Elbe). The theoretical water level heights for a 9-meter event resulted from adding a proportional difference between the summit values of the actual high-water and the modelled HQ100 (proportion stipulated by experts from the Office of Environment in Dresden). Triangulation of these theoretical water level height values based on the profile axes (modification according to method B) resulted in a TIN model of the water surface level. 3D overlay of the water level with the DTM (cut&fill operation) lead to a classification of areas with gain (water level above DTM) and loss (water level below DTM), whereas the gain areas form the potential flood plain. Since the result (GRID raster) is very diffuse, especially in the lowland, the images had been smoothed by filter operations before the resulting vector geometry were derived. The elimination of areas smaller than 500 m² shall be considered as a generalisation on the vector layer. Finally, areas not connected hydraulically with the trunk of the river Elbe had been eliminated and specific cases had been critically validated from hydrological points of view.

Since additional statements had to be made on the water level height of inundated areas, the differences between DTM and water surface level were computed on a raster basis. Here, the negative values of the examined area are in keeping with the water level heights. Additionally, the resulting flood plain was computed for the disaster protection of the city using varied heights of the water surface level from a level of 5 m every 0.5 m up to a level of 10 m.

4.3 References


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