

Characteristics of potential hazards such as chemical, flood and hydrometeorological to life and health occurring in the area of The Capital City of Warsaw

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Summary:

This paper details the threats to life and health in the area of the capital city of Warsaw, with particular emphasis on existing industrial plants, their production and materials stored therein. It discusses the chemical, transport, flood and hydrometeorological hazards. This paper describes in detail the causes of risks and provides their assessment. The work contains a rich set of factual data related to the characteristics of Warsaw location and threats to its citizens.

Key words: land relief of the capital city of Warsaw, chemical hazards, facilities with hazardous substances, flood and hydrometeorological hazards, risk assessment.

Warsaw is situated on the Vistula river, which involves a section of 27 km within the city. The bed of the Vistula river that runs from the southeast to the northwest divides the city in the left-bank part (Warsaw side), lying on a denudation moraine plain (altitude up to 115 m AMSL) and the right-bank part (Praga side), situated in the valley (altitude up to 90 m AMSL). The bed's width varies from 1 km in the southern part of the city, to 0.6–0.7 km in the northern region, where it is more compact.

The lowest natural point is at 78 m AMSL in the valley of the Vistula River at the border of the capital city of Warsaw with Winnica housing estate of Jabłonna municipality; the highest natural point is at 116 m AMSL in the south—west part of the site where the Palace of Culture and Science was built. The highest artificial point is Szczeńliwicka Hill (139 m AMSL). The average

level of Warsaw area represents about 100 m AMSL.

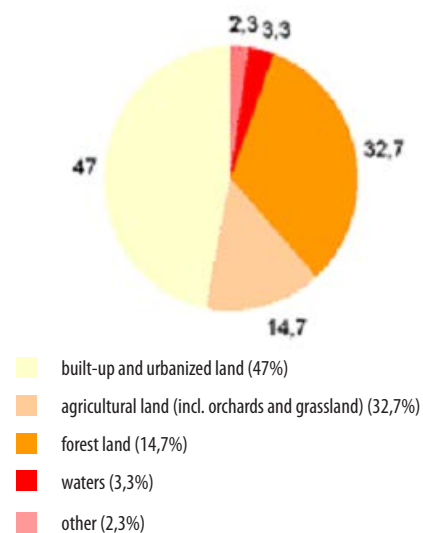


Figure 1: Warsaw area by type of use.

The Capital City of Warsaw covers an area of 518 km² and extends over 30 km on the north – south axis and 26 km on the east – west axis.

The Act of March 15, 2002 on the structure of the capital city of Warsaw (Journal of Laws No. 41, item 361, as amended) provides that Warsaw as the capital of the Republic of Poland is a municipality having the status of the city with county rights. It consists of 18 supporting units – the districts.

1. The boundaries of Warsaw's districts:

The boundaries of the district Warsaw-Bemowo: the south side of Kampinoska street, the south side of Ksiezykowa street, an extension of Powazkowska str., the south side of Powazkowska str., the west side of al. Armii Krajowej, the western border of the Kolo grove, the west side of the railway line crossing Górczewska str. and Połczyńska str., then continues on the section of Dzwigowa str., along the south side of the railways to Krancowa str. where it intersects Połczyńska str. by its east side and runs to Podgrodzie str., Batalionow Chlopskich str., then through the fields along Azurowa str. up to Fortowa str., garden plots, Fortowa str., Henryka Hubala Dobrzanskiiego str., along its extension to Radiowa str., which intersects, and by the west side of Estrady str. to Kampinoska str.

The boundaries of the district Warsaw-Białoleka: the northern edge of the Gen. Stefan Rowecki bridge at the north along the course of the Vistula river parallel to Przyrzecze str., along Brzozowa str., Szkolna str. up to the railway Warsaw – Legionowo, along the railroad tracks to the Choszczówka station, Chlubna str. up to the edge of Choszczówka forest, the Choszczówka forest edge, a dirt road to the Bródno Canal, Kobia-lka str., Olesin str., Chudoby str., Berenson str., to the west up to a dirt road off Oknicka str., along the dirt road to Torunska Route, along the Torunska Route up to the course of the Vistula river.

The boundaries of the district Warsaw-Bielany: the course of the Vistula river, the northern edge of the Gen. Stefan Rowecki bridge, the north side of al. Armii Krajowej, the south side of Powazkowska str., an extension of

Powazkowska str., the south side of Ksiezykowa str., the south side of Kampinoska str., the west side of Estrady str., Rekopis str., the west side of Kampinos National Park, Wyjsciova str. crosses Trenow str. and along Estrady str., Pancierz str., Pulkowa str. Dziwozony str. to the Vistula river.

The boundaries of the district Warsaw-Mokotów: extension of Batory str., along Batory str., Boy – Zelenski str., the south side of Unii Lubelskiej Square, Klonowa str. Spacerowa str., Gagarin str., Podchorazych str., Czerniakowska str., southern border of MPWiK (Warsaw water supply plant) areas, the course of the Vistula river, the course of Wilanówka river, extension of Zawodzie str., the south side of Zawodzie str., the south side of Augustówka str., the north side of Goplańska str., the east side of Nemirowska str., the south side of Nałęczowska str., the east side of Sobieski str., the south side of Arbuzowa str., the west side of Przy Grobli str., the south side of al. Wilanowska, the north side of Dolina Służewiecka str., the east side of Pulawska str., the south side of al. Wycsigowa, an extension of Boksterska str., the south side of Boksterska str., an extension of Boksterska str., the west side of the railway line Warsaw – Radom, Zwirki i Wigury str.

The boundaries of the district Warsaw-Ochota: the south side of the railway line on the section Warsaw Wlochy – Warsaw West, WKD line, Al. Jerozolimskie, Chałubiński str., al. Niepodleglosci, Batory str., an extension of Batory str., Zwirki i Wigury str., the south – west side of the railway line with stations Warsaw Rakowiec and Warsaw Al. Jerozolimskie.

The boundaries of the district Warsaw-Praga-Południe: the Warsaw cross-city line, Boruty str., an extension of Boruty str., the north side of the railway line Warsaw – Siedlce running along Zabraniecka str. and Gwarkow str., to the south on the eastern side of the prison, the northern, eastern and southern border of the Olszynka Grochowska grove, the west side of Torowa str., the south – east side of Marsa str., the south side Ostrobramska str., the north – east coast of Nowa Ulga Canal, the course of the Vistula river.

The boundaries of the district Warsaw-Praga-Północ: the north side of Gen. Grot – Rowecki bridge, the north side of Toruńska str., the east

side of the railway line Warsaw–Legionowo with a station Warsaw Praga, the north side of the railway line running along the Platynowa and Naczelnikowska streets, an extension of Boruty str., Boruty str., the Warsaw cross-city line, the course of the Vistula river.

The boundaries of the district Warsaw-Rembertów: parallel to Skrajna and Powstancow streets by the northern boundary of garden plots, to Chełmżyńska str. along the northern boundary of the forest to Zolnierska str. (crossing it by the boundaries of Zabki and Zielonka community), from Kadrowa str. along the north side of Paderewski str. to Budnicza str., the west side of Mokry Lug str. to the railroad tracks, the west side of the railway line Warsaw–Tuszczyńska str. to Cyrulikow str., the northern boundary of Cyrulikow str. to Okuniewska str., then to the south along the eastern part of the forest to the extension, the north side of Korkowa str., the eastern and northern boundaries of the factory area, an extension of Gozdzikow str., the east side of Rekrucka str., the south-east side of Marsa str., the west side of Torowa str., the southern, eastern and northern boundaries of Olszynka Grochowska grove to prison, to the north (at the east side of the prison) to Gwarkow str., the north side of Gwarkow str., the east side of Skorpionia str., to the north along the western boundary of the grove to the garden plots at Skrajna str.

The boundaries of the district Warsaw-Śródmieście: the north side of the peripheral railway line on the section from the John Paul II str. to the Vistula river, the course of the Vistula river, the south boundaries of MPWiK (Warsaw water supply plant) areas, Czerniakowska str., Kadetow str., Gagarin str., Spacerowa str., Klonowa str., the south side of Unia Lubelska Square, Boy-Zelenski str., Batory str., al. Niepodległości, Chałubiński str., John Paul II str.

The boundaries of the district Warsaw-Targówek: the border runs through Radzymińska Mall, crosses Radzymińska str., further through garden plots, Kamrową str., Lodygowa str., Dolna str., through garden plots to Skorpionia str., the east side of Skorpionia str., an extension of Skorpionia str. to the railway line, the north side of the railway line Warsaw-Siedlce running along Gwarkow and Zabraniecka streets, the north side of the railway

line running along Naczelnikowska and Plantowa streets, the east side of the railway line Warsaw–Legionowo with a station Warsaw–Praga, the north side of Torunska str. to the mall.

The boundaries of the district Warsaw-Ursus: the western boundary to the north along the railway line, from Warsaw–Skierniewice to Warsaw-Odolany, from the contact between Warsaw-Odolany railway line with Warsaw-Poznan line along the west side of the Warsaw-Poznan line to Warsaw-Skierniewice line, diagonally by the railroad tracks to Zapustna str., along the southwestern border of Zapustna str., the cemetery, Badylarska str., the west side of Badylarska str., the north side of the railway line, the northern edge of Makowa str., Bodycha str., the north side of Bodycha str., to the north from Bodycha str. several meters to the north from Gorna Droga str. Gorna Droga str. is a newly-built residential road providing access to the housing area. This street does not come up to the railway line Warsaw Skierniewice. Further on, the border runs through the fields intersecting Piastowska str., which in Piastow is called Wincenty Witos str.. Then the boundary runs along the south side of railway line (partly along Szarych Szeregow str. in Piastów) up to Noakowski str. in Piastów, further to the north the boundary runs along the western edge of the rail connector of Warsaw-Łowicz and Warsaw-Skierniewice lines. Boundaries of Ursus, Piastow na Ozarow municipality converges at the culvert under Konotopa Canal subgrade. This culvert is south of Bony str. in Ursus.

The boundaries of the district Warsaw-Ursynów: the western boundary of green areas between Karnawal and Czempinśka streets, the north side of Czempinśka str., the west side of the railway line Warsaw-Radom, an extension of Bokserska str., the south side of Bokserska str., an extension of Bokserska str., the south side of al. Wycsigowa, the east side of Pulawska str., the north side of Dolina Służewiecka str., the south side of al. Wilanowska, the west side of Przy Grobli str., the south side of Arbuzowa str., the top of the Warsaw Escarpment, the northern, western and southern boundaries of the Natolin Reserve Park, the top of the Warsaw Escarpment, the west side of Wczasowa str., Prawdziwka str., along the west side of Osiedlowa str., the south

side of Kuropatwy str. through Pulawska str., along garden plots, up to Gogolińska str., by the railroad tracks, garden plots to Kórnicka str., by extension of Dawidow str., the west side of the railroad tracks to S. Starzynski str., by fields to Kinetyczna str., Czempińska str.

The boundaries of the district Warsaw-Wawer: from the Vistula river along the Nowa Ulga Canal, further the section of Ostrobramska str., Marsa str., Rekrucka str. (to the east above Begonii and Starego Doktora streets), the north side of Korkowa str., the eastern border of the Mazowiecki Landscape Park, up to Letniskowa str. (on the section between Wczasowa and Wiejska streets), Wiejska str., Bruckener str., Ziarnista str., Werbeny str., crossing Wal Miedzyszyński str., to the west – the Vistula river.

The boundaries of the district Warsaw-Wilanów: the course of the Vistula river, the border crosses Wal Zawadowski str., Włoki, Sagi, Wiechy, Waflowa, Luk Drewniany streets, the top of the Warsaw Escarpment, the southern, western and northern boundaries of the Natolin Reserve Park, the top of the Warsaw Escarpment, the south side of Arbuzowa str., the east side of Sobieski str., the south side of Naęczowska str., the east side of Nemirowska str., the north side of Goplańska str., the south side of Augustówka str., the south side of Zawodzie str., an extension of Zawodzie str., the course of Wilanówka river.

The boundaries of the district Warsaw-Włochy: the south side of the railway line Warsaw-Lowicz, the south-west side of the railway line with stations Warsaw Al. Jerozolimskie and Warsaw Rakowiec, the west side of the railway line Warsaw-Radom, the north side of Czempinska str., the western border of green areas between Karnawal and Czempińska streets, the administrative border of Raszyn municipality (eastern), and Ursus district (eastern).

The boundaries of the district Warsaw-Wola: the south-western boundary of Industrial Zoliborz built-up areas, the north side of the peripheral railway with station Warsaw-Gdanska, John Paul II str., Al. Jerozolimskie, WKD line, the south side of the railway line on the section Warsaw-Włochy-Warsaw West, the west side of the railway line crossing Połczyńska and Górczewska streets, the west side of the Kolo grove, the north-west side of al. Armii Krajowej.

The boundaries of the Wesola district: from the north the woodland along Okuniewska str. comprising Pl. Wojska Polskiego housing estate to Cyrulikow str. (in Rembertów district), from the west: Gajowa str., the area adjacent to Bukowa and Sosnowa streets, Wspolna str., Jagiellońska str., the woodland of the Mazowiecki Landscape Park up to Wawerska str., Wawerska str. to Kazita str., to the south-east through a wooded area of the Mazowiecki Landscape Park to the Zielony Lug Reserve, from the south: from the Zielony Lug Reserve to the border with Wiązowna municipality through land of the Mazowiecki Landscape Park to the north-east to Lublin Highway; from the east: Lublin Highway, woodlands along Lakowa str., Stanisława Wigury str., Orla str., along the border with Wiązowna municipality (from the border with Wawer district, extension of Prabucka str., in the village of Zagorze on the level of the Neuropsychiatric Hospital for Children and Youth, the boundary turns towards Lublin Highway by an arc of 1200 m length, then by the north side of the road in the village of Majdan (Wiązowna municipality). Further on, the border runs by the east side of the Lublin Highway to the intersection with Brzeski Tract.

The boundaries of the district Warsaw-Żoliborz: the north-western boundary of the municipal cemetery, the north-west side of al. Armii Krajowej, the north side of the Gen. Grot-Rowecki bridge, the course of the Vistula river, the north side of the peripheral railway line with a station Warsaw Gdanska, the south-western boundary of Industrial Zoliborz built-up areas, the southern limit of the municipal cemetery.

2. Chemical hazards

The main source of the chemical hazards are hazardous substances occurring in more than 50 enterprises of the capital city of Warsaw.

Dangers may arise during:

- Production,
- Storage,
- Transport,
- Use, or
- Destruction (neutralization) of hazardous materials.

Table 1: Plants with high and increased risk of a serious industrial accident.

Name and address of facility	Type of dangerous goods	Quantity/ tons/	Main threat
Plants with a high risk of a serious industrial accident ^{*)}			
1. ORLEN GAZ Sp. z o.o. Rozlewnia Gazu Płynnego w Warszawie – ul. Swojska 47 (LPG bottling plant)	– propane-butane	270.0	fire-explosion
Plants with an increased risk of a serious industrial accident ^{**)}			
2. Centrum Naukowo-Produkcyjne Elektroniki Profesjonalnej RADWAR. S.A. – ul. Poligonowa 30 (scientific and production center of professional electronics)	– very toxic, – toxic, flammable and oxidizing substances	27.8 110.5	toxic, fire
3. Chłodnie Warszawskie MORSPOL S.A. – ul. Marywilska 26 (cooling plant)	– ammonia	100.0	toxic, fire
4. Tarchomińskie Zakłady Farmaceutyczne POLFA – ul. Fleminga 2 (pharmaceutical plant)	– ammonia	19.0	toxic, fire
5. PETROLOT Sp. z o.o – ul. Gordona Benetta 2	– aviation fuel	6800.0	fire-explosion
6. Zakład Separacji Powietrza Linde Gaz. Linde Gaz Polska Sp.z.o.o – ul. Pstrowskiego 30 (air separation plant)	– oxygen	1430.0	fire-explosion
7. Przedsiębiorstwo Handlu Chemikaliami „CHEMIA”, Baza magazynowa – ul. Rzeczna 6 (chemicals trade company)	– oxidizing substances	50.0	fire-explosion

^{*)}These plants, due to the amount of hazardous substances used, pose the greatest threat to humans and the environment in Warsaw.

^{**)}Substances collected in the above plants pose a significant fire risk involving chemicals, as well as explosion or environmental contamination risks.

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3. Other plants with dangerous substances

Besides plants included in the group of a high or increased risk, in the city center or near large

housing estates there are plants that use hazardous chemicals in smaller quantities, but because of their location they are also a threat to humans and the environment.

Table 2: Other plants posing a risk of chemical accident.

Name and address of facility	Type of dangerous goods	Quantity /tons/	Main threat
Plants posing a high toxic risk			
8. MPWiK w m.st. Warszawie S.A. Zakład Wodociągu CENTRALNEGO - ul. Koszykowa 81 (central water supply plant)	- chlorine	8.0	toxic
9. MPWiK w m.st. Warszawie S.A. Stacja Strefowa Wodociągu Północnego - ul. Borecka 1 (water supply plant, station of the northern pipeline zone)	- chlorine	6.0	toxic
10. MPWiK w m.st. Warszawie S.A. Zakład Wodociągu Praskiego - ul. Brukselska 21 (water supply plant, Praga pipeline)	- chlorine	4.8	toxic
11. Warszawski Ośrodek Sportu i Rekreacji. Tor Łyżwiarski „Stegny” - ul. Inspektowa 1 (Warsaw sport and recreation center, skating track)	- ammonia	9.5	toxic, fire
12. Zakłady Przemysłu Tłuszczowego - ul. Radzywińska 122/124 (fat processing plant)	- ammonia	7.0	toxic, fire

	Name and address of facility	Type of dangerous goods	Quantity /tons/	Main threat
13.	DANONE Sp z o.o - ul. Redutowa 9/23	- ammonia	6.0	toxic, fire
14.	Zakłady Mechaniczne PZL-WOLA SA. - ul. Fort Wola 22 (mechanical plant)	- ammonia	4.3	toxic, fire
15.	Chłodnia Przemysłowo-Handlowa „MORS-POLO” - Al. Prymasa 1000-lecia 62 (cooling plant)	- ammonia	3.1	toxic, fire
16.	SERWAR Sp. z o.o. - ul. Hoża 51 (cheese production)	- ammonia	0.8	toxic, fire
Plants posing a high risk of fire				
17.	PW Hestia - ul. Polczyńska 10	- pyrotechnic materials	80.0	explosion
18.	DAEWOO-FSO MOTOR - ul. Jagiellońska 88	- petrol. oil - paints, varnishes - solvents - acids	~144 ~40 ~20 14.0	high fire-explosion risk
19.	P. Z. Cussons Polska S.A. - ul. Szwedzka 20	- ethanol - abs acid - propane butane - triethylamine	30.0 18.0 20.0 2.5	flammable, corrosive, in case of fire posing a threat to humans and the environment
20.	Warszawska Fabryka Farb Graficznych S.A. - ul. Kawęczyńska 1 (ink factory)	- acetone - ethanol - isopropanol - ethyl acetate	3.4 20.0 23.0 10.0	high fire risk
21.	Fabryka substancji zapachowych POLLENA-AROMA - ul. Klasyków 10 (perfume factory)	- benzyl chloride - chloroform - ethanol - methanol - acetic anhydride	6.0 30.0 40.0 52.0 20.0	high fire risk, toxic compounds may be formed during a fire
22.	The State Mint S.A. - ul. Pereca 21	- ammonia - acids - bases - flammable substances	0.1 7.2 6.5 7.5	high fire and toxic risk
23.	Polish Security Printing Works S.A. - ul. Sanguski 1	- solvents - sulphuric acid - sodium hydroxide - hydrogen peroxide	~40 7.2 12.0 14.5	high fire risk, corrosive, toxic compounds may be formed during a fire
24.	Warsaw Pharmaceutical Plant "Polfa" S. A. - ul. Karolkowa 22/24	- nitroglycerin on lactose - acetone - propylene glycol - ethanol	1.1 0.6 4.2 3.5	high fire-explosion risk
25.	MPWiK w m.st. Warszawie S.A. Zakład Oczyszczalni Ścieków "CZAJKA" - ul. Czajki 4/6 (wastewater treatment plant)	- biogas - pix (ferric coagulant)	10000m ³ 50	high fire and toxic risk
26.	KORAM ZSM POLAND Sp.z o.o. - ul. Annopol 4 (production of plastic components)	- isocyanate	20.0	toxic compounds are formed during a fire (hydrogen cyanide, phosgene)
27.	Gas stations	- petrol - gas		fire-explosion

	Name and address of facility	Type of dangerous goods	Quantity /tons/	Main threat
Other plants using hazardous chemicals				
28.	Procter Gamble Operations Polska S.A. - ul. Zabraniecka 20	- sodium hypochlorite - sodium hydroxide	49.0 30.0	Different types of chemicals posing a local threat (on site)
29.	Warszawskie Zakłady Przemysłu Nieorganicznego STOCHEM - ul. Strażacka 89 (inorganic industry plant)	- nitric acid - phosphoric acid	20.0 20.0	
30.	Elektrociepłownia Warszawskie S.A. EC Żerań - ul. Modlińska 15 (heat plant)	- sulphuric acid	100.0	
		- hydrochloric acid	150.0	
		- sodium hydroxide	50.0	
		- sodium hypochlorite	5.0	
		- sodium chlorite - minced lime	2.0 25.0	
31.	Huta L.W. Sp. z o.o. - ul. Kasprowicza 132 (steel mill)	- sulphuric acid - nitric acid	100.0 10.0	
32.	Warszawskie Zakłady STOMIL - ul. Grochowska 9 (rubber processing plant)	- sodium fluosilicate - potassium hydroxide	1.6 6.0	
33.	Elektrociepłownia SIEKIERKI S.A. - ul. Augustówka 1 (heat plant)	- hydrochloric acid - sodium hydroxide	350.0 280.0	
34.	Polskie Zakłady Optyczne - ul. Grochowska 316/320 (optical factory)	- acetone - methylated spirits	1.2 1.3	
35.	CEMAT - SILIKON S.A. - ul. Wólczyńska 133 (manufacture of electronic valves, tubes and other electronic components)	- hydrofluoric acid - nitric acid >70%	0.4 1.0	
36.	Centralny Ośrodek Sportu - ul. Łazienkowska 6 a (sport center)	- ethylene glycol - freon	66.0 0.3	
37.	EADS PZL Warszawa Okęcie S.A. - Al. Krakowska 110/114 (aircraft manufacturer)	- acids - cyanides	3.0 0.1	
38.	IMP-BUD FIVE Sp. z o.o. - ul. Duchnicka 3 (steel construction, heat treatment, electroplating, machining, welding)	- acids - cyanides - sodium hydroxide	1.4 0.1 0.5	
39.	Institute of Biochemistry and Biophysics of the Polish Academy of Sciences - ul. Pawińskiego 5 a	- liquid nitrogen - flammable substances	4.0 1.2	
40.	Institute of Organic Chemistry of the Polish Academy of Sciences - ul. Kasprzaka 44/52	- solvents	2300.0	
		- concentrated acids	250.0	
		- concentrated bases	150.0	
		- oxidizing materials	30.0	
41.	Pharmaceutical Institute - ul. Rydygiera 8	- methanol - ethyl acetate - chemical reagents	1.0 0.5 ~0.5	
42.	Institute of Precision Mechanics - ul. Duchnicka 3	- cyanides	~0.1	
43.	Tele and Radio Research Institute - ul. Ratuszowa 11	- chemicals (different)	~1.0	
44.	State Geological Institute - ul. Rakowiecka 4	- acids	0.4	

	Name and address of facility	Type of dangerous goods	Quantity /tons/	Main threat
45.	Pharmaceutical company "ANPHARM" S.A. - ul. Annopol 6	- ethylene glycol - chemical reagents	5.7	Different types of chemicals posing a local threat (on site)
46.	Warsaw Welding Equipment Factory "PERUN" - ul. Grochowska 301/305	- acids - chemical reagents	1.3	
47.	Documentary and Feature Film Production Company WFDiF - ul. Chefmska 21	- anhydrous ammonia	0.4	

4. Other sources of chemical hazards

4.1. Road transport

Due to the absence of ring road in Warsaw hazardous substances are transported by the main streets, where there is a heavy traffic and a high risk of failure of the vehicle carrying the hazardous chemicals or other communication accident with its participation.

The substances mostly transported in Warsaw are:

- Chlorine – 446 tons;
- Ethyl alcohol – 82.5 tons;
- Sodium hydroxide – 23 tons;
- Ferrosilicon – 22 tons;
- Potassium nitrate – 20 tons;
- Ammonia – 2.2 tons;
- Dimethylamines – 2.6 tons (data from the Municipal Headquarters of the State Fire Service, annual transport).

4.2. Rail transport

Shipments of hazardous materials, coming into the city of Warsaw in compact drafts of cars, i.e. with one type of goods, are transported directly to the destination station:

- Warszawa Wschodnia (Warsaw East),
- Warszawa Główna Towarowa (Warsaw Main – Commodity),
- Warszawa Okęcie.

From these stations shipments go to adjacent sidings, whose users are usually the recipients of the goods. Shipments of dangerous goods transported in a distributed system (trains with different goods, not only dangerous, for different recipients) come to a transfer station Warsaw Praga, from where they are directed to the shunting stations: Warsaw East, Warsaw Main – Commodity, as well as outside the area serviced by the Freight Department in Warsaw.

5. Flood and hydrometeorological threats

5.1. Flood hazards

The Vistula river creates the greatest risk of flooding for Warsaw, due to its size and number of water borne; and the average degree of risk is created by:

- Długa river,
- Wilanówka river,
- Służewiecki Potok (Służewiec Stream).

5.2. The Vistula River

Characteristics of the river in Warsaw

- mileage in the profile Warsaw Port of Praga: at the 513.3 km of the Vistula river,
- length within the city 32 km (at the 497 – 529 km of the Vistula river).

5.2.1. Characteristics of flood control structures.

In Warsaw, the Vistula is surrounded by levees and road embankments performing the function of the levees. The total length of these structures is about 57 km. Embankments of other courses have a length of about 12 km and they are: the levee of the Jeziorka river – 5.6 km and the levee of Długa river – 5.5 km. Due to the nature of protected areas all Warsaw embankments belong to the highest 1st class of importance.

The current state of levees does not provide complete flood protection.

On the right bank, a total of 4.3 km of levees require improvement:

- **because of its location on the permeable soil which creates the possible filtration of water flooded into the area protected by levee:**
 - Wał Miedzeszyński (Miedzeszynski Levee), Wawer, area of Cyklamenow str.,

- Wał Miedzeszyński, Wawer, area of Jeziorowa str.,
 - Wał Miedzeszyński, Wawer, the middle section of Jeziorowa and Bronowska str.,
 - Wał Miedzeszyński, Wawer, area of Kadetow str.
 - Wał Miedzeszyński, Wawer, area 250 m south of Kosmatki str.
 - Wał Gołędzinowski, Praga North, 900 m section of the levee, from Wybrzeże Helskie str. to Batalion Platerówek str.
 - **because of the proximity of old river bed, allowing water filtration through the ground:**
 - Wał Miedzeszyński, Wawer, 150 m section of the levee, area of Skalnicowa str.,
 - Wał Miedzeszyński, Wawer, 100 m section of the levee, between Chodzieska and Jeziorowa str.,
 - Wał Miedzeszyński, Wawer, 770 m section of the levee, between Kadetow str. up to 200 m south of Wojsławicka str.
 - **because of the insufficient height of the levee:**
 - the beginning of Wał Miedzeszyński – at the 501.0 km of the Vistula river,
 - Wał Miedzeszyński, the culvert area at the mouth of Nowa Ulga Canal at Kosmatki str.,
 - a distance between the Poniatowski Bridge (from Sokola str. – at 512.25 km) and the Gdanski Bridge (up to 200 m north of Ratuszowa str. – at the 515.00 km of the Vistula river), there are: diametral levee and an embankment forming Wybrzeże Helskie str. The lowest ordinate of the crown of diametral levee = 84.80 m AMSL – i.e. 0.9 m too low in relation to the required height of the levee – occurs between Okrzei and Ks. Kłopotowskiego streets at the 513.85 km of the Vistula river.
 - **there are also three points posing a potential danger of water entering the area protected by the levee:**
 - Wał Miedzeszyński at the 6 675 m, Praga South between Algierska and Sosabowski streets – the bottom of culvert is below the level of the 1000-year flood (exceedance probability $Pe = 0.1\%$), i.e. 959 cm on the water gauge in the Praga Port,
 - Wał Miedzeszyński at the 6 950 m, Praga South between Algierska and Sosabowski streets – the bottom of culvert is below the level of the 1000-year flood ($Pe = 0.1\%$),
 - Wał Miedzeszyński at the 6 985 m, Praga South between Algierska and Sosabowski streets – the bottom of culvert is below the level of the 1000-year flood ($Pe = 0.1\%$).
- On the left bank of the Vistula 5 [km] of levees require modernization.**
- Wał Moczydłowski, Wilanów, the levee section with a length of 1800 m, between the 3300 and 5100 meter of the levee, from the level of Pretowa str. To Wloki str. – the area of the Siekierki Heat Plant ash landfill, the slope of the levee from the river at risk of losing stability,
 - Wał Moczydłowski, Wilanów, the levee section with a length of 950 m, between the 7750 and 8800 meter of the levee, 450 m south and 500 m north of Glebowa str., the river flows at the distance of 30 – 50 m from the slope of the levee, in case of flood there is risk of slope erosion,
 - Wał Moczydłowski, Wilanów, the levee section with a length of 500 m from Syta str. To the north, between the 9100 and 9600 meter of the levee, the levee's slope may lose its stability as a result of soil erosion,
 - Wał Moczydłowski, Wilanów, the levee section with a length of 660 m, between the 9100 and 9760 meter of the levee, bad state of the levee's slope protection, there is possible that soil will be washed out from the slope,
 - places where the crown of the levee is lower than required:
 - Wał Śródmiejski, opposite the entrance to the Port of Praga, the crown elevation 85.85 m AMSL, 10 [cm] above the water level $Pe = 0.1\%$ (a 1000-year level = 959 cm in the Port of Praga), about 20 cm too low,
 - Wał Buraków – Kazuń, at the 525.85 – 528.00 km of the Vistula, the crown elevations 82.40 m AMSL, up to 20 cm below the water level $Pe = 0.1\%$ (a 1000-year level = 959 cm in the Port of Praga), i.e. up to 50 cm too low in relation to the requirements.

The above assessment of levees situation was developed by Hydroprojekt Warszawa Sp. z o.o. in 2000 for the Warsaw-Centre municipality contract No. 493/N. The assessment was published in the paper entitled «Computer map of the flood risk coverage in the capital city of Warsaw».

NAME OF THE LEVEE	MOCZYDŁOWSKI				ŚIEKIERKOWSKI	CZERNIAKOWSKI	ŚRÓDMIEJSKI
CLASS	I				I	I	I
Width of the foot [m]							
Section number			IM 1	IM 2	IM 3	IM/S 4	
The amount of materials needed to strengthen the levee w – sandbags [pcs] f – foil [m ²] t – filtration fabric [m ²]			w = 27 960 f = 36 000	t = 3 800; rock filling	IM3;m; w = 12 000 f = 13 200	IM/S4: a) w = 1840 t = 640; b) w = 3 280 t = 1 280	
Protected areas	Wilanów, Sadyba, Dolny Mokołów (Siekierki Heat Plant + ash landfill, Central Waterpipe intake)						
Area [km ²]	65.20						

The detailed description of levees is presented in Tables 3 and 4:

- Marked in yellow are levees sections where water may enter the area behind the levee as a result of filtration through a permeable body of levees or through permeable soils in the subsoil.
- Marked in blue are levee sections located near the former old river beds where the ground creates favorable conditions for water filtration.
- Marked in red are places where the crown of the levee does not meet the high requirements (is too low).

cont. of Table 3

NAME OF THE LEVEE	POTOCKI		MŁOCIŃSKI	
CLASS	I		I	
	beginning	end	beginning	end
The Vistula mileage [km]	515.8	521.4	523.3	524.8
Levee mileage [m]	0.0	5600	0.0	1300
Crown elevation [m] AMSL Cr	86.50	83.91	84.83	83.88
Height [m]	Average 3.5		Average 2.8	
Width of the crown [m]	4.0		3.8	
Protected areas	Żoliborz		Bielany	
Area [km ²]	2.60		1.20	

cont. of Table 4.

NAME OF THE LEVEE	SITOWIE	
CLASS	III	
DESCRIPTION	beginning	end
The Vistula mileage [km]	499,8	499,5
Levee mileage [m]	0.0	300
Area [km ²]	0.11	

Source of tables 3 and 4: Own calculations on the basis of the levees' characteristics contained the paper entitled «Computer map of the flood risk coverage in the capital city of Warsaw» prepared by HYDROPROJEKT WARSZAWA S. A.

Table 5 summarizes the amount of material needed to protect vulnerable sections of levees color-marked in Table 3. (Characteristics of the

levees at the left bank of the Vistula river in the capital city of Warsaw) and Table 4. (Characteristics of the levees at the right bank of the Vistula river in the capital city of Warsaw)

The colors in this table represent methods of strengthening the individual sections of the levees.




-  Strengthening the places that necessarily require it.
-  Strengthening the places that necessarily require it + additional strengthening of adjacent space increasing the degree of protection.
-  Strengthening the places that necessarily require it, when replacing 65% of andbags by sand coverage.

Table 5: List of materials needed to protect the levees.

Section No.	Name of the levee	Bank	Levee's mileage [m]	Section length [m]	Cause of risk	Protection method	Material:			
							sandbags [pcs]	Filtration fabric [m ²]	foil [m ²]	sand [m ³]
pM ₁	Miedzeszyński	right	0 - 20	~ 20	the crown too low ~ 1 [m]	Danish wall 10 layers of 10 [cm] each	~ 800	0	~70	~ 20
pM ₂	Miedzeszyński	right	55 - 75	~ 20	sand in the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~ 783	~ 260	0	~ 15.7
						b) as in a) + protection of a downstream slope	~ 1515	~ 520	0	~ 30,3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~ 280	0	~ 78
pM ₃	Miedzeszyński	right	1000-1150	150	the old river bed, possible filtration through the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~ 5658	~ 1950	0	~113.16

Section No.	Name of the levee	Bank	Levee's mileage [m]	Section length [m]	Cause of risk	Protection method	Material:			
							sandbags [pcs]	Filtration fabric [m ²]	foil [m ²]	sand [m ³]
pM ₃	Miedzeszyńsk	right	1000-1150	150	the old river bed, possible filtration through the subsoil	b) as in a) + protection of a downstream slope	~10940	~3900	0	~218.8
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~2100	0	~ 630
pM ₄	Miedzeszyński	right	1850-2020	170	the old river bed and sand, possible filtration through the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~6441	~2210	0	~128.82
						b) as in a) + protection of a downstream slope	~12455	~3952	0	~249.1
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~2380	0	663
pM ₅	Miedzeszyński	right	2490-2510	~ 20	sand in the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~783	~260	0	~ 15.7
						b) as in a) + protection of a downstream slope	~1515	~520	0	~ 30,3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~ 280	0	~ 78
pM ₆	Miedzeszyński	right	3510-3530	~ 20	sand in the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~783	~260	0	~ 15.7

Section No.	Name of the levee	Bank	Levee's mileage [m]	Section length [m]	Cause of risk	Protection method	Material:			
							sandbags [pcs]	Filtration fabric [m ²]	foil [m ²]	sand [m ³]
pM 6	Miedzeszyński	right	3510-3530	~ 20	sand in the subsoil	b) as in a) + protection of a downstream slope	~1515	~520	0	~ 30,3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~ 280	0	~ 78
pM 7	Miedzeszyński	right	3630-4570	940	the old river bed and sand (4570 m), possible filtration through the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~35283	~12220	0	~705.66
						b) as in a) + protection of a downstream slope	~68215	~24440	0	~1364.3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~13160	0	~3666
pM 8	Miedzeszyński	right	5190-5210	~ 20	sand in the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric loaded with bags	~783	~260	0	~ 15.7
						b) as in a) + protection of a downstream slope	~1515	~520	0	~ 30,3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~ 280	0	~ 78
pM 9	Miedzeszyński	right	5400-5500	100	the crown too low 0.36 [m]	single wall 4 layers up to 10 [cm]	1000	0	0	20
pM 10	Miedzeszyński	right	6095-6120	35	the crown too low ~ 1 [m]	Danish wall 10 layers of 10 [cm] each	~1400	0	0	~35

Section No.	Name of the levee	Bank	Levee's mileage [m]	Section length [m]	Cause of risk	Protection method	Material:			
							sandbags [pcs]	Filtration fabric [m ²]	foil [m ²]	sand [m ³]
pM 11	Miedzeszyński	right	6675		bottom of the culvert below the water level $P_e = 0.1\%$	blockage of the culvert $\varnothing \sim 1$ [m] with the sandbags	~16	0	0	~0.4
pM 12	Miedzeszyński	right	6950		bottom of the culvert below the water level $P_e = 0.1\%$	blockage of the culvert $\varnothing \sim 1$ [m] with the sandbags	~16	0	0	~0.4
pM 13	Miedzeszyński	right	6985		bottom of the culvert below the water level $P_e = 0.1\%$	blockage of the culvert $\varnothing \sim 1$ [m] with the sandbags	~16	0	0	~0.4
pM 14	Miedzeszyński	right	516-516.9 km of the Vistula	900	permeable grounds in the subsoil	a) the area of about 13 [m] width behind the levee covered by filtration fabric	~33783	~11700	0	~675.66
						b) as in a) + protection of a downstream slope	~65315	~23400	0	~1306.3
						c) the area of about 13 [m] width behind the levee covered by filtration fabric and soil	0	~3780	0	~3510
IM 1	Moczydłowski	left	3300-5100	1800	Lack of stability in the upstream slope	cover the upstream slope with foil and rows of sandbags	~27960	0	~36000	~559.2
IM 2	Moczydłowski	left	7750-8800	950	distance of the river from the levee's foot 30-50 [m]	cover the costal slope with the fleece and stones	0	~3800	0	~
IM 3	Moczydłowski	left	9100-9760	660	Bad protection of the upstream slope	cover the upstream slope with foil and rows of sandbags	~12000	0	~13200	~240

Section No.	Name of the levee	Bank	Levee's mileage [m]	Section length [m]	Cause of risk	Protection method	Material:			
							sandbags [pcs]	Filtration fabric [m ²]	foil [m ²]	sand [m ³]
IM 4	Moczydłowski/ /Siekierkowski	left	9760- 9800	40	permeable subsoil	a) the area of about 16 [m] width behind the levee covered by filtration fabric loaded with bags	~1840	~640	0	~36.8
						b) as in a) + protection of a downstream slope	~3280	~1280	0	~65.6
						c) the area of about 16 [m] width behind the levee covered by filtration fabric and soil	0	~680	0	~192
Strengthening the places that necessarily require it						NECESSARY QUANTITY	129345	29760	49270	2598.3
Strengthening the places that necessarily require it, when replacing 65% of sandbags by sand coverage						Necessary quantity – c) method Sand coverage instead of bags	43208	27660	49270	9848.4
Strengthening the places that necessarily require it + additional strengthening of adjacent space increasing the degree of protection						Necessary quantity protection of the base + slopes of levees	209473	63492	49270	4200.7

5.2.2. Causes of hazards

The raise of water level in the Vistula can be caused by:

- Intense rainfall in the basin of the Upper and Middle Vistula. Throughout the plains dangerous rise of water occurs after rainfall of 60 – 80 mm within 2 hours, and 30 mm in the mountains. The threat of flooding as a result of rainfall usually occurs from June to September;
- The rapid melting of snow cover in the basin of the Upper and Middle Vistula. It's favored by rapid warming with a simultaneous rainfall and the frozen ground, which causes rapid surface runoff. This occurs most often from the second half of February to the first decade of April;
- Ice and sludge congestions. Sludge congestions appear usually in December and January during sudden, large temperature drops (up to – 10 ° C), the accumulated mass of sludge under ice cover blocks the river bed in the area of small flow of water.
- Ice congestions occur most often in the second half of February and in March, in places convenient for accumulation of floating ice, i.e. in the narrow places, sandbanks, islands, places of a sudden change in flow direction and on the bridge profiles;
- In Warsaw section of the Vistula the places particularly at risk of congestion are: Wysoczyzn (464 – 465 km), Brzumin (468 – 469 km), Radwanków (473 km), the mouth of Swider river at Dębina (483 – 491 km), the mouth of Jeziorka river at Kepa Zawadowska (493 – 498 km),

Nowy Dwor Mazowiecki – Łomianki – Buchnik (520 – 545 km).

- Swelling of water level at the obstacles. The obstacles in the riverbed, such as compact groups of trees, bushes, bulky waste, can swell the water to a height of up to 1 m. Swellings of water can occur in shallow areas of the river, formed by deposition of material derived from erosion, incl. shore erosion. In these areas the items carried by the stream may wedge (eg, fallen trees, ice float). At the Warsaw section of the Vistula river erosion occurs in the following sections:
 - the left bank: Wolka Dworska, (478 km) – length 60 m, Ciszycza Obórki, (493 km) – 500 m; Kepa Oborska, (495 km) – 1100 m; Kepa Okrzewska, (497 km) – 700 m,
 - the right bank: Tarchomin (527 km) length of 200 [m], distance from the foot of the levee 20 – 30 m, threatening its stability.

Potential time, after which the water starts to percolate through the break.

There was a geotechnical investigation performed and it was determined the course of filtration for the weakest place of Rajszewski Levee, located at the 5 800 meter from the Grot – Rowecki Bridge.

Seepages at the foot of a downstream slope occur after 24 hours of the persistence of flooded water.

5.3. The risk assessment

The entire low situated left-bank part of Warsaw is in the range of a 1000-year flood water (exceedance probability $P_e = 0.1\%$). This covers the area from the so-called Warsaw Escarpment, i.e. the entire Wilanów, the eastern half of Mokotow, the south – east part of Srodmiescie (downtown), the small north-east part of Zoliborz and a narrow strip adjacent to the Vistula river in Bielany district. On the right bank, this range of the flood water covers the western half of Wawer district, the entire Praga North and Praga South, a narrow strip on the west of Rembertow, all Targówek and almost all Białołęka.

In the event of a flood of water and the raise of its level above the edge of the riverbed for the

average water the areas located in the inter-levee land will be flooded. The area located behind the levee will be flooded in case of water overflow through the crown of the levee or the entrance of water through the places not protected – the basin of Port of Praga.

Currently, the least protected areas are near the Zoo park and the Port of Praga, as well as some places at the Rajszewski Levee in Białołęka district.

In November 2004, modernization works of the Rajszewski Levee have begun on the section from the Seminary (area of Mehoffer str.) to the northern limits of the City of Warsaw. The works should be completed in 2005, as a result the tightness of the levee's body and its base will be improved.

In 2005, the Provincial Board of Land Melioration and Water Installations in Warsaw will start to prepare the documentation related to the modernization of the Moczydłowski Levee above the Wastewater treatment plant «South».

Potential flooding ranges were developed by Hydroprojekt Warszawa Sp. z o. o. in 2000 for the Warsaw-Centre municipality within the contract No. 493/N. The assessment was published in the paper entitled «Computer map of the flood risk coverage in the capital city of Warsaw».

Table 6: Description of the volume of water.

Theoretically the water will occur	Exceedance probability	Water level at the gage in the Port of Praga [cm]	Elevation of water table [m AMSL]
once in 20 years	$P_e = 5\%$	763	83.71
once in 100 years	$P_e = 1\%$	855	84.63
once in 1000 years	$P_e = 0.1\%$	959	85.67

State of alert and danger point for the capital city of Warsaw have been identified by the indications of the gage in the Port of Praga:

STATE OF ALERT: – 600 [cm], elevation of water table 82.08 m;

DANGER POINT: – 650 [cm], elevation of water table 82.58 m.

Table 7: The population living in flood areas of Warsaw.

Areas within the range of flood with exceedance probability P_e %	$P_e = 5\%$ 20-year flood	$P_e = 1\%$ 100-year flood	$P_e = 0.1\%$ 1000-year flood
Number of people			
Right-bank districts	114 249	231 996	435 111
Wawer	2 094	3 111	11 822
Praga Południe	104 708	179 843	183 748
Rembertów	-	-	1 739
Praga Północ	1 245	31 854	72 797
Targówek	-	-	123 392
Białołęka	6 202	17 188	41 613
Left-bank districts	27 646	115 961	139 838
Wilanów	1 255	10 980	12 176
Mokotów	20 695	73 419	89 177
Śródmieście	-	19 875	25 739
Żoliborz	3 276	3 742	4 279
Bielany	2 420	7 965	8 467
Total	141 895	347 957	574 949

Source: Own study based on flooding range set by Hydroprojekt Warszawa Sp. z o.o. Długa river

5.4. Długa river

Characteristics of the river Location:

Białołęka district and areas to the east of Warsaw.

Basin: the area around the towns of Sulejówek, Wolomin, Rembertów, Marki;

Source area: the areas north of the village of Dębe Wielkie;

Receiver: Żerań Canal;

Major tributaries: Czarna Struga;

Administrator: Provincial Board of Land Melioration and Water Installations, Warsaw branch. Increased rainfall in the basin cause the dynamic growth of the water level and flow.

Characteristics of flood control structures

Along the both sides of the Długa river there are levees of 5450 m from the dam in the town of Marki to its estuary at Żerański Canal. The levees were performed incorrectly, they have too small spacing, height and width, and inadequate soil compaction. There is a lack of road along the levee that would allow protection activities.

The concept of the Długa river levees modernization was developed in 2004.

The risk assessment

The Długa river threatens to flood the one-third of Białołęka district area (10 km²), i.e. housing estates of Kały Grodziskie, Brzeziny, Mańki Wojdy. The threat may occur only in the event of interruption of the levees, or the overpassing the levee's crown by the flood wave.

5.5. Wilanówka river

Characteristics of the river

Location: District of Wilanów and the area of Konstancin – Jeziorna.

Source area: the areas west of the village of Konstancin – Jeziorna.

Receiver: the Vistula river, estuary through the levee's lock.

Major tributaries: Potok Służewiecki.

Overall length: 16.5 km; within the limits of Wilanów district: 9 km.

Width: 4 – 8 m

Depth: 0.5 – 1.5 m

Administrator: Provincial Board of Land Melioration and Water Installations, Warsaw branch. The Wilanówka river flows by siphon under the Jeziorka river.

The risk assessment

In the case of heavy rainfall or rapid snow melting it is possible to raise the water table of the Wilanówka river and the local flooding of adjacent areas.

5.6. Potok Służewiecki

Characteristics of the river

Location: Districts of Usynów and Wilanów

Source area: the areas of the airport «Okecie».

Receiver: the Wilanówka river.

Major tributaries: Wolnicki Canal, Wolnicki Ditch;

Width of the bottom at the section of Puławska str. – Dolina Służewiecka str.: 1.5 – 2.0 m;

Depth of the section of Puławska str. – Dolina Służewiecka str.: 1.5 – 2.0 m;

Width of the bed at the section of Dolina Służewiecka str. – Wilanowskie;

Lake: 3.0 – 4.5 m;

Depth of the bottom at the section Dolina Służewiecka str. – Wilanowskie;

Lake: 1.5 – 2.0 m;

Flow rate at Wilanowska point: from years 100 – 330 l/s, during the thaw: 115 – 732 l/s. Stream discharges treated rain wastewater from sewage OSD Okęcie Airport and untreated rain wastewater from the basin: Służewiec, Służew nad Dolinka, Ursynów and Pasma Pyrskie.

The risk assessment

Severe rain and quick thaw of snow cause the water surface elevation and the possibility of river flooding.

Areas at risk of flooding are: a crossroads of Dolina Służewiecka str. and Al. Wilanowska, and the area of Arbusowa str., where 150 families live. NOTE! One of many versions of Potok Służewiecki remodeling was approved. Currently, the Provincial Board of Land Melioration and Water Installations in Warsaw prepares documentation for the next stages of works.

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Meteorological hazards

Meteorological hazards are random phenomena, the occurrence of which is difficult to predict in sufficient advance. The Institute of Meteorology and Water Management forecasts these phenomena based on its own observations.

Strong winds

Strong winds are a threat to:

- overhead power lines,
- overhead telecommunication lines,
- radio and telecommunications masts,
- elements of the building.
- trees.

Excessive precipitation (rain, snow)

Excessive rainfall, rapid snow thaw are a threat to: – streets, – underground passages, – road and rail tunnels, – subway, – depressions, – some facilities such as sewage treatment plants, basements.

Icing

The icing and frosting may be a threat to:

- trees,
- power lines,
- telecommunication lines,
- roads (roadways and sidewalks),
- railways: tracks and contact system,
- buildings, gutters (hanging icicles).2

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