Spatial Risk Analysis in the Town of Kyjov

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Abstract: - This article deals with the issues of risk mapping using the geographic information system. These issues are described employing a case study conducted in the town of Kyjov. The case study is focused on the principle of risk mapping, which consists of the creation of a vulnerability map, threat map and the resulting risk map. The paper demonstrates the use of spatial risk mapping method for the risk analysis. The case study presented in this article justifies the hypothesis of the suitability of the GIS for the purposes of risk mapping. In addition, the case study carried out in Kyjov maps individual types of vulnerability, in other words the major assets in the territory. Furthermore, the article deals with mapping the threats in this town. On the basis of obtained data and the maps of vulnerability and threats the case study also presents the creation of the resulting risk map. Generally, the article verifies the hypothesis of using the risk mapping method for the needs of risk analysis in municipalities.

Key-Words: - Risk Analyses, Crisis Management, Information Support, Geographic Information System, Risk Mapping, Risk Assessment.

1 Introduction

Undoubtedly, safety risks pose major problems for towns and villages. Not only do these risks affect the population of municipalities but they also impact on other valuable assets located in their territory. For instance, these assets include housing constructions, roads, power distribution, services, etc. The first move in the process of management and elimination of these risks is the identification of the risks in each particular area. There are large numbers of analytical methods used for risk evaluation. Individual methods serve to identify risks in various sectors of human activities. One of the risk evaluation methods is the one called “risk mapping”. Risk mapping uses spatial components of the risk. Spatial expression using the spatial component of risk is possible for the vast majority of safety risks. These are risks that can be expressed spatially, e.g. the leakage of dangerous chemical substances (DCS), traffic accidents, floods, etc. Above all, the major advantage of risk mapping is the high degree of visualization of results and low demands for their presentation.

2 Problem Formulation

Kyjov is located in the South Moravian region and belongs to the district of Hodonín. The town lies on the river Kyjovka and is located less than 20 km from the district town of Hodonín, 30 km from the town of Uherské Hradiště and less than 50 km from the regional administrative center Brno. The town is surrounded by the Kyjov Hills and the Chřiby Mountains located to the north of the town. The town of Kyjov is a center of folklore traditions of the sub-region called Kyjovské Dolňácko. Kyjov is situated in the northern part of the Hodonín district and comprises of four separate cadastral areas, namely: Nětčice, Boršov, Bohuslavice and Kyjov. The town center is located in the valley of the Kyjovka River along its left bank. The lowest point of the city is at 183 m a.s.l. to the south of the town where the Kyjovka River leaves the cadastral area. The highest point is the Chapel of St. Roch located at 257 m a.s.l. The town is surrounded by the deforested hilly areas with vast fields, vineyards, and orchards. The peaks of the Věteřov Highlands, the Ždánice Forest and the Chřiby Mountains are situated not far from Kyjov to the west and north. There are many organizations and institutions available for the citizens of Kyjov, such as sports facilities or institutions of state administration and local government. The most important institutions include land registry, religious and social institutions, kindergarten, elementary and secondary schools, building authority, cinema, community center, library, museum, senior citizens center, nursing home, youth center and others. Industry is also an inherent part of the town. The largest

employers in the Hodonín district are the Kyjov Hospital and companies, such as Vetropack Moravia Glass and Šroubárny Kyjov, the screw factory.

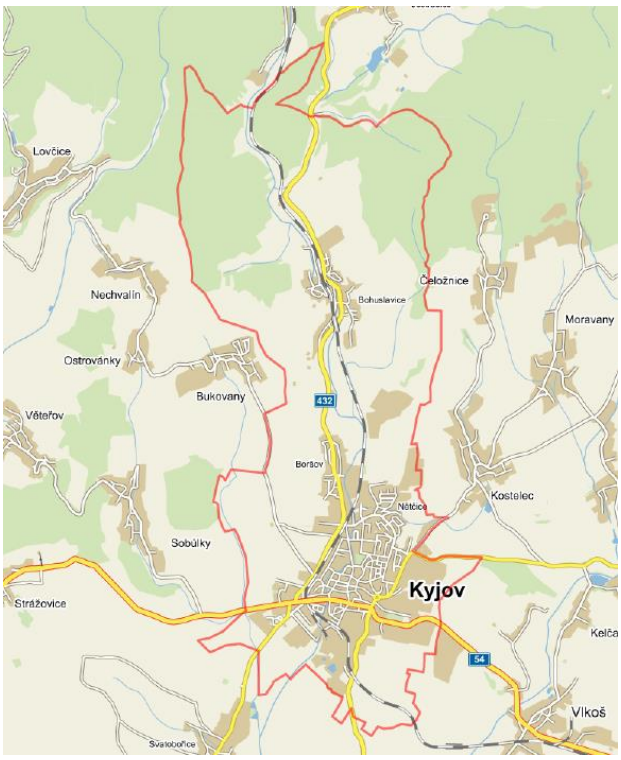

Fig. 1. The map of the Kyjov cadastral area.

Kyjov was also known for its oil industry and lignite. Lignite extraction caused the introduction of the mining industry in Kyjov. The remains of the mining industry are visible in the landscape even today. The map of the Kyjov cadastral area is shown in Fig. 1. Maps of risk, threat and assets are significant benefits for the town and its administration. The possibility of presenting the acquired information to the public is also advantageous.

The use of the risk mapping method for the risk analysis in Kyjov is associated with a major problem, which is the absence of spatial data describing the threats active in the town. This includes information about most types of threats, especially these with clearly defined spheres of action. These are, for example, DCS leakages, floods, etc. Therefore, the major part of spatial data describing individual threats must first be created and implemented into the geographic information system. Subsequently, the actual risk mapping can be performed.

Table 1 describes the properties of the selected analytical methods. The primary area of the method is marked X and the secondary area is market O. As we can see in table the methods RM (risk mapping) is most suitable for risk analysis of the city territory. Name of the methods are: RM – risk mapping, FEI – Fire and Explosion Index, CEI – The Composite Exposure Indicator, CPR 18E – Purple Book, What-if, HAZOP – Hazard Operation Process, FMEA – Failure Mode and Effect Analysis, FTA – Fault Tree Analysis, ETA – Event Tree Analysis [32].

Current risk analysis results do not identify risks in space, but only in terms of their type. Spatial risk mapping is represents a benefit for the staff of crisis management and for the population [24].

3 Problem Solution

The risk mapping method is based on two basic maps, namely a vulnerability map and a threat map. The vulnerability map contains basic data about the spatial arrangement of vulnerable assets while the threat map contains a spatially expressed overview of threats active in the given territory. The making of vulnerability and risk maps is based on a basic risk equation that identifies risk as a function of vulnerability and threat (see Equation 1). The resulting risk is then given by the presence of threat and vulnerability in the same territory. Thus, the resulting risk map is created by the intersection of the vulnerability and threat maps. The principle of risk mapping is depicted in Fig. 2.

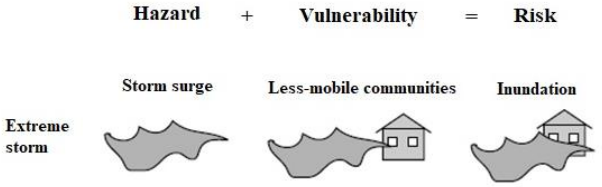

Fig. 2. The principle of risk mapping.

$$Risk = T(H(Eh),V(Ev)) \quad (1)$$

Tab. 1. The table of comparison of analytical methods [32]

	RM	FEI	CEI	CPR 18E	What-if	HAZOP	FMEA	FTA	ETA
Identification of risk sources	X	X	X	X		O			
Determination of emergency scenarios			O		X	X	X	O	O
Estimate the probability scenarios								X	X
Estimate of possible consequences	O	O	O		O	O	O		
Determination of risk	O	O							
Risk assessment	O								

2.1 Materials and methods

For the case study, general methods of analysis, spatial risk mapping, synthesis and observation were used. In addition, methods of observation and abstraction were used. In particular, these methods were employed to obtain and process information needed to identify assets and threats in the territory of Kyjov.

The spatial data found in the ArcČR 500, the geographical database, was used to create the threat, vulnerability and risk maps, while the SW application QGIS 2.6.1 was used for processing this data. The SW Terex 3.1.1 was used to identify areas threatened by the leakage of dangerous chemical substances. The flood-land model of the Dibavod database was used for the 100-year, 50-year and 20-year floods. In addition, the data obtained from the CENIA (Czech Environmental Information Agency) and State Land Authority was used to identify locations threatened by soil erosion.

2.2 Risk mapping in Kyjov

As previously mentioned, the risk mapping method is based on the creation of vulnerability and threat maps. Individual maps are based on obtained data and its conversion into spatial form.

2.1.1 Vulnerability map

Vulnerability is presented by assets located in the territory of Kyjov. In particular, the crucial assets/vulnerability in Kyjov include:

- Fire Rescue Service;
- Health-care facility – Hospital in Kyjov;
- Police of the CR and municipal police;

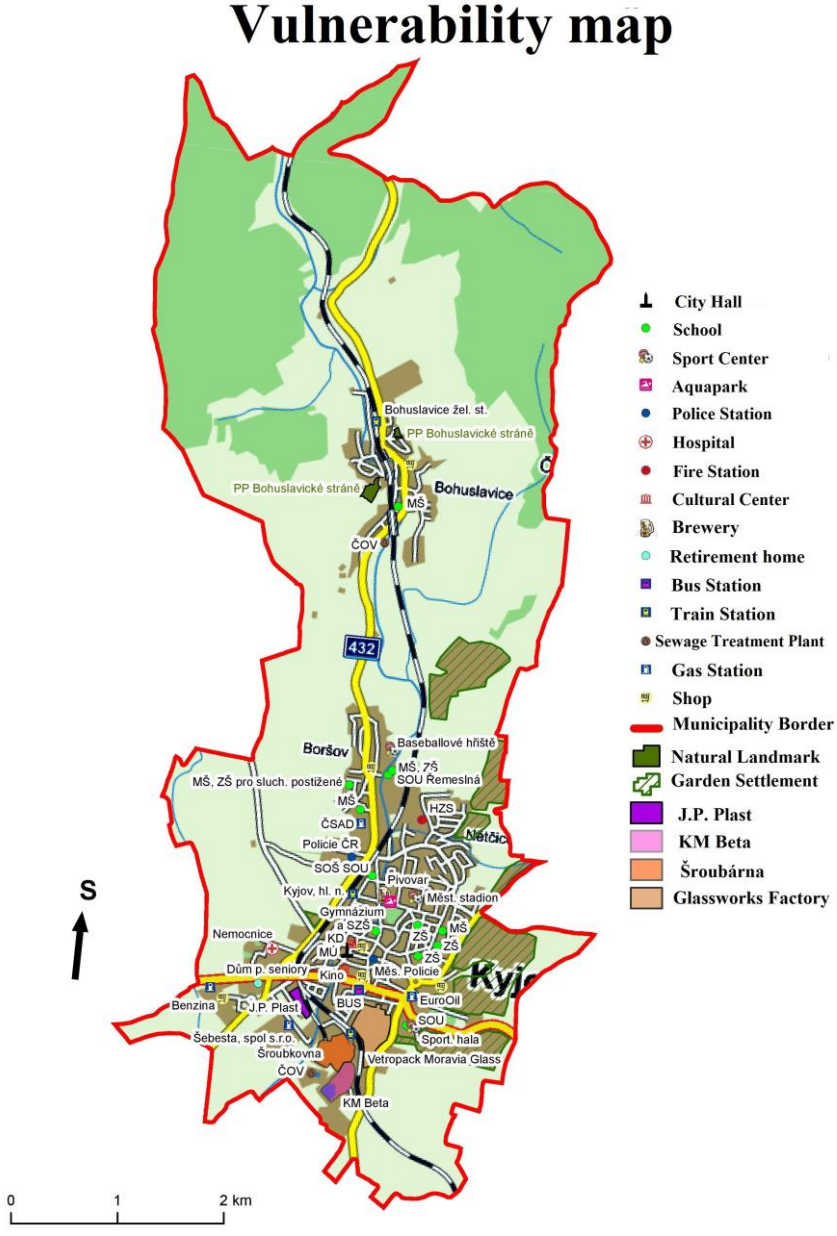

Fig. 3. The vulnerability map.

- Town authority;
- Cultural Centers – Community center, Panorama Cinema;
- Outdoor swimming pool;
- Senior citizens center;
- Train and bus stations;
- Shopping centers – Lidl, Kaufland, Penny, COOP, and Hruška;
- Residential areas – the center of the town, housing estates Lidická, U Vodojemu,
- Klínky, Za Stadionem, Zahradní, Boršov, Nětčice, Bohuslavice;
- Gas stations – Šebesta, spol. s r.o., EuroOil, Benzina, ČSAD, KRALUPOL a.s., PRIMAGAS s.r.o.;
- Selected schools in Kyjov – Primary schools Komenského, Újezd and Dr. Joklíka, Klvaňa Grammar School and School of Nursing Kyjov, Secondary Vocational School for Car Mechanics Kyjov, and Secondary Vocational School Havlíčkova Kyjov;

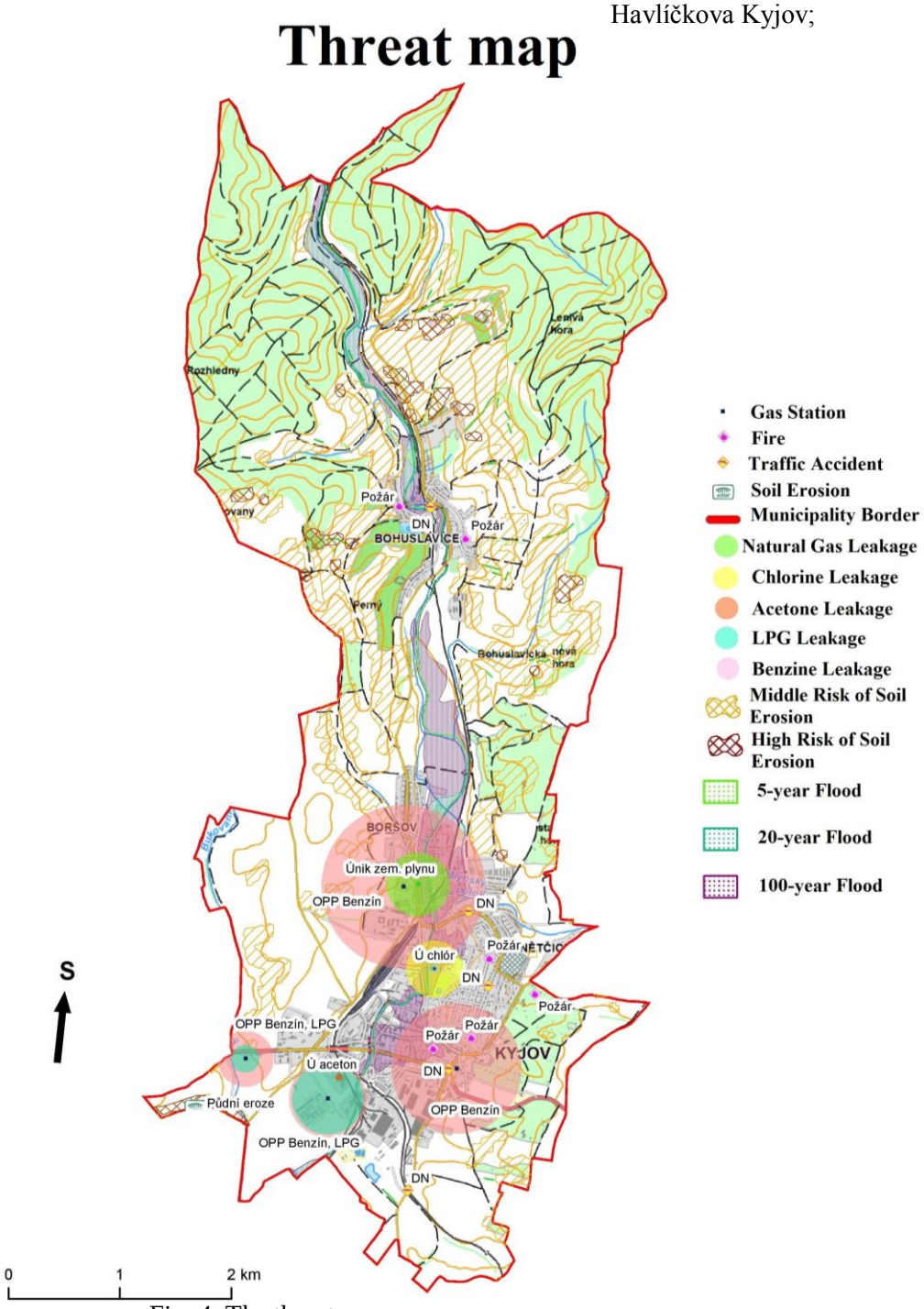

Fig. 4. The threat map.

- Companies – Kyjov Brewery, glass factory Vetropack Moravia Glass, Šroubárny Kyjov (the screw factory), J. P. Plast, KM Beta;
- Evacuation centers (facilities) – Primary Schools Dr. Joklíka and J. A. Komenského, Secondary Vocational School Havlíčkova, rooming houses.

Individual assets were entered to the vulnerability map, which is depicted in Fig. 3. Most assets are concentrated in the town center.

Detailed parameters/attributes of individual assets are recorded in the geographic database. These include, for instance, the numbers of rescue equipment and employees, the numbers of students and employees in school facilities, the capacities of sports grounds and cultural centers, etc. They could not, however, be listed in this article because of their great scope.

Making the vulnerability map is the first step of risk mapping; it is followed by making the threat map.

2.1.2 Threat map

The threat map is the second stage of creating the resulting risk map. The threat map was created based on information about threats in Kyjov. This information was obtained from the publicly available sources and additional data was provided by the Department of Crisis Management in Kyjov.

The main safety threats include:

- Flood;
- Fire;
- Accidental leakage of a dangerous chemical;
- Traffic accident;
- Soil erosion.
- The following threats can also be taken into consideration:

Natural emergency events

- Abiotic emergency events;
- Biotic emergency events;

Anthropogenic emergency events

- Technogenic emergency events;
- Sociogenic emergency events;
- Agrogenic emergency events;

The threat map is depicted in Fig. 4.

Nevertheless, these threats were not included in the threat map. Reasons for their non-inclusion in the resulting threat map are: their great scope of activity, low likelihood of occurrence, low impact on safety of the town, absence of necessary data or high complexity of spatial expression.

2.1.3 Risk map

The resulting risk map was created by the intersection of the vulnerability map and threat map. The risk map of Kyjov is presented in Fig. 5. The detail of the most risk area is shown in Fig. 6.

The resulting risk map is depicted in Fig. 5 and 6. It contains an overview of assets in the territory of the town of Kyjov together with major threats. The intersection between assets and threats constitutes the resulting risks. The map makes it easier for people to find out if they are in hazardous areas, and to prepare for problems they may encounter.

The main risks in Kyjov

Flood

In the town of Kyjov and its adjacent parts a total of 3 levels of flood activity are possible. Levels of flood activity indicate the extent of flood danger. These levels are bound to the standard limits, which are usually water-levels or flow rates recorded in the measuring profiles of watercourses, or to limit and critical values of other phenomenon.

- 5-year flood

The 5-year flood is marked green in the risk map. Areas that would be flooded are almost negligible. Water stays in a river bed and the potential overflow is imminent only in a small surrounding valley, which is not a major problem.

- 20-year flood

Other risk represented in the map is a 20-year flood, which threatens a wider zone and is marked in the map by a blue dot-dash line. A possible source of the flood is the watercourse beginning in the Kyjov Jih industrial zone but water is held in the river bed there and does not cause practically any damage to Kyjov. This is due to the fact that the river banks in Kyjov have been enlarged so that in the event of increasing water level the flood would not pose such a great threat as most water would remain in the river bed. The next overflow zone during the 20-year flood would be the football field in the village of Bohuslavice.

- 100-year flood

This flood is marked by violet color in the map. In this case, the Lidická housing estate would be included in the flooded zones; the flood would then move on through the Riegrova Street to the Panorama cinema. In addition, the bus station with the LIDL store, housing estate and Jungmannova and Kollárova Streets, through which the water would continue to flow towards the square, would become flooded. This would mean that pharmacies, town hall, municipal authority, municipal police, community center, and individual shops would be at risk. Through the Komenského Avenue the water would reach the park, and it would further endanger the local brewery, outdoor swimming pool, town stadium, health center, and the Klvaňa Grammar

School and School of Nursing Kyjov. In addition, the housing estate Mezi Mlaty, the senior citizens center and the museum at Palackého avenue would be flooded. In the cadastral areas of Nětčice and Boršov, the local cemetery and houses would also be flooded. In the village of Bohuslavice the local elementary and nursery schools, the post office and local football field would be endangered as well.

Fuel leakage

The risk map shows areas where there is a possibility of fire, explosion and leakage of fuel. The most frequent places include gas stations where there is a risk of fuel ignition or explosion of natural gas. Parameters of individual sources of risk are presented in Table 1. These are designation of the source, DCS type, DCS quantity, type of threat, hazardous area, and number of persons at risk. Individual parameters are given for the maximum amount of the DCS.

Gas station Šebesta spol. s r.o.

Gas station Šebesta spol. s r.o. residing at Svatoborská 591, 697 01 Kyjov provides gasoline and diesel fuels.

Gas station Benzina

Gas station Benzina residing at Strážovská 1381/9, 697 01 Kyjov provides gasoline and diesel fuels.

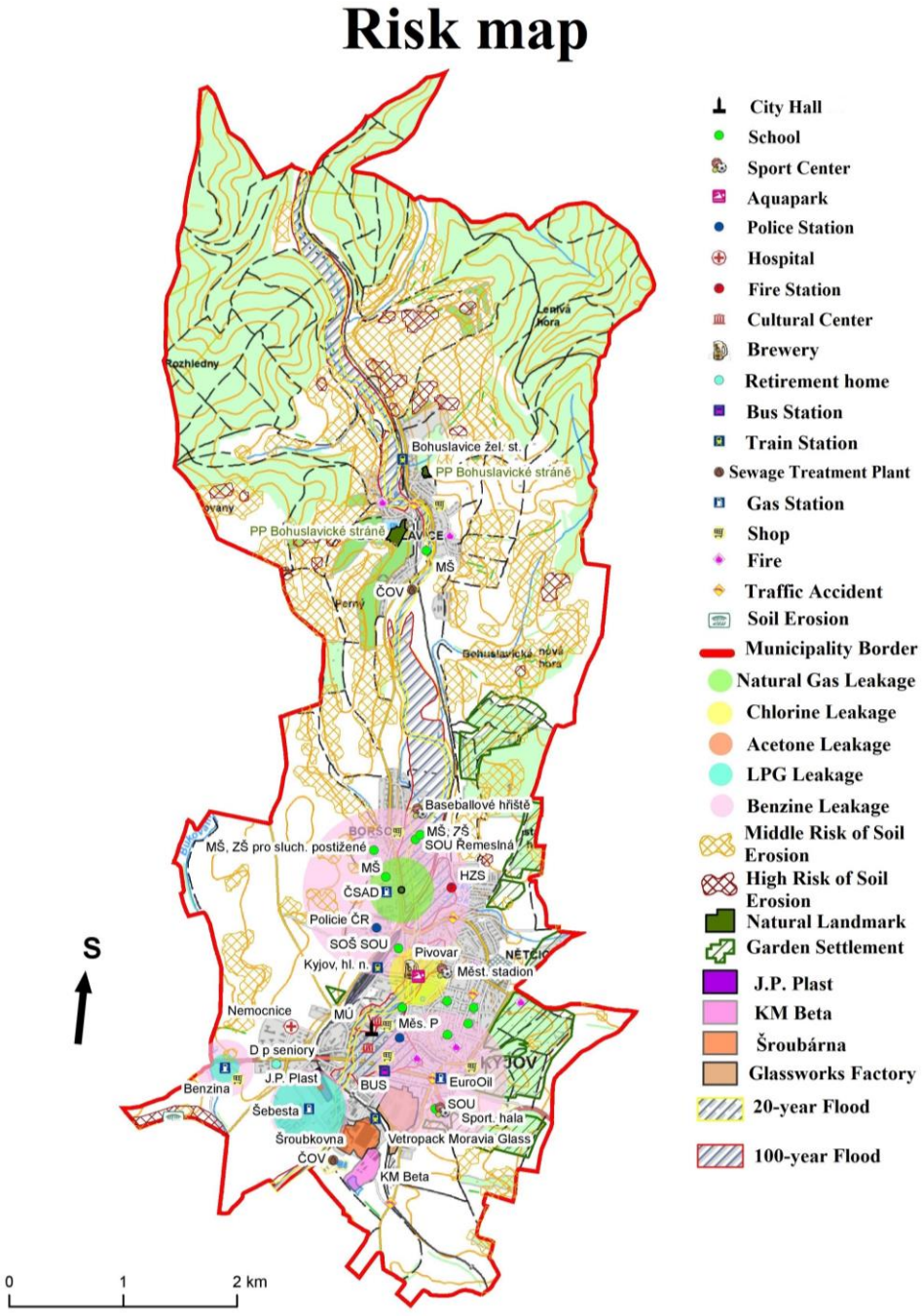

Fig. 5. The risk map.

Gas station EuroOil

Gas station EuroOil residing at Tyršova 135/1, 697 01 Kyjov provides gasoline and diesel fuels.

Gas station ČSAD

Gas station ČSAD, residing at Boršovská 2228/5, 697 01 Kyjov provides diesel fuels.

Leakage of dangerous chemical substances

The risk map shows where the DCS leakage may occur. For these risks, the companies Vetropack Moravia Glass, Šroubárny Kyjov, J.Plast s.r.o., and outdoor swimming pool Kyjov were chosen.

Vetropack Moravia Glass

Vetropack Moravia Glass company specializes in the production and sale of container glass for the food, canning and beverage industry.

A possible threat is the leakage of oil in a quantity of 10 tons stored within the company.

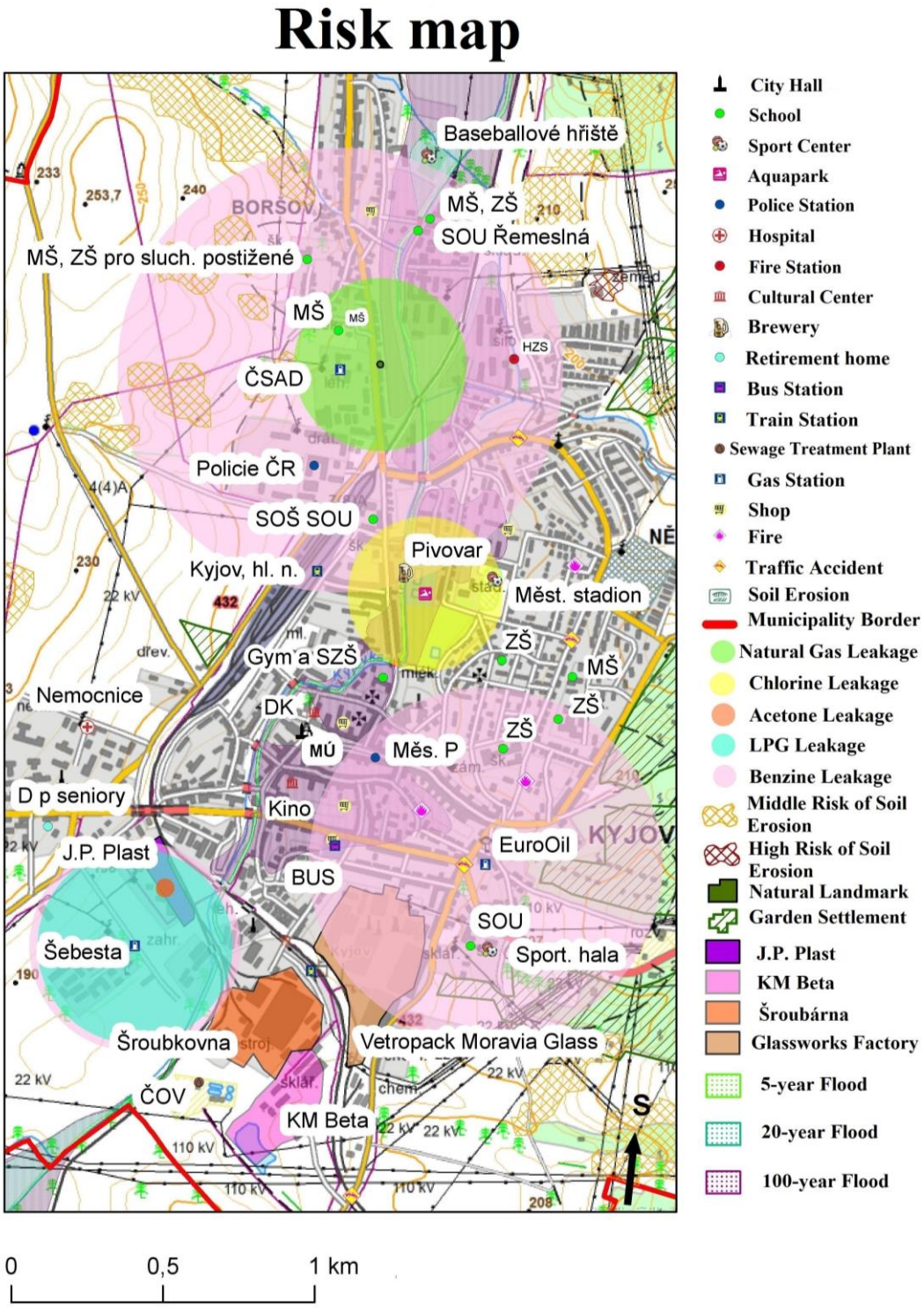

Fig.6. The detail of resulting risk map

When oil containers are emptied they are removed by a specialist company and replaced. As a safety measure and to prevent contamination of the soil and the environment, the company has a large collecting tank under its storehouse, which would take up all the oil in the event of an accident. [25]

Šroubárny Kyjov, the screw factory

Šroubárny Kyjov is a longtime traditional producer of fasteners, which are made by hot-forming. The company keeps a large amount of technical oil that could, in the event of leakage, contaminate the environment. As a safety measure, the company has a collecting pit whose capacity corresponds to the amount of oil stored. [26]

J. P. Plast, s.r.o.

The company J. P. Plast residing at Svatoborská 988 in Kyjov was established in 1994 and specializes in the production of plastic containers. At the premises of the company there is a risk of fire and leakage of the DCS. There is polyethylene in the volume of 75 tons, 200 liters of acetone and 1,500 liters of hydraulic oil at the factory site. In addition, the company stores over 40,000 pieces of plastic products. Should the acetone tank be exposed to a large-area fire, it is necessary to move away any persons within a distance of 31 m because there is a danger of first-degree burns in this area. However, this sector would not pose a great risk to the residents of Kyjov because the evacuation would occur only at the premises of the company. [24] Nevertheless, a substantial problem would be the fire of the storehouse with products and other plastics.

Outdoor swimming pool in Kyjov

The outdoor swimming pool is located in the town park and it provides the possibility of refreshment in two swimming pools. A possible threat is the leakage of chlorine gas used to clean water. Chlorine is stored in steel pressure cylinders with a content of 65 kg. Pressure cylinders are kept in a special storehouse that must be ventilated, and the maximum of 10 pressure cylinders can be stored there. This storehouse is located outside the swimming pool area. However, a single pressure cylinder is connected to a device for water purification in the swimming pool area. Any failure of the single pressure cylinder with a one-time gas leakage forming the cloud would mean that all persons found within 256 m of the leakage could be exposed to a toxic substance. This threat would be influenced by the direction of wind. This area (circular sector) would require evacuation of persons. A recommended exploration of the area affected by toxic concentration would have to be carried out up to 438 m from the leakage point. Exposure of chlorine can cause irreversible damage to the immune system, blood, heart and respiratory tract. In particular, chlorine is dangerous because it reacts with moisture in the respiratory tract and the hydrochloric and hypochlorous acids are produced; these have a caustic effect on the lungs and cause death. [27] [28]

Natural gas leakage caused by disruption of the gas pipeline

There is a relatively large gas network in Kyjov, which is mainly underground. A high-pressure gas pipeline leads through the west end of the Kyjov cadastral area. This pipeline has a diameter up to 400 mm and is under ground. Further, there is a high-pressure gas pipeline with a pressure of 0.4 MPa to 4 MPa. Largely, this pipeline is made of steel. The main purpose of this pipeline is to supply gas to the gas pressure reducing stations from where the gas is supplied to the customers through the medium and low-pressure pipelines. In the medium-pressure pipeline the gas pressure is 5 kPa to 0.4 MPa and the diameter of the pipes is about 160 mm. In the low-pressure pipeline the gas pressure is up to 5 kPa and the pipe diameter is smaller. Usually, both types of pipes are made of polyethylene.

The pipeline may be damaged during excavation works and the natural gas which is highly explosive can leak to the surroundings. According to the list of emergency events (EE) in the cadastral area of Kyjov, this already happened on 31 August 2016 in Boršovská Street in Kyjov, Netčice. Fortunately, there was no explosion during the EE. This EE was modeled to identify possible consequences (see the risk map). During such EE the population within a radius of 285.8 m from the point of the leakage would have to be evacuated. In a cone with a side of 94 m people would be threatened by the direct flash fire. This cone would be dependent on wind direction. A possible pressure wave could be felt by people within 632 meters from the point of the leakage.

4 Conclusion and discussion

The case study of risk mapping in Kyjov proves the suitability of this method for practical applications. The outputs of risk mapping correspond to the real risks active in the territory of Kyjov. Due to restrictive conditions in the field of the selected threats, the case study provides space for further elaboration. Especially, this includes the spatial expression of other types of threats. In addition, there are threats and risks which are less likely to occur. The creation of spatial data for these threats, however, represents a valuable contribution to the area of risk analysis in Kyjov. Another topic

for future research is making a map of cumulative risks. The map of cumulative risks makes it possible to divide the Kyjov territory into individual risk fragments depending on the degree of risk in individual spatial fragments.

Therefore, the obtained results form the basis for further work and development of these findings. The case study has shown that DCS leakages are one of the most serious risks in Kyjov, mainly due to possible extensive consequences. For this reason, DCS leakages are substantial risks, despite the lower probability of their occurrence. The second most serious risk which poses a major threat is the flood.
From the perspective of assets, the most vulnerable are the Integrated Rescue System and the population. The vulnerability of assets is primarily given by their value and human life represents the highest value possible. A particular number of the population found in hazardous areas can be read from the resulting risk map.

The case study presented in this article justifies the hypothesis of the suitability of the GIS for the purposes of risk mapping. A beneficial outcome of the case study is also the verification of the hypothesis of achieving a high degree of visualization of risks within the territory of the municipality. This fact makes it possible to effectively inform both population and professionals about the occurrences of specific risks in a particular area [33]. Moreover, the inhabitants can easily find out what risks there are and where exactly they can occur. All this allows responsible professionals to focus on solving a particular type of risks in any particular area. Therefore, precautions do not have to be taken throughout the whole town. In addition, the article creates suitable conditions for further expansion when using the GIS in other areas of security research.

The risk mapping process with the use of the GIS enables the spatial expression of the risk and the overall visualization [34]. Owing to this, the outputs obtained are easier to understand and are applicable in real-life conditions. Moreover, maps of threat, vulnerability and risk are an effective tool for the identification of risk areas in the given locality, which enables safety measures to be taken in order to manage the risks or eliminate them [35]. However, there are some problems connected to the effective use of the GIS for risk mapping, namely the knowledge of the system and the demands on time for completing the work. The data for GIS are the other problems. The problem is mainly the data of risk analysis area - the specific data. The authorities can solve these problems be providing experienced workers who could perform the analyses for the individual regions.

A further research is conditional on testing the method in a larger territory, which requires the collection of extensive quantities of data.

With the GIS and other information technologies being increasingly used in public administration one can also anticipates the increase in the skills of the responsible staff. This general fact will contribute to a more efficient use of the GIS within the risk mapping and it will also help to solve the main problems.

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