NOAH

Interreg Baltic Sea Region

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REPORT ON PILOT IMPLEMENTATION OF EXTREME WEATHER LAYER

Output 2.4 of Interreg Baltic Sea Region project NOAH

Protecting Baltic Sea from untreated wastewater spillages during flood events in urban areas

Contents

Introduction

The NOAH project aims to protect the Baltic Sea from untreated wastewater spillages during flood events in urban areas. For this purpose, passive and active methods like holistic urban planning, real time control of urban drainage systems and raising stakeholder awareness are harnessed. The present report covers project results on Implementing Extreme Weather Layer (EWL) for reducing urban runoff.

The proposed **holistic planning support tool – Extreme Weather Layer (EWL)** is a combination of hydraulic modelling, climate scenarios and other urban planning datasets considered via GIS or otherwise. It connects the results of a storm water system hydraulic model with urban planning to visualize the plots most vulnerable to present and future flooding risks. Extreme weather events and consecutive flooding risks are directly related to the risk of rinsing hazardous substances and nutrients into the receiving waters. Therefore, water pollution risk level is interconnected with flood risk communicated through EWL to citizens and urban planners. EWL is complementing the exiting planning system, rising thus the capacity of project municipalities to handle risk of pollution spillages to the Baltic Sea during flood events.

The report covers state of the art of urban planning with consideration of urban pluvial flooding and gives the initial recommendations how to improve the planning processes. In addition, the report provides a rough step-by-step guide for creating the EWL and gives an overview how the EWL was implemented in pilot cities and discusses further possibilities for integrating the developed tool into decision-making process. According to the application, the EWL was planned to be implemented in 6 partner towns. However, during the project activities 2 additional partner towns were interested in the implementation. The developed tools in all 8 pilots are presented in the report as case studies.

The report covers undertaken actions, faced deficiencies and solutions to these, and most importantly **concrete guidelines for embedding EWL into the planning procedure** for the public authority responsible for urban run-off management and implementation of passive (non-structural) methods.

The report will be finally presented as a part of the project handbook (A4.3) and contributes to: 1) Increasing institutional capacity for better data acquisition, for better planning and to ultimately reducing risks of untreated wastewater spillages to the BS; 2) Anchoring project results into daily routine of public municipalities; and 3) Transferring of the project results outside the project partnership.

Initially the report should have been an input for the pilot implementation of activity A3.4 in WP3. As A2.4 was extended due to COVID19 and ends simultaneously with A3.4, then coherence of pilot interventions with EWL implementation has been coordinated by close communications between project partners. Main outputs of WP2 and WP3 are now issued in period 4. This, with the extended project duration, allows sufficient time for results evaluation and generalization in WP4.

1 Policy context: country specific urban planning policy and pilot specific procedures

The aim of this chapter is to assess the need to adjust the planning policy and local regulations in order to add EWL into the planning procedure. Also, making suggestion for necessary changes in the policy and regulations.

1.1 Country profile: Denmark

Overview of urban planning policy and local regulations (related to UDS)

In Denmark, planning related to the water sector can be divided into planning of water resources, overall physical planning, and planning of technical infrastructure, as illustrated on Figure 1.

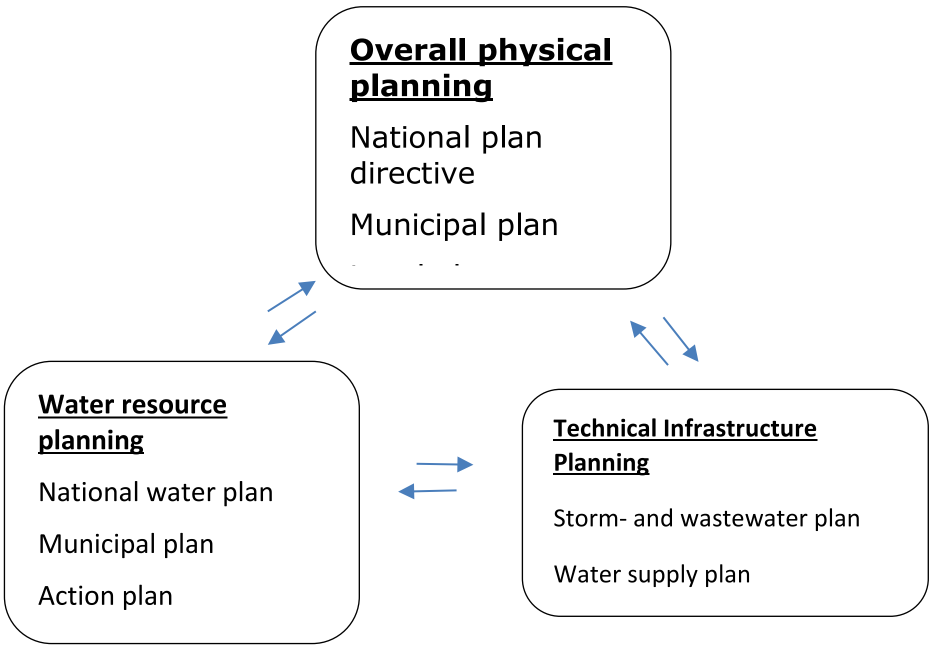

Figure 1: The integrated Danish planning hierarchy

The various plans in the planning hierarchy needs to be closely coordinated, since changes in one plan can have large consequences for the other plans. Ideally, e.g. the utility company will be collaborating with the municipality already in the process of making a new local plan for the physical planning, to ensure that planned changes do not create large problems with the stormwater handling. There are many expensive examples of this collaboration not taking place, but also many examples of the opposite, that have led to cost-efficient and high-quality city development taking both economy, liveability, nature and storm- and wastewater handling into account.

As part of the implementation of the Water Framework Directive two important sets of plans are made every five years; the River Basin Management plans and the Flood Risk Management plans. In an urban context, the first relates to the natural recipients and are thus important for issuing discharge permits, while the second relates to urban areas flooding from rivers, streams and from the sea. In the Danish interpretation of the Water Framework Directive rain induced flooding in cities is not included in this. Instead, this is covered by the municipal Climate Adaption Plans. Table 1 shows the most important plans related to urban water planning in Denmark.

Table 1: Most important plans related to urban water planning in Denmark.

Planning level	Published by	frequency	Deals with	Scale
Municipal Plan	Municipalities	12 years	City development, areal usage.	Municipal
River Basin Management Plans	The Danish Environmental Protection Agency	5 years	Environmental status of rivers and streams.	National/regional
Flood Risk Management Plans	Danish Costal Authority	5 years	Flood risk from rivers and the sea.	National
Municipal Climate Adaption plans	Municipalities in collaboration with the utility companies	-	Risks related to climate change in urban areas.	Municipal

Municipal Climate Adaption plans
The mandatory Municipal Climate Adaption Plans have become the centre of urban flood risk management. Behind such plan is a thorough analysis of i.e. urban flood risk from rainstorms. This work has to include the following:

1. Flood maps

Flood maps are made using hydrological models for rainstorms of various return periods, using hydrodynamic models such as SWMM or MIKE URBAN for simulating pluvial flooding for areas with drainage systems. In order to produce reliable flood maps, the 1-dimensional hydrodynamic models used for simulating the flows and levels in the drainage system have to be coupled with a 2-dimensional hydrodynamic model of the surface, which makes the simulations rather computational demanding. The flood maps have to be produced for rainfall event return periods of 5, 10, 20, 50 and 100 years, respectively. In order to consider the expected climate changes the rainfall should be multiplied with climate factors. The climate factors are produced by the Danish Meteorological Institute based on climate predictions. The usage of the factors is extremely simple, since it only requires that the modeller multiply all rainfall data with the relevant factor.

2. Value maps

The value maps show the value of buildings, infrastructure and assets in general that might be affected by flooding, in order to be able to assess the consequences of flooding.

3. Risk maps

The risk maps are produced by combining the information of the risk of flooding from the flood maps with the values that can be lost as stated in the value maps. Thereby the risk maps show in which areas there statistically will be the largest economical losses due to flooding over many years into the future.

Stormwater discharges and combined sewer overflows

Regulation of stormwater discharges and combined sewer overflows is handled through discharge permits that are issued by the municipalities, considering i.e. information from the River Basin Management Plans on the status and vulnerability of the recipients. These permits are given in the design phase and are usually based on documentation made using hydrodynamic models. Also, here, safety/climate factors are used, but it is not regulated which factors to use, so this can differ greatly from one municipality to another. A review of discharge permits found factors used ranging from 1.0 to 1.56[1].

The current regulation is rather new so it would be premature to suggest larger changes. There are, however, details that could be improved. The handling of raising groundwater levels is not explicitly considered in the water plans. This is becoming an increasing problem and the current legislation prevents the utility companies from trying to solve the problems.

Furthermore, the way that discharge permits are given should be standardized, since these are of paramount importance for the dimensioning of the technical water infrastructure and for the recipients.

1.2 Country profile: Estonia

Overview of urban planning policy and local regulations (related to UDS)

Spatial planning in Estonia is hierarchical and four different planning levels can be distinguished. These plans are national spatial plans, county wide spatial plan, municipal comprehensive (general) plans and detailed plans (see Table 2 for specifications).

The planning procedure is regulated with Spatial Planning Act[2]. The planning procedure is coordinated by different public authorities depending from the hierarchical level (national plans are coordinated by Ministry of Interior and detailed plans are coordinated by local municipality governments).

In addition to official spatial planning procedures established within Spatial Planning Act, land use decisions that can have strong effect to urban flood vulnerability or reinvent the urban areas in regions prone to urban flooding are made also based on other regulations.

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[1] Jensen, et al, 2020;

[2] *RT I, 26.02.2015*

According to the Estonian planning and building legislation[2,3], detailed plans are required only in limited cases of urban developments – it is possible to erect new buildings, enlarge exiting buildings and increase impermeable areas with building permit procedure. Also, different thematic development plans (ie. water supply and sewerage development plans[4], Sustainable Energy and Climate Adaptation Plans etc), are developed for urban areas that propose actions that affect urban vulnerability to flooding as well as redesign areas, with high flooding risk (see Figure 3).

Possible climate scenarios are considered within strategic environmental impact assessment (SEA) procedure of comprehensive plans, no clear procedure is assigned for this[5]. For detailed plans the SEA is normally not applied, it is obligatory only if detailed plan foresees actions with significant environmental impact[5]. In some cases also environmental impact assessment (EIA) procedure is assigned to detailed plans (in cases where development within the property potentially results a significant environmental impact), but according to the Estonian legislation EIA procedure does not consider climate change scenarios.

The valid design standard (presently processed to be renewed) used for designing urban drainage systems[6] is presently not considering climate scenarios and potential future extreme weather events.

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[3] *RT I, 05.03.2015*
[4] *RT I 1999, 25, 363*
[5] *RT I, 21.12.2019*
[6] EVS 848:2013

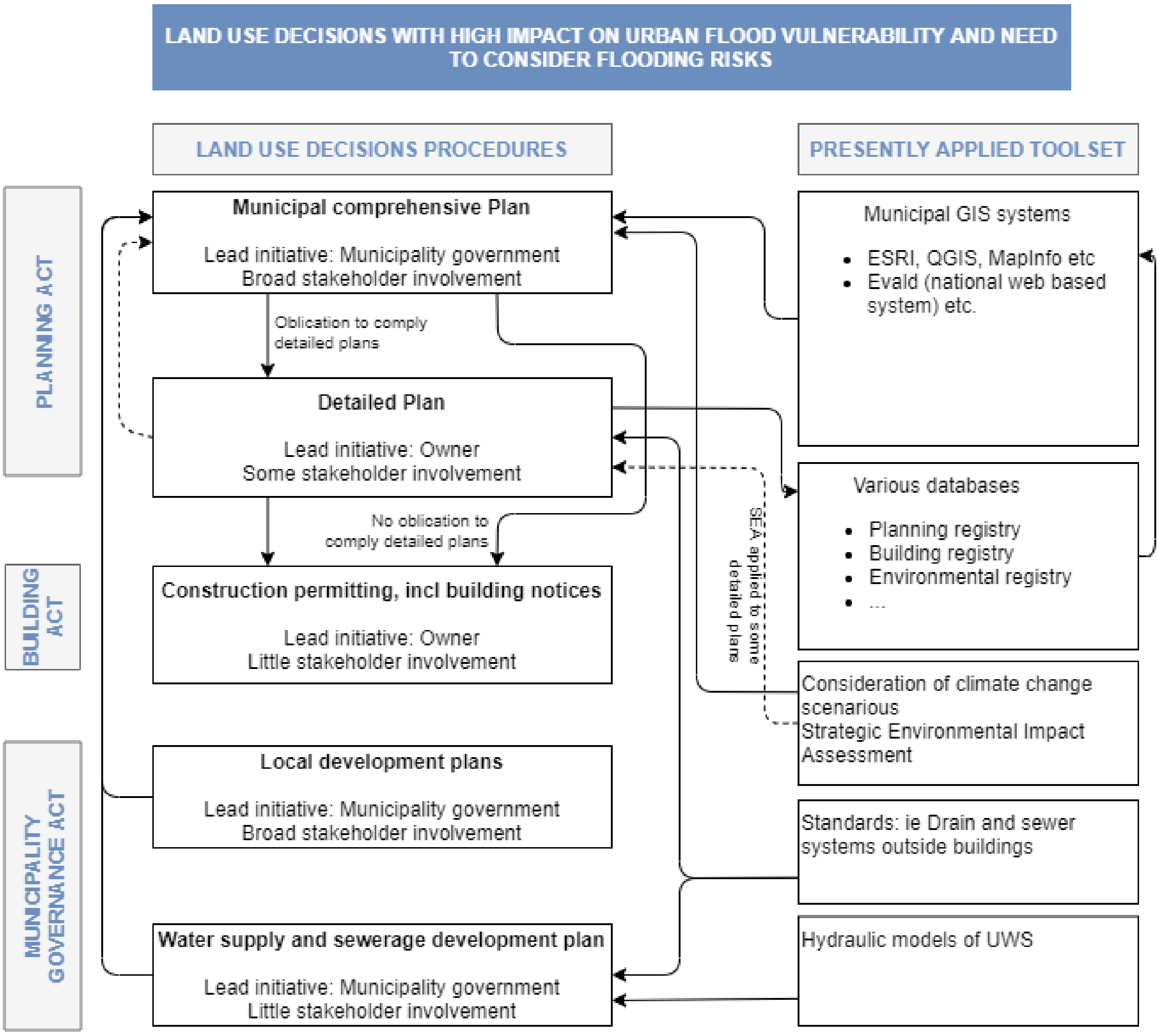

Figure 2 Land use decisions with high impact to urban flood vulnerability and need to consider flooding risks

Table 2 Estonian spatial planning hierarchy and consideration of urban floods

Planning level	Typical Scale	EIA/SEA	Revision	Land use decisions within the planning level have impact to urban flooding vulnerability	Planning level has to consider urban flooding risk
National Spatial Plan	Schematic	SEA obligatory	10 years	Too generalized to have significant impact to change vulnerability to urban flooding	Coastal flooding scenarios are in some extent considered. More detail level of flooding risk not considered.
County Wide Spatial plan	1:100 000-1:150 000	SEA obligatory	10 years	The plan determines: • Land use principles and conditions for public waterbodies; • Land use principles for recreation areas, green and blue ecological networks; • Directions for municipal comprehensive plans;	Plan considers: Coastal flooding scenarios; Upstream flows of blue networks. More detail level of flooding risk not considered.
Municipal Comprehensive Plan	1:5000-1:30 000	SEA obligatory	10 years	The plan determines: • the general use and building conditions of the planning area incl. conditions for issuing design specifications, assigning principal purpose of land use, the maximum built-up floor area etc.; • corridors of utility lines and networks: incl. stormwater related; • areas where the preparation of a detailed plan is mandatory.	Plan is obliged to define the boundaries of areas of repeated flooding of the natural waterbodies (floods directive); Typically floodings caused by extreme weather events combined with urban drainage system failures not considered.

Detailed plan	1:500-1:1000	EIA assigned in some cases	- (5 years)*	The plan determines: • Increase of built upon area and impermeable surfaces; • Changes in land cover in green areas.	Planning object specific design to sustain utility network performance.

* No official revision procedure, but detailed plans can be repealed after 5 years if plan has not been commenced.

Approach described above causes following challenges:

- Climate scenarios considered only in some decision-making levels, approach for doing this is static and is not scaled to single-property level;
- UDS system capacity is considered in thematic infrastructure development plan (water supply and sewerage development plan), but not assessed as a whole on other land use decision levels.
- Pluvial flood risk and floods related to UDS failure is not considered in urban planning procedures, which means no mitigative measures are foreseen;
- UDS utilities are designed on land-unit scale in detailed plans, no broader understanding on UDS system performance is considered;

1.3 Country profile: Finland

Spatial planning and implementation of Finnish land use is based on the national land use objectives and zoning, which are defined in the Land use and Construction Act[7]. National land use targets are set by the Ministry of the Environment in co-operation with other ministries, provincial associations and other relevant authorities and bodies. The main responsibility for zoning lies with the Environmental Ministry whose responsibilities include the planning related to zoning guidance and the development and manufacture of zoning legislation.

Spatial planning in Finland is, as in Estonia, hierarchical and can be distinguished into four levels. The four levels of spatial planning and zoning are national spatial plans, provincial wide spatial plan, municipal comprehensive plans and detailed plans. The Environmental Ministry guides the planning of the so-called lower level spatial planning, which are implemented trough zoning. There are three main zoning levels, with some cross-section zoning, which are provincial zoning, general zoning and city zoning. The planning authority depends on the spatial planning level from the Environmental Ministry, to provincial councils and local municipalities. The size of the planned area decreases towards city zoning as the specifics and details of the zoning increase.

A comprehensive reform of the Finnish Land Use and Construction Act is currently being planned, which is expected to be completed in March 2021. This might bring new changes to spatial planning in Finland, but the main structure will most likely remain.

The Finnish EIA legislation[8] defines projects that must always be subjected to an environmental impact assessment (EIA). EIA of plans and programs, or SOVA, are environmental impact assessments that are done as a part of preparation of plans and programs. The EIA is also applicable to smaller projects or to projects other than those covered by the regulation, provided that potential significant adverse

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[7] MAL 132/1999
[8] YVA 252/2017

environmental effects are considered. The party planning the project is responsible of taking care of the necessary environmental assessments. Correspondingly, the planning can be carried out by a private company or a public body such as the Finnish Centre for Economic Development, Transport and Environment, better known as ELY Center. The procedures are guided and supervised by the ELY Center, which acts as the liaison authority. In the Finnish national legislation (EIA and SOVA, section 2), Environmental impacts includes the concept of effects on the climate and in the Directive amending the EIA Directive (2011/92/EU) (2014/52/EU) it is required that the EIA procedure for projects assess the climate impacts of projects as well as their vulnerability to climate change.

Yet, presently used standards do not put high importance on the considerations of climate scenarios and potential future extreme weather events when it comes to the planning of urban drainage systems.

1.4 Country profile: Latvia

Spatial planning in terms of flood risk areas in Latvia mainly concerns fluvial and coastal flooding, flooding from extreme stormwater events is largely an uncovered area where more work is needed. The main regulation acts governing spatial planning, stormwater management and flood management are described below, with implications mentioned for spatial planning in potential flood risk areas.

Water management law specifies preparation of River Basin Management Plans in accordance with the EU Water Framework Directive and Initial Flood Risk Assessment and Flood Risk Management plans in accordance with the EU Floods Directive for the four river basin management districts of Daugava, Gauja, Lielupe and Venta rivers.

Flood risk management plans (FRMP) for years 2016-2021 have been approved for the 4 river basin districts of Latvia (Daugava, Lielupe, Gauja, Venta) in accordance with the EU Flood Directive. FRMPs contain quite detailed analysis of flood risks due to spring snow melt, storm surges, ice accumulation, specifying particular areas and measures, however cover stormwater-related flooding only in general, without specific spatial references. For example, specific goal No. 5 of Daugava river basin FRMP is "To prevent flooding of local territories caused by rain and spring melt, by arranging and developing surface runoffs and rainwater drainage systems", without stating specific territories. FRMPs for the next period are under preparation at the moment and initial flood risk assessment has been prepared. Just as in the previous period, the assessment denotes specific areas for fluvial and coastal flooding and touches upon stormwater-related flooding only in general. This is mainly due to technical difficulties in assessing flood risks and flooded due to the absence of generally accepted low cost method for mapping such areas, a problem that is not unique only to Latvia but indeed is being tackled at the level of EU Floods Directive task force.

As a part of the process in preparing FRMPs, flood risk information system (called PRIS) and flood maps for spring melt and storm surges flooding with probability one in 10, 100 and 200 years have been prepared for the entire territory of Latvia (Figure 3)[9]. However, the maps at the moment do not consider climate change and resulting sea level rise and change in weather patterns (snow accumulation, winds, etc.), this is to be done some time in 2021.

[9] https://hidro.meteo.lv/#

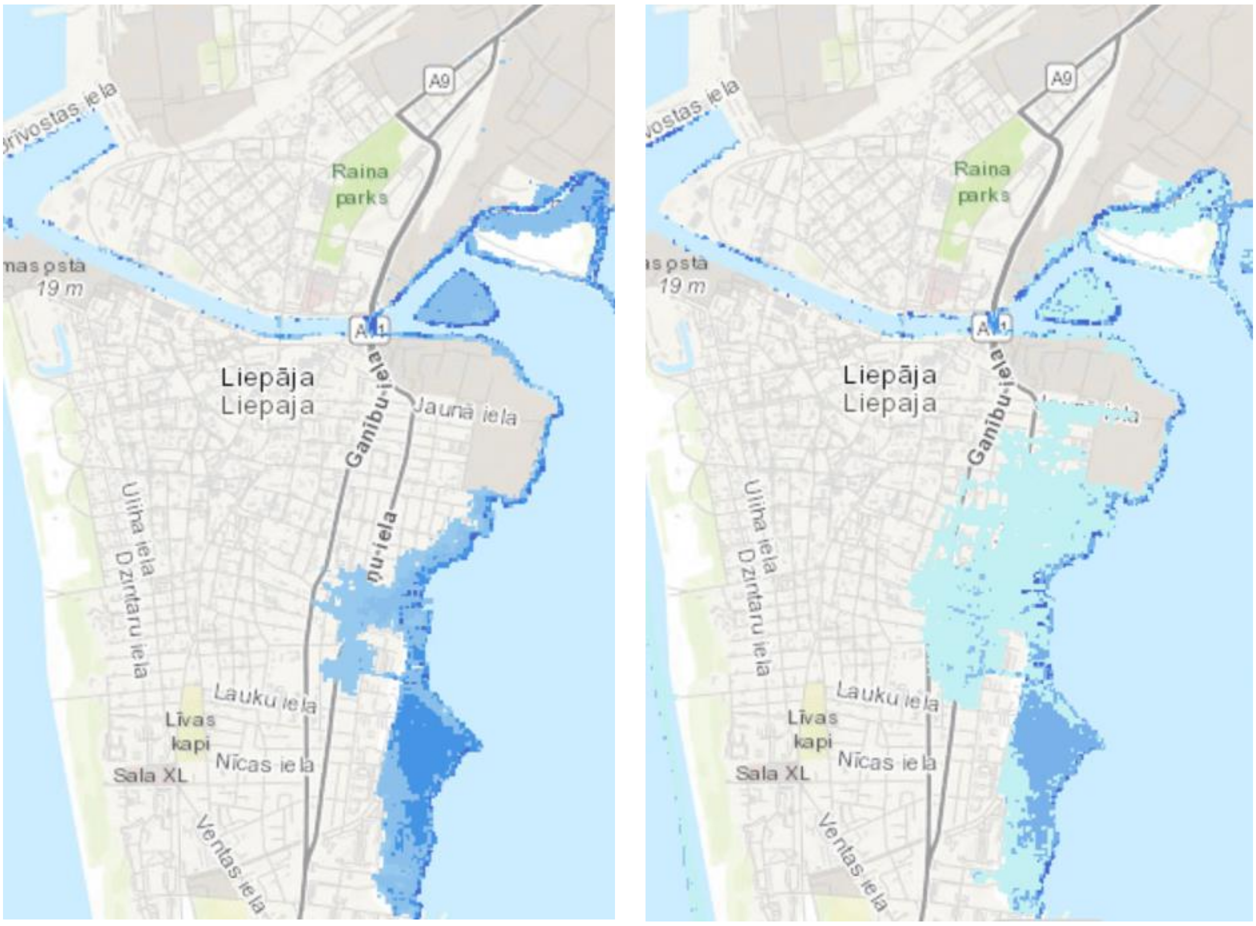

Figure 3 Flood maps for spring snow melt floods (left) and storm surge floods (right) with occurrence once in 10, 100 and 200 years for the city of Liepaja central part from the Flood Risk information system

Law **"On Protective belts"** specifies that protective belts of water bodies have to include flood risk areas and consequently, they determine the activity and set the construction restrictions in these areas. This means that restriction of any activities in the flood risk areas concern only coastal and fluvial flooding and pluvial (stormwater) flooding is not covered.

Cabinet Regulation No. 406 of 3.06.2008 "Methodology of determining protective belts of surface water bodies" define the procedure for determining flood prone areas, defining them as zones where flooding is regularly observed or modelled flood zones with 10% (once in 10 years) occurrence probability.

Law **"On Local Governments"**, which provides that collection, drainage and purification of wastewaters irrespective of the ownership of the residential property, as well as flood control measures are the autonomous functions of local governments.

Spatial Development Planning Law entitles a local government to govern rainwater management and flood risks in the spatial plans, local plans, detailed plans, and thematic plans. The law requires to take into account during local spatial planning national sectoral documents, including FRMP, Flood Risk maps etc. Therefore, flood risks identified nationally as well as in local studies need to be considered in the local spatial planning documents. In practice this means that areas of spring melt and storm surge flooding with occurrence probability of 10% are included in all local spatial planning documents, with corresponding restriction on activities and new construction in these areas.

Law on Water Management Services, which states that rainwater drainage into centralised collecting systems is a public water management service, in turn rainwater drainage into separate system is not public water management service; the Law also provides that local government shall issue binding regulations regarding operation and usage of centralised sewerage, as well as that local governments CAN issue binding regulations regarding stormwater management, which means it is up to local governments to issue local rules on flood protection, discharge limitation, green infrastructure etc. This also means that in theory the mentioned binding regulations may include a tariff for stormwater management.

Land drainage Law, which states that 1) the land owner or legal possessor or municipality shall perform the initial inventory of the land drainage system of a single property and of land drainage system for common use; 2) land drainage system of a single property shall be operated and maintained by the owner or legal possessor of the relevant land; 3) land drainage system for common use shall be operated and maintained by owners or legal possessors of the relevant land 4) the construction, operation, and maintenance of land drainage system of local government significance for common use shall be ensured by the owners or legal possessors of the relevant land. The local government may participate in construction, operation, and maintenance of a land drainage system of local government significance for common use.

Cabinet Regulation No. 714 of 3.08.2010 "On Operation and Maintenance of Land drainage System" provides for requirements to be met by owner or legal possessor of land in usage, care and preservation of land drainage system, imposing high liabilities on owners and legal possessors of lands.

Cabinet Regulation No. 378 of 7.07.2015 "Regarding Procedure of Calculation, Distribution and Payment of Construction, Operation and Maintenance Costs and Procedure, under which a Local Government Participates in Construction, Operation and Maintenance of Land drainage System of Local Government Significance for Common Use, as well as in Covering the Mentioned Costs" provides that a local government can finance maintenance activities of land drainage system of local government significance for common use, which belongs to private and legal persons, only if the system is under flooding risk related to storm surges or spring melt or in emergency situations. If the emergency situation has arisen resulting from violations of laws and regulations (e.g. owner's negligence), the municipality must charge the respective land owner, meaning lengthy procedures involving, inter alia, litigation.

Considering practical difficulties of such procedures, in practice many important land drainage systems instrumental for flood risk management, are poorly maintained.

To summarise the above-mentioned legal acts, the national level planning provides for flood risks assessment and maps flood risk areas related to coastal and fluvial flooding resulting from storm surges, spring melt and ice accumulation, and local level planning documents (municipal plans, local plans, thematic plans, detailed plans) must take these areas into account and follow restrictions and measures. However, mapping of flood risks resulting from extreme storm events is each municipality's own business. Please see below the table 3 with main spatial and water resources management documents relating to urban floods.

Table 3: Most important plans related to urban floods in Latvia.

Planning level	Published by	Frequency	Deals with and scope	Scale
Municipal Plan	Municipalities	12 years	City development, areal usage, determines new zoning and identifies flood risk areas (coastal and fluvial flooding)	Municipality
Local Plan	Municipalities	As needed	Clarifies building conditions in the area, must consider development conditions including flooding risk (coastal and fluvial flooding) and infrastructure	Part of municipality (e.g. neighbourhood, several city blocks)
Detailed Plan	Municipalities	As needed	Clarifies building conditions in the area, must consider development conditions	Land plot or several land plots

			including flooding risk (coastal and fluvial flooding) and infrastructure	
Flood Risk Management Plans	Latvian Danish Costal Authority	6 years	Coastal and fluvial flooding areas identified, pluvial flooding mentioned in general	National and regional (river basin districts)

Some municipalities like Riga, Jelgava (Figure 4) or Liepaja (Figure 5), have been proactive in identifying potential flood risk areas in relation to extreme precipitation and have provided protection measures in some areas. Pilot stormwater catchment basin plans have been prepared identifying risks, their economic significance and resulting level of flood protection and measures. However, this approach is only coming to existence and NOAH project can greatly contribute to the development of science-based and cost-effective approaches to urban flood prevention and management.

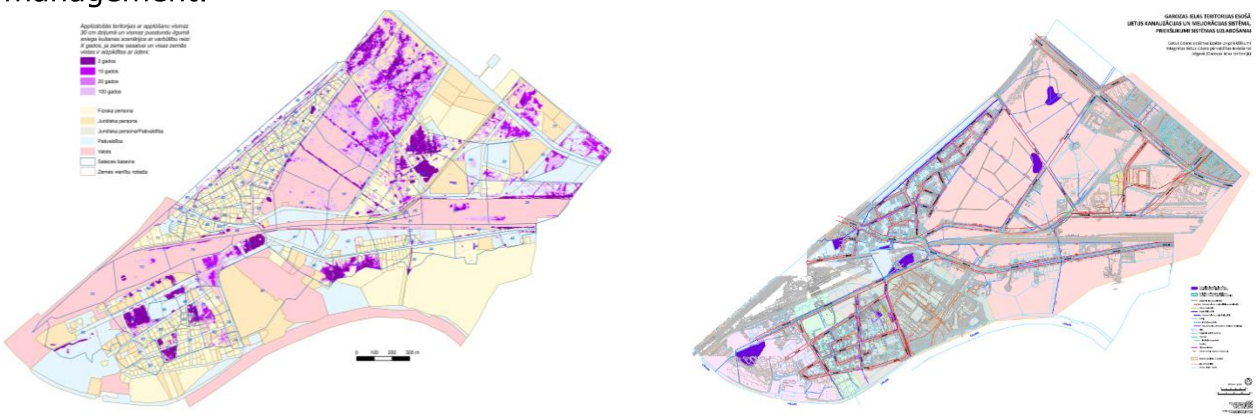

Figure 4 Modelled flood areas (extreme precipitation and snow melt of different probabilities) and proposed flood risk management measures in Garozas Street catchment basin pilot management plan in the city of Jelgava

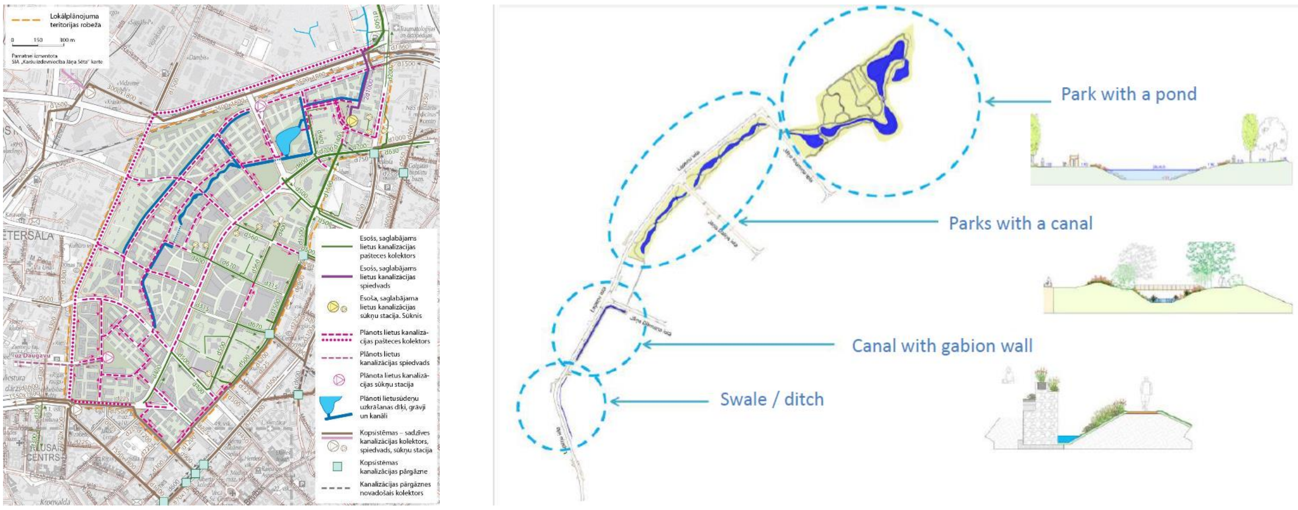

Figure 5 Planned urban drainage system for Skanste neighbourhood in Skanste local plan (left) and technical design of the first stage of the blue-green corridor (right). The system is designed to withstand extreme storm of probability once in 200 – 500 years, depending on the area it will service in the future. The first stage will be completed by 2021

1.5 Country profile: Poland

At the national level, the basic document is **The National Spatial Development Concept 2030 (NSDC 2030)**[10]**,** which is the most important national strategic document that addresses the spatial planning management of Poland.

Voivodeship spatial development plans consider the provisions of the national spatial development framework programme. The NSDC records under the arrangements are binding on **voivodeship spatial development plans (**VSDP), within the scope specified in the Law on spatial planning and development of 2003. This means an obligation to introduce area of operation and programming to the **voivodeship spatial development plans,** which were indicated in **The National Spatial Development Concept 2030**. It is necessary condition to determine VSDP compliance with NSDC and compliance of planning documents of lower level with VSDP.

At the local level (commune level) spatial planning is own task of the commune. For the entire area of the commune, a strategic document is prepared – the Study of the conditions and directions of spatial development. For areas selected in the study, a mandatory local spatial development plans are prepared (LSDP — Polish: MPZP).

Areas included in the documents at the regional and local level.

One of the selected areas are those in which there is a risk of flooding. In the mentioned planning documents a cause analysis is performed for them. Planning documents also indicate appropriate legal basis for action. For example, flood risk maps constitute the basis for spatial development planning at its various levels in areas at risk of flooding. The maps indicate areas where the probability of flooding is low, medium and high.

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[10] Ministry of Regional Development Warsaw 2012

For other areas prone to flooding, programs and projects are indicated, such as regional programs, urban projects and programs for coastal zones (i.e. The Sea Coast Protection Program, defining activities aimed at securing the coast against storm and flood hazards (Journal of Laws of the Republic of Poland 2016, Item 678)).

The aim of the preliminary flood risk assessment is to determine the areas at risk of flooding, i.e. areas where there is a significant flood risk or where a high risk is likely to occur. Preliminary assessment is performed based on available or readily obtainable information including:

1. hydrography, topography and land development;
2. description of historical floods, which have caused significant negative effects on human life and health, environment, cultural heritage and economic activity;
3. assessment of the potential negative effects of floods that may occur in the future;
4. forecast of long-term development of events, in particular the impact of climate change on the occurrence of floods.

Moreover, implementing the EU policy on adaptation to climate change, in October 2013 the Council of Ministers of the Republic of Poland adopted document developed by the Ministry of the Environment: „Strategic Adaptation Plan for sectors and areas sensitive to climate change by 2020 with a perspective by 2030" (SPA 2020). This document indicated the need to shape urban spatial policy considering climate changes. The Ministry of the Environment addressed a proposal for cooperation to the largest urban centers. Its aim was to develop plans for adaptation to climate change. The adaptation plan is related in particular to Strategy for Responsible Development (Polish: SOR), The National Spatial Development Concept 2030 (NSDC 2030 – Polish: KPZK) and National Urban Policy until 2020 (Polish: KPM). In the Strategy for Responsible Development, in the area of the environment actions are indicated to adapt to the effects of drought, counteract the effects of floods, and protect water resources. One of the actions is also development of green and blue infrastructure of urbanized areas in order to maintain spatial connectivity inside these areas and with open areas, and to support the processes of adaptation to climate change. The adaptation plan includes actions coinciding with the actions of the Strategy for Responsible Development.

Table 4 Indication of three specific areas regarding existing flooding risk and reference to the plans and strategic documents which are obligatory

	Type of functional area	Document/entity indicating the criteria	Document/entity of area delimitation (delimitation of boundaries)	Actions for the indication	Indication resulting from the National Crisis Management Plan	Related documents
Systemic actions to protect the sea coastline against erosive activity of the Baltic Sea and storm flood risk, and its management	Exposed to the risk of flooding on the scale of river basins	NSDC; the Water Law Act of 18 July 2001	National Water Management Board (National Water Management Holding Polish Waters) in consultation with Regional Water Management Boards; Maritime Offices	Preparation of documents indicated in the Water Law Act by the President of National Water Management Board: flood risk maps, river basin management plans	Coordination with the National Crisis Management Plan; Plans and programs for the Odra and Vistula basins and, if necessary, for other rivers. Flood risk management plans (PZPR)	State water policy until 2030, including the 2016 stage; The strategy of sustainable agriculture and rural development; Investment programs (Regional Water Management Boards) Preliminary flood risk assessment (Polish: WORP); Flood hazard maps (Polish: MRP); Flood risk management plans (Polish: PZRP)
	Coastal zone	NSDC; A group of representatives of ministers competent for local government, regional development, transport, building industry, spatial economy and housing, maritime economy, fishing, environment, water management	Voivodship development strategies Relating to the land: The Voivodeship spatial development plan (VSDP); Relating to the sea: The Territorial sea development plan (TSDP)	Appointment of the consultative team by the minister competent for regional development	Establishing a spatial development study for the coastal zone	Guidelines of the Ministry of Regional Development; Maritime policy; Sectoral strategies; Voivodeship development strategies; Integrated coastal zone management; the Act on the Marine areas of the Republic of Poland and maritime administration [Journal of Laws of the Republic of Poland 2003 No. 153, Item 1502]

Preventing spatial conflicts resulting from natural conditions (depression area, proximity to the sea, flood risk)	Żuławy Region				**Establishing** preparation of development plan and strategy for Żuławy Region	Guidelines of the Ministry of Regional Development; Sectoral strategies; Voivodeship development strategies; State water policy until 2030, including the 2016 stage; Programme: Comprehensive Flood Protection of Żuławy Region until 2030, including 2015 stage ("Żuławy Programme 2030")

Table 5 Polish spatial planning hierarchy and consideration of urban floods

Planning level	Typical Scale	EIA/SEA	Revision	*Main purpose*	*Flooding protection*
The National Spatial Development Concept 2030	Schematic	SEA	20 years	Programs containing government tasks, for the implementation of a public purpose investments of national importance	Indication of three specific areas regarding to existing flooding risk and reference to the plans and strategic documents which are obligatory. Indication of decision units to coordinate the actions on the third area. (See Table 4)
Voivodeship spatial development plans	1:100 000 1:200 000	SEA	10 years	Programs containing tasks, for the implementation of a public purpose investments of regional importance	They take into account: the River Basin Management Plans Flood risk management plans The small retention programs Environmental protection programs The Strategic adaptation plan for sectors and areas sensitive to climate change by 2020 with a perspective by 2030 (SPA 2020) If it covers an area of high flood risk – agreement with National Water Management Holding Polish Waters
Study of the conditions and directions of spatial development	1:10 000 1:20 000 1:25 000	SEA/EIA	6-10 years	The study takes into account the conditions resulting in particular from the requirements for flood protection. The conditions related to the occurrence of areas of particular flood risk are considered; investments and their locations are indicated that reduce the risk of flooding.	Flood risk maps prepared by the National Water Management Board They take into account: the River Basin Management Plans Flood risk management plans The small retention programs Environmental protection programs If it covers an area of high flood risk – agreement with National Water Management Holding Polish Waters
Local spatial development plan	1: 500 1:1000 1:2000 1:5000	EIA	10 – 15 years	The boundaries and methods of land or facility development, including the development of flood hazard areas, are indicated. A document of the nature of local law on the basis of which the building permit is issued.	If it covers an area of high flood risk – agreement with National Water Management Holding Polish Waters; MPA Project – Urban Adaptation Plans The ecophysiographic study being the starting material for the development of “Study of the conditions and directions of spatial development” and “Urban Adaptation Plans (MPA)”; Areas of particular risk to floods along with the assessment of environmental resistance to legal and physiographic limitations in the development of these areas are indicated;

Out of the six objectives of spatial policy of the country expressed in The National Spatial Development Concept, two relate to the issue of adaptation to climate change. First one is formation of spatial structures supporting the achievement and maintenance of high-quality natural environment and landscape. Second one is increasing the resistance of the spatial structure to natural hazards. The adaptation plan is also aimed at improving the quality of the natural environment in the city and increasing the city's resilience to threats related to climate change.

The city of Slupsk is one of 44 large urban centers in Poland, which are particularly at risk due to the effects of climate change and where the conditions resulting from the city's own characteristics, historical processes and the dynamics of development may increase these threats. Climate change adaptation plan (MPA) for Slupsk was developed in 2018. It was adopted in 2019 by the City Council and its implementation began in the same year. The plan indicates the vision, primary objective and specific objectives of the city's adaptation to climate change (by 2030), which should be achieved through the implementation of selected adaptation actions in the four most sensitive sectors of the city, such as: public health/vulnerable groups, water management, transport and tourism (in terms of recreational areas in the city). The adaptation plan is related to documents on adaptation to climate change at the international, community and national levels, but also at the regional level. Adaptation actions are consistent with the EU and national policies in the field of adaptation to climate change as well as development policy of Slupsk, expressed in the city's strategic and planning documents.

The adaptation plan includes a diagnostic part, in which climatic phenomena and their impact on the city were described. The sensitivity of the city to these phenomena and the ability to independently deal with the effects of climate change were also assessed. In response to the risks identified in the diagnostic part of the document, adaptation actions necessary for implementation in order to increase the city's resilience to the current and predicted future phenomena were defined. The plan includes three types of activities:

1) *Organizational activities*: relate to changes in local law in the field of spatial planning, organization of public space, creating guidelines in situations of climatic hazards, improving the functioning of municipal services or hazard warning systems, e.g. preparation/updating of instructions for public services in case of extreme meteorological and hydrological phenomena, extension of the monitoring and warning system;

2) *Information and education activities*: supporting actions, raising social awareness of climate and promoting good adaptation practices. They make it possible to adapt the city and its inhabitants through appropriate educational programs and intensified information activities (i.a. education / promotion / information about good and bad practices);

3) *Technical activities:* investment activities covering the construction of new or modernization of existing infrastructure, which contributes to the protection of the city against the negative effects of climate change, such

as: construction and development of the blue-green infrastructure systems or increasing the share of biologically active area through limiting impermeable surfaces in the city or unsealing them.

The Adaptation Plan also defines the rules for the implementation of adaptation actions (responsible entities, funding framework, monitoring indicators, assumptions for the evaluation and updating of the document).

The implementation of the Adaptation Plan is a process that requires the involvement of many entities managing and operating in the city. To implement the Adaptation Plan, the existing institutional framework of the city's development policy is used, whereas coordination of the implementation of the adaptation action plan is entrusted to the Department of Municipal Economy and Environmental Protection of the Municipal Office of Slupsk. Due to the horizontal nature of adaptation, the implementation of the Adaptation Plan will take place through communication and cooperation between the involved entities. Among the significant entities involved in the implementation of the Adaptation Plan should be mentioned the Municipal Office of Slupsk represented by the following departments: Department of Municipal Economy and Environmental Protection, Department of Security and Crisis Management, Department of Spatial Policy, Department of Construction, Department of Communication and Transport, Department of Health and Social Affairs, Department of Real Estate Management and Business. Other entities involved in the implementation of the Adaptation Plan are i.a.: Slupsk Water Supply Company, ENGIE EC Slupsk, City and District Geologist in Slupsk, State Fire Service, Municipal Conservator of Monuments, Regional Directorate for Environmental Protection in Gdansk (RDOŚ), Voivodship *Fund for Environmental Protection and Water Management in Gdansk* (WFOŚiGW).

The implementation of the Adaptation Plan also requires the participation of the inhabitants of the City of Slupsk, as well as social organizations, in particular working for the protection of the environment, and excluded social groups. The scientific community and entrepreneurs are also expected to be involved in adaptation actions. Considering the risks associated with climate change in the development of research and in strategic and financial planning can stimulate new technologies to adapt and contribute to a better implementation of the Adaptation Plan.

The adaptation plan is subjected to monitoring of the implementation of actions in two-year cycles (2021-2030). The implementation of the actions will be assessed every six years (2024 and 2030). Furthermore, every six years an update of the Adaptation Plan for the City of Slupsk is also planned.

1.6 Proposal for addressing urban pluvial flooding in planning and decision-making (related to UDS)

Though the project proposal indicated the aim to propose universal changes/adjustments in the urban planning policy and regulations for the whole Baltic Sea region, after analysis of the country profiles it is evident that these suggestions vary highly because the regulations and official procedures differ significantly. The report does address the shared concern that the present procedures applied for urban planning lack capacity to consider climate change concerns as well of UDS performance on daily decision-making in urban governance.

The main barrier for not considering pluvial flooding risks related to extreme weather events to urban planning is the technical complexity of the UDS performance. Municipal officials have rough understanding of the stormwater management and do understand the risks of increased built environment raising the risk of stormwater related flooding, but avoid it mostly by applying precautionary principle or handle the risk areas site-by-site, by more detailed designs. These barriers revealed a significant relevance and potential of NOAH project activities.

NOAH project proposes to apply the Extreme Weather Layer (described in the following section of the report) in the municipal GIS systems and by that integrate the tool into daily decision-making procedure. Extreme Weather Layer allows to integrate UDS digital twin by urban planning datasets as well as include a possibility to simulate the causes of the decisions according to the climate scenarios formulated for the specific area (country or regional level). Such an approach allows to consider climate scenarios on routine land-use decisions, in which normal cases complicated climate risk modelling would not be cost-optimal and thus not practiced.

An example how to integrate the EWL into Estonian land-use planning procedures is illustrated in Figure 6 Integration of the EWL into Estonian landuse planning system It shows that such an approach allows to integrate climate change consideration into planning flood proof urban environments into various decision-making levels starting by single building notices and reaching up to making strategic plans about critical infrastructure. This is a significant step to overcome the obstacles in planning procedure.

The guideline how to develop the EWL and how it has been implemented in NOAH partner cities is described in the following chapter.

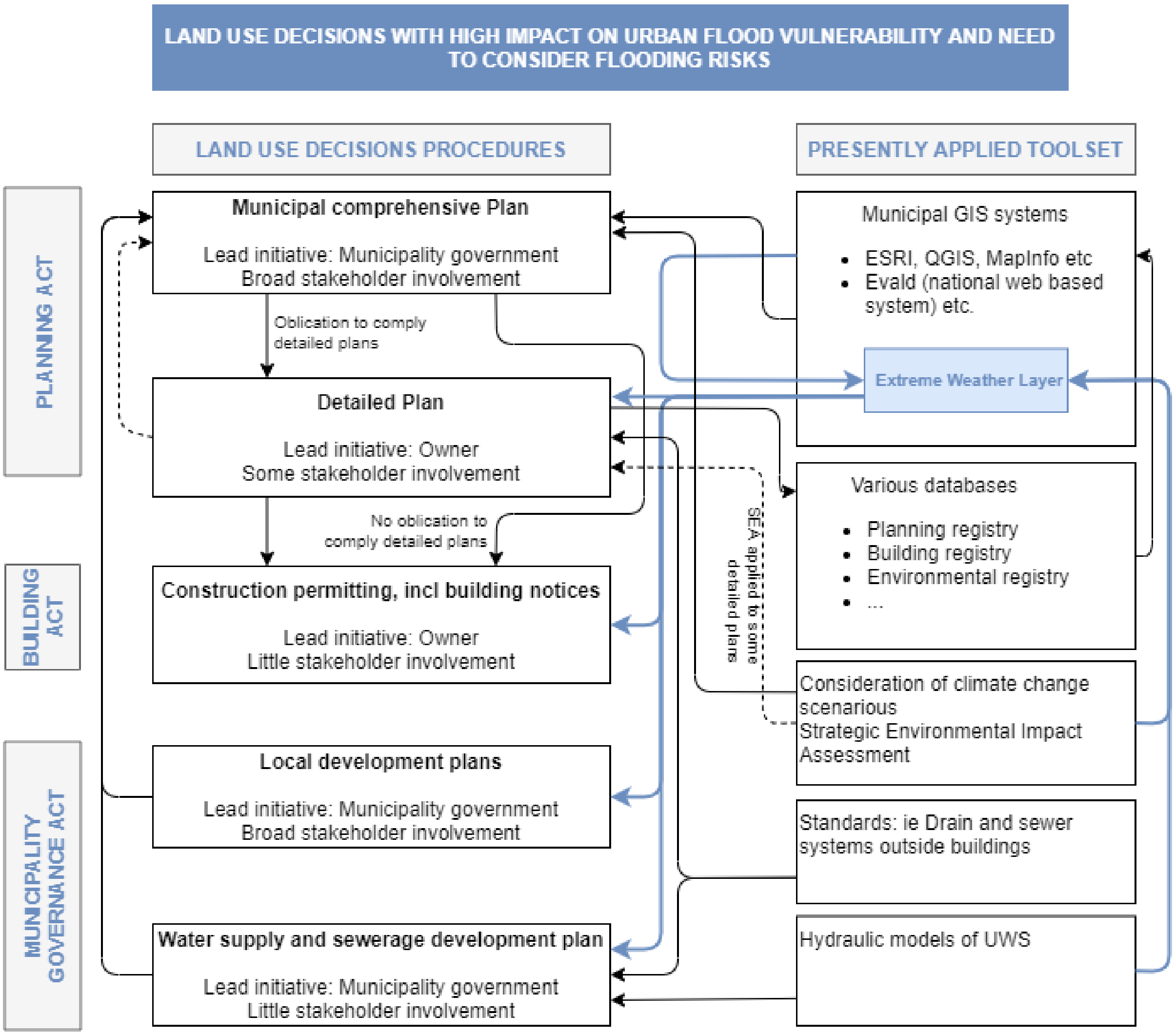

Figure 6 Integration of the EWL into Estonian landuse planning system

2 Methodology for creating Extreme Weather Layer (EWL)

Holistic planning support system – Extreme Weather Layer (EWL) is a combination of hydraulic modelling, climate scenarios and other urban planning datasets considered via GIS or otherwise. It connects the results of a storm water system hydraulic model with urban planning procedures. In case of the NOAH project, the hydraulic calculation was performed using the model software EPA SWMM 5.1 (The EPA Storm Water Management Model).

It is a dynamic rainwater simulation model used to simulate the quantity and quality of runoff from both one-off and continuous events (mainly in densely populated areas) with urban planning decisions to visualize the plots most vulnerable to present and future flooding risks.

The EWL is built on the digital twin of the existing storm water system and considers the data about the pipes, manholes, ditches and other technical elements, land use, topography, soil types etc. in the urban environment to gain information how the stormwater system and the catchments respond to different rainfall events.

Data for the model build-up comes from various sources and depends on the data availability in the municipality. Clear traffic-light manner color-coding will make EWL usable for urban planners not having profound expertise in environmental engineering. For example plots and cadastral units with "red" (highest flood risk) are easily detectable and the need of mitigative measures like local LID solutions, retention facilities etc. can be underlined and incorporated into planning procedure by the local municipality.

Initial idea is developed by TalTech Urban Water Systems Research Group, further development and implementation of the tool is done in cooperation with the project consortium of academies and pilot municipalities.

The step-by-step guide is provided in chapter 4.

3 Methodology description for adding EWL into the planning procedures

The EWL is built on the digital twin of the existing storm water system and it considers the data about the pipes, manholes, ditches and other technical elements, land use, topography, and soil types in the urban environment to simulate how the storm water system and the catchments respond to different rainfall events. In this work, the hydraulic calculations have been performed using the software EPA SWMM (The EPA Storm Water Management Model).

The process diagram (Figure 7 Layout of the holistic planning layer.Figure 7) shows the interlinkages between different components needed for the EWL planning tool. The core engine of the tool is a dynamic rainfall-runoff-subsurface model simulating the stormwater flow through catchments and pipelines.

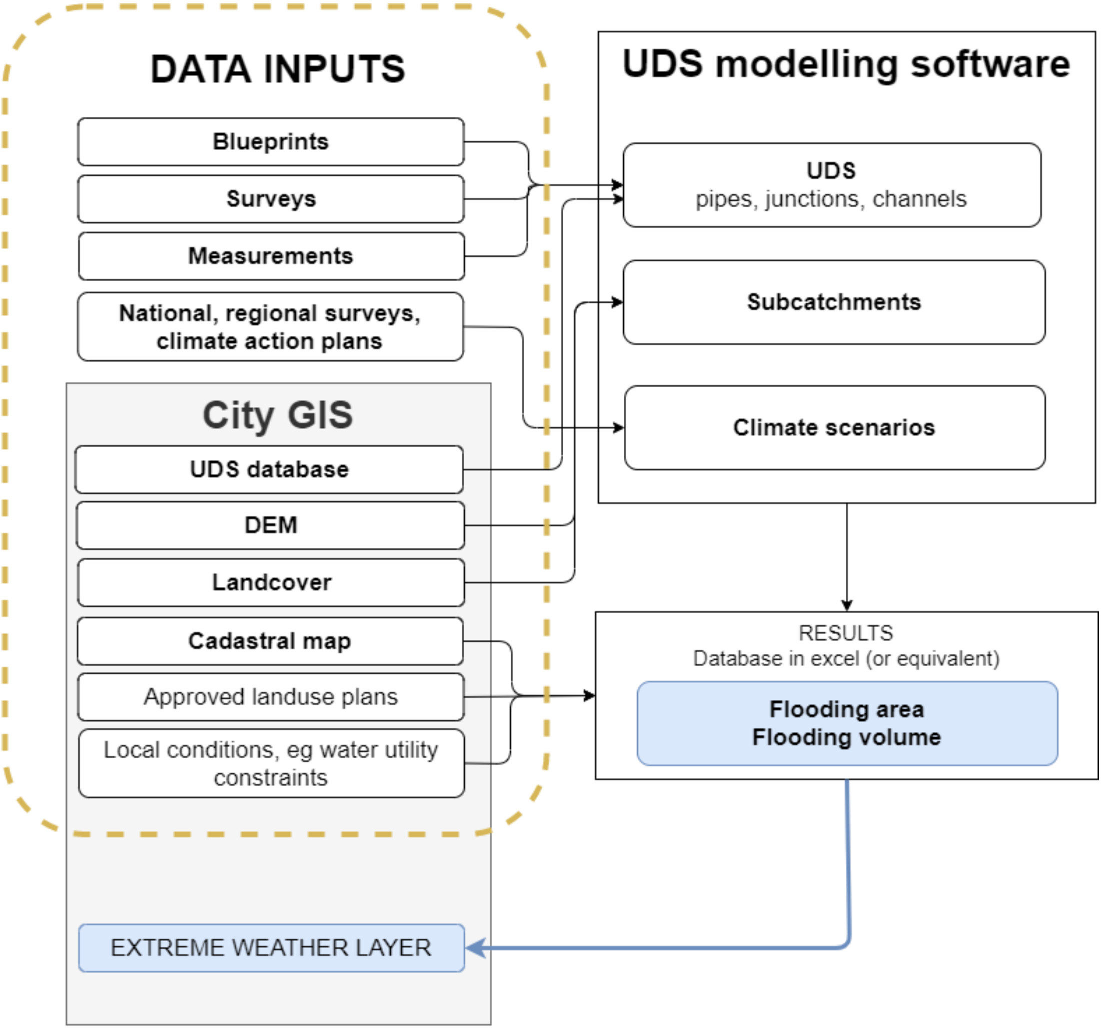

Figure 7 Layout of the holistic planning layer.

The risk simulations can be developed for as many climate scenarios as needed, in the present work 3 scenarios were considered. For more information on why such scenarios were selected for the pilots, see NOAH report O2.3.

The flood prone areas are presented in traffic light manner to clearly indicate to the planning specialist unfamiliar with flood modelling which properties and areas in the city are more affected by pluvial floods. At the same time, the tool can be used to define design criteria for connecting new developments with the existing UDS and find suitable technical solutions (real-time control solutions for UDS, NBS etc.) for flood mitigation. In addition, the EWL can be used to detect the properties where additional requirements are foreseen for buildings (e.g., planning higher plinths, forbidding to plan basements, underground parking etc. to avoid floods).

Also, flood risk prevention can be addressed in planning decisions in different scales and assessing land-use impacts of different units. EWL initially is intended to be developed on catchment level but allows it to be translated also to land parcels and if needed also to any other area of interests (planning plot etc.). Also, the methodology provided allows to implement the EWL in high detail, but similarly generalized to a broader scale and implemented only for large-scale planning (see case of Slupsk).

Implementation of EWL in urban environments has been performed in co-operation with pilot municipalities. Depending on the existing GIS system for spatial planning, EWL was aggregated to the existing system with site and system specific differences. Presently the EWL has been implemented only to visualize flood-prone areas, but work is ongoing under A4.1 to apply the system for decision making procedures.

4 Testing EWL in real life conditions

4.1 Cases Haapsalu, Rakvere, Pori, Söderhamn: coordinated by TalTech

Extreme weather layer was developed for 2 Estonian pilot towns, Haapsalu and Rakvere and for partner cities Pori in Finland and Söderhamn in Sweden. First examples of application of the EWL in the mentioned towns are given in the figures below.

Figure 8 Flooding risk levels presented for Haapsalu by traffic light methodology for scenarios 1, 2, 3 for catchment level

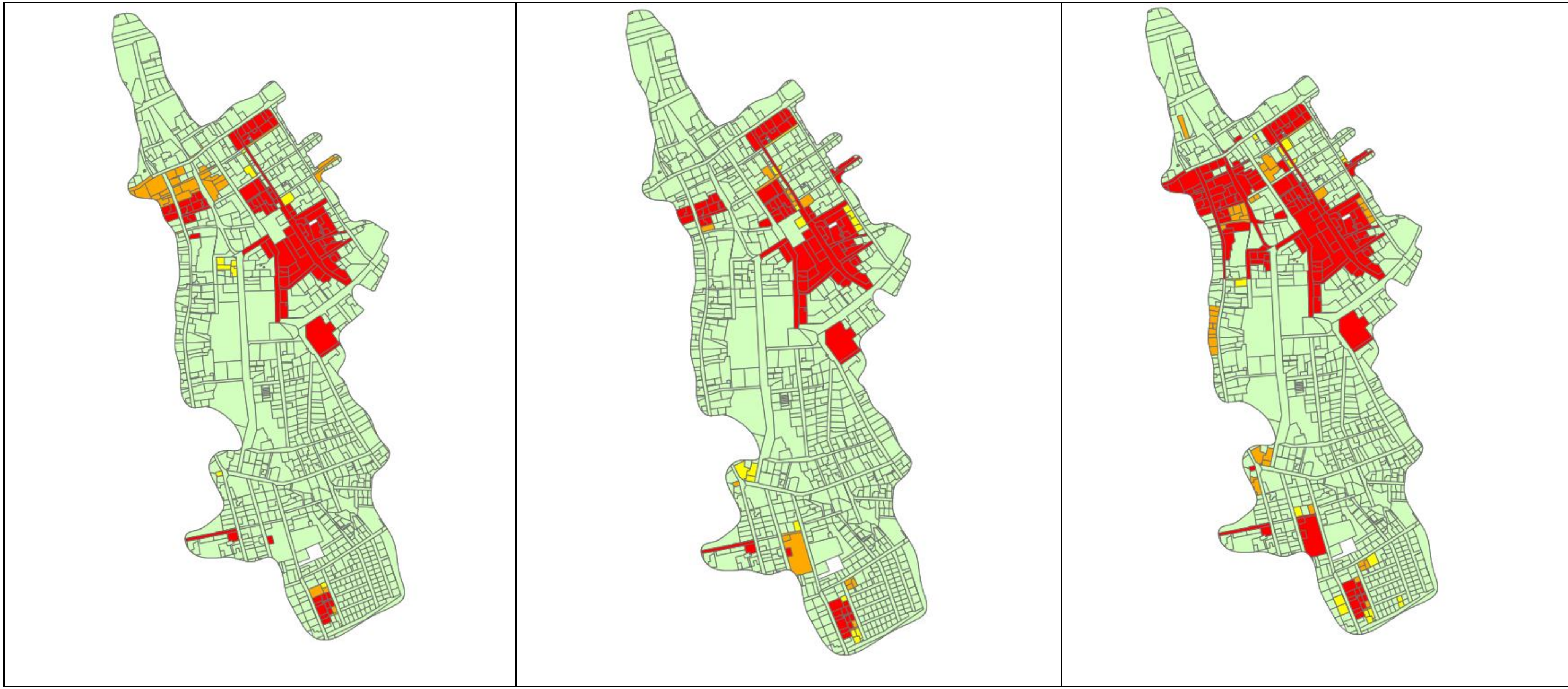

Figure 9 Flooding risk levels presented for Rakvere for scenarios 1, 2, 3 for land parcel level

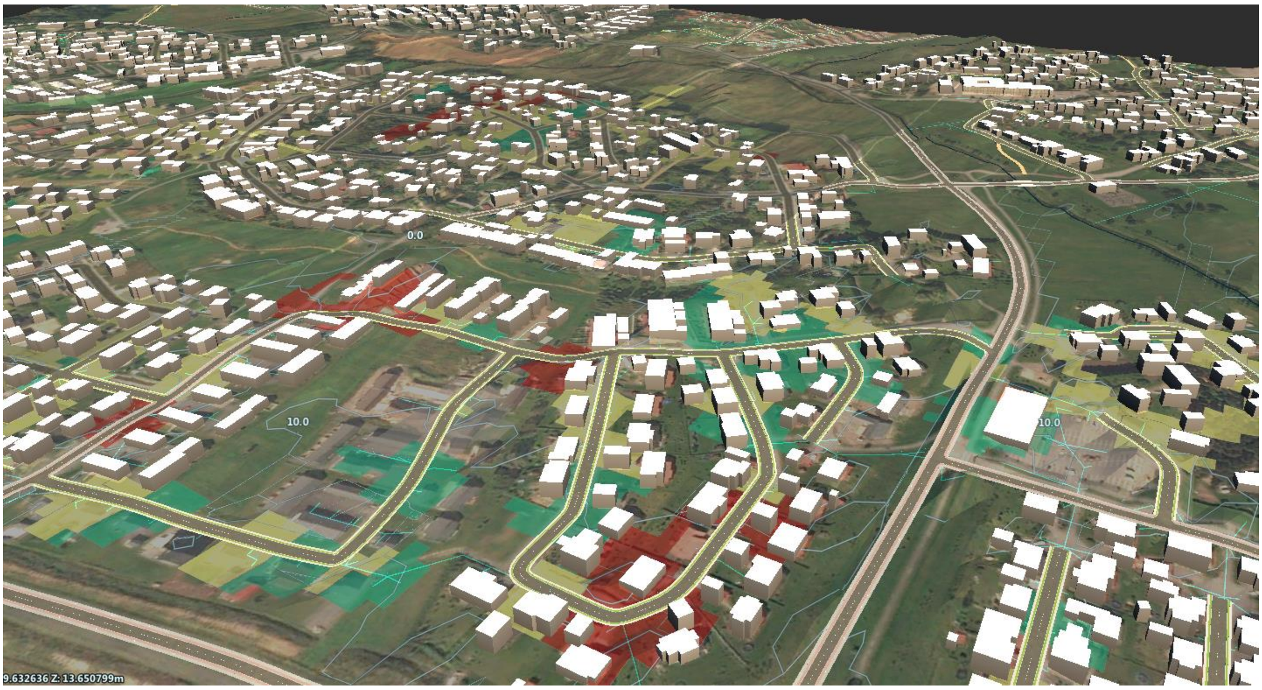

Figure 10 For visualization purposes it is possible to apply the EWL also in Infraworks or on any other civil infrastructure design software capable on assigning graphic characteristics based on data attributes, example of Pori.

Figure 11 Söderhamn model on catchment level (above) and translated to the scale of land-parcel (below)

4.2 Case Liepaja, Jurmala and Ogre: coordinated by RTU

Extreme weather layer was developed for 3 Latvian pilot towns, Liepaja, Jurmala and Ogre, first examples of application of the concept described briefly in Figure 12 and further elaborated below.

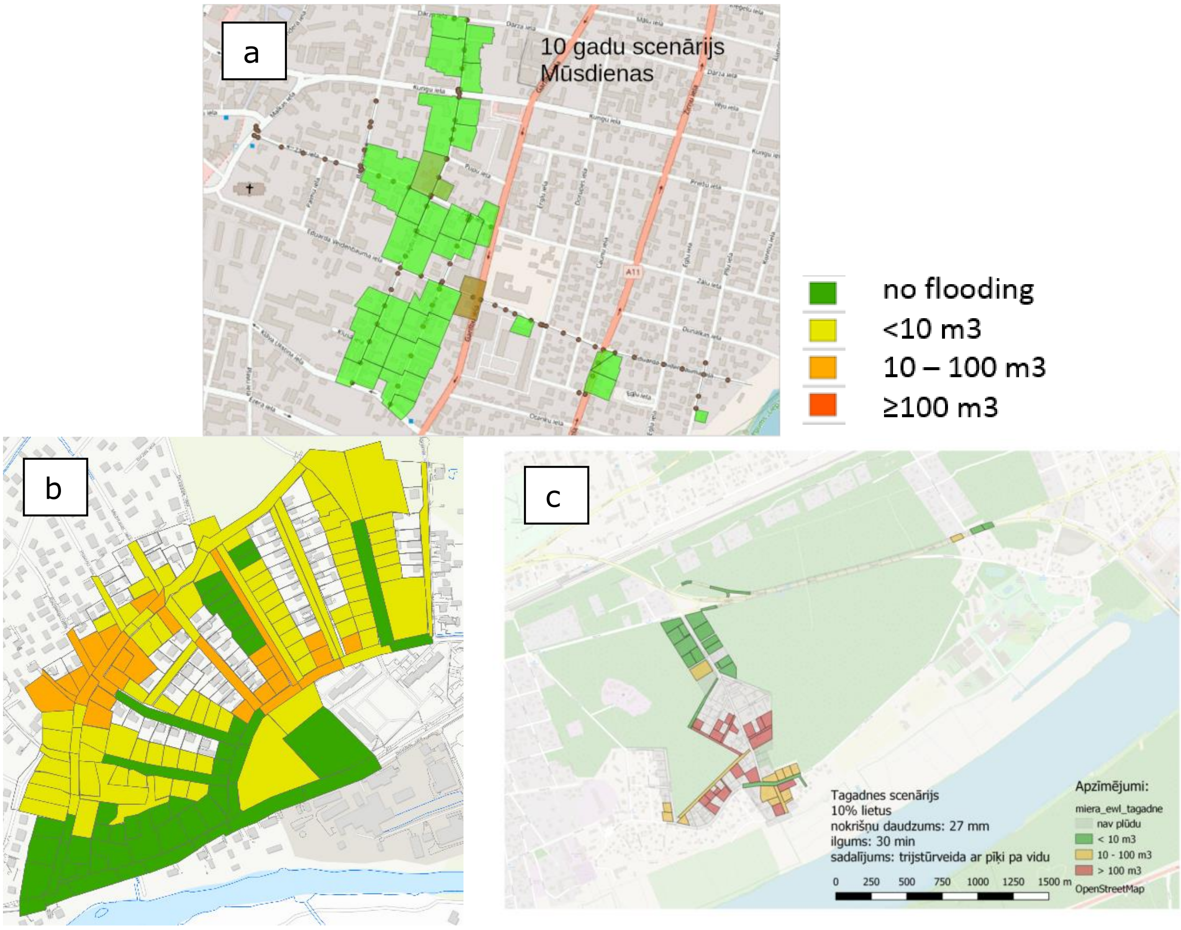

Figure 12 Visualized static EWL maps for the pilot areas from the left to the right (a) Liepaja in Tebras Street catchment basin, (b) Ogre in Loka Street catchment basin and (c) Jūrmala in Miera Street catchment basin for scenario describing present situation. The colors represent total overflow volume of all manholes/gullies at each subcatchments [m^3].

4.3 Large scale implementation case: Slupsk

Generally, the EWL has been implemented in accordance to the main steps presented in the chapter 4 "Example of a step-by-step guideline for implementation of EWL". The minor exceptions were required due to the scale of the pilot application and the input data availability. The hydraulic model used for the calculation of impacts of various rainfall events was based on the municipality's (Słupsk Water Supply) GIS database, which included detailed structure of the sewer system. i.e. several thousands of manholes, pipe sections and their characteristics. However, the spatial database existing at the initial stage of the NOAH project implementation did not comprise borders and features of individual catchments. Therefore, one of the assumptions of the EWL method – one catchment for each inlet – was difficult to follow.

Difficulties resulted from

(1) the large number of catchments which would have to be delineated (such task does not fall into the scope of the NOAH project due to the unreasonable work load) and

(2) the fact that only the combined part of the sewer system has "real" catchments, while the remaining (separated) part has uncertain drainage areas which contribute to individual manholes.

Nonetheless, the whole analyzed area (22 km^2) was parameterized and divided into nearly 300 catchments. It was achieved with the application of the official spatial planning datasets, i.e. digital elevation model and the Database of Topographic Objects prepared and distributed in Poland by the Head Office of Geodesy and Cartography based on the legal regulations (Journal of Laws of 2011 No. 279 item 1642; Journal of Laws of 2020 item 1304). Using these inputs, the direct application of GIStoSWMM5 or other catchment delineation tools resulted in the generation of slopes-based drainage areas, which were not in accordance with the urban development.

Consequently, the next slight deviation from steps listed in the chapter 4 was the manual delineation of catchments based of the topography, while the elevation data was of secondary importance. To increase the spatial resolution of the EWL, outputs are presented for manholes instead of catchments. All the remaining steps of the EWL were followed unchanged.

The Extreme Water Layer was also analysed in terms of the volume of flooding originating from individual manholes. Flooding classes were defined for Słupsk as follows:

- Green: $Q < 25\ m^3$
- Yellow: $25\ m^3 \leq Q < 100\ m^3$
- Red: $Q \geq 100\ m^3$

Figure 13 below present analysed one of the possible scenarios used for analysis and the number of manholes falling into individual flooding classes.

The full potential of the EWL in Słupsk can be reached after the detailed division of the whole study area into individual (small) catchments is done. Nonetheless, the EWL analyses should be considered as a screening tool capable of the indication of districts at risk and estimation of relative increase of flood risk related to the climate change.

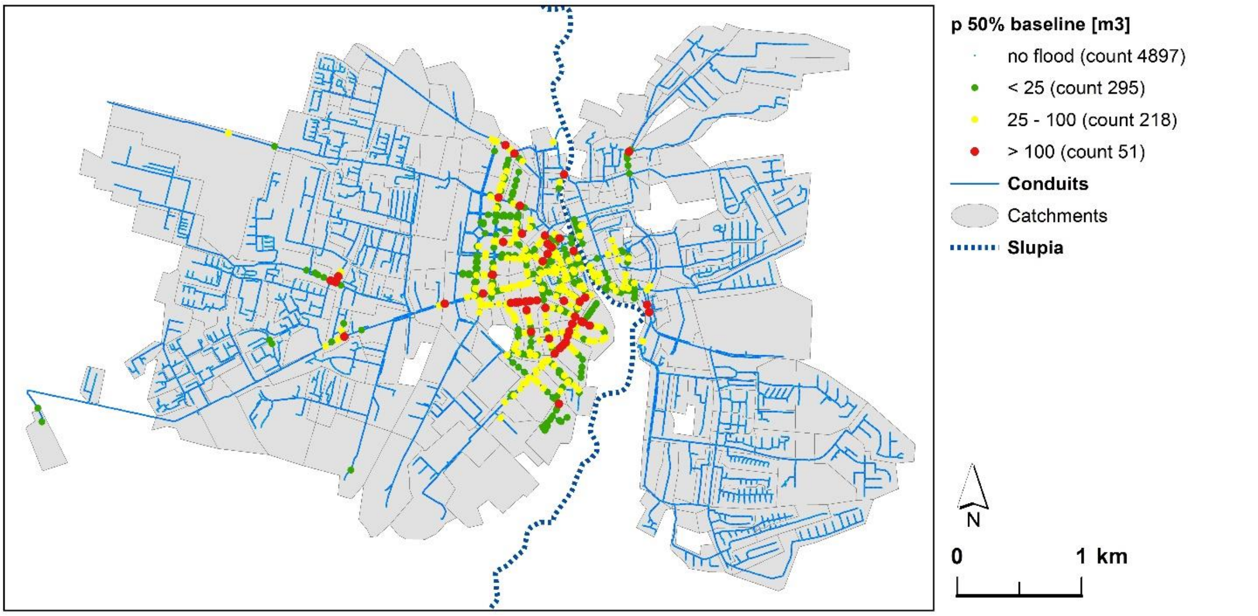

Figure 13 Example of EWL visualization developed for Slupsk

5 Putting EWL into everyday action - recommendations based on the current experiences of implementing EWL

The urban planning data which the EWL can be integrated with is very site specific, the EWL can be applied to various GIS platforms and even special digital interface could be developed.

The EWL can be used in the planning procedure for various purposes. The expected impact is mainly seen in three areas (see Figure 14):

1) **Analysing the flooding risks in the urban area under different climate scenarios**. This option enables the urban planner to detect the potential flood prone areas with different risk levels now and in the coming decades. Simple graphical layout can support the communication with developers and property owners when explaining the possible constraints regarding the changes in land use or volume of buildings.

2) **Analysing the effects of new developments on the urban area under different climate scenarios.** This option enables the urban planner to graphically present the changes in flood prone areas caused by changes in land use (e.g., from park to parking lot) and building volume of a specific plot to the whole catchment area in the urban area. In that option, EWL is a decision support tool for the planning specialist making available to see the effect of plot-based changes in a holistic city scale manner.

3) **Defining the mitigation measures and technical requirements for new developments**. EWL is based on a hydraulic modelling tool. Therefore, it can be used to define technical requirements for single developments (e.g., maximum storm water runoff from the plot to the UDS) in order to reduce the flooding risks in the downstream areas. The effect of different flood risk mitigation measures (plot based NBS, tanks, infiltration etc.) can be analysed and concrete solutions can be provided for each development. The impact of the technical and mitigation measures can be analysed using different present and future climate scenarios. This allows the urban planners to detect the effect of the solutions in short- and long-term plans.

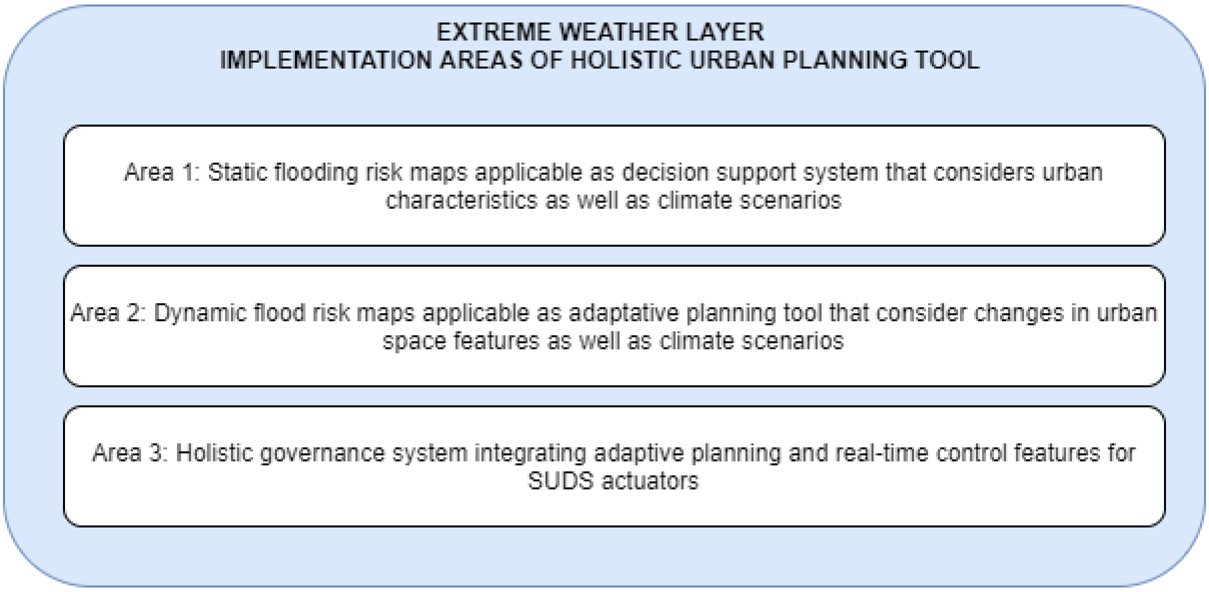

Figure 14 Increment of adaptation capacity of the extreme weather layer as holistic urban planning support system.

Potential to integrate with other urban flooding risk assessment tools

In Ogre case EWL static maps are expected to be combined with modelling results of River Ogre (Figure 15) and ice maps. The river floodplain simulation was performed using LISFLOOD-FP model which visualizes hydrological rainfall-runoff processes. The main observed historical problems were due to pluvial flooding caused by ice compositions.

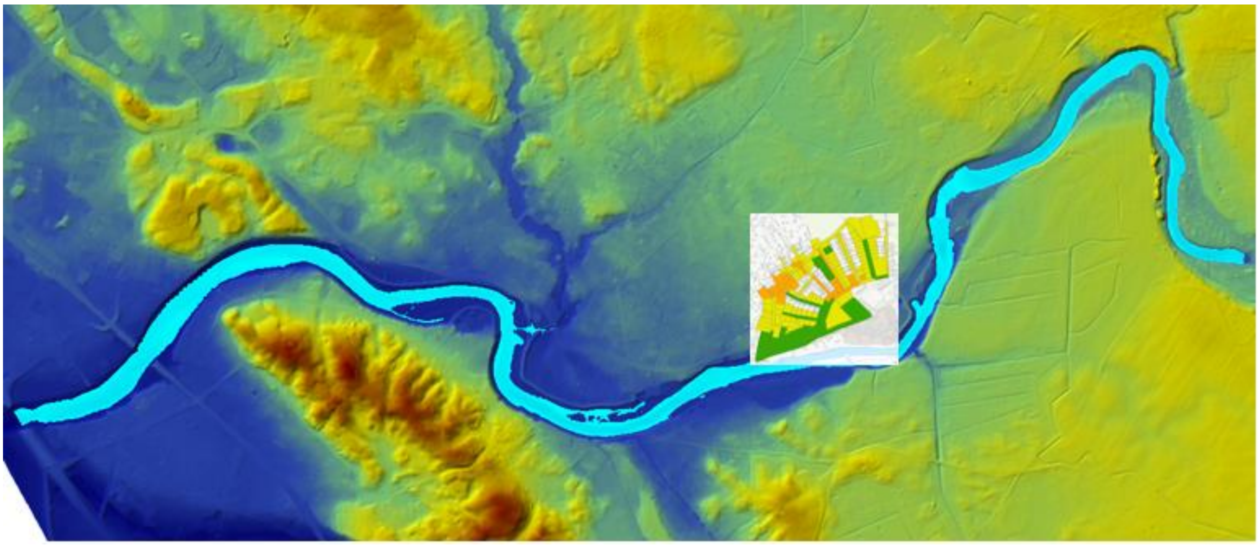

Figure 15 Combined EWL static map with preliminary floodplain simulation results in Ogre

The LISFLOOD-HP hydrological model generates 12 h forecasts of inundation zones hourly. The results of flood simulation are presented as a raster map with information about the depth of water in the flooded territory. Flood forecasting results are automatically published at the CesiumJS based geo-portal for prior notification about emergency situations. The web service provides possibilities of viewing layers with flood contours from the beginning of the modelling process up to 12 h forecast.

To predict the river water levels for the upcoming period of 12 hours on a daily base, a trend-adjusted exponential smoothing model is applied to observed water hourly level time series. By application of a symbolic regression method, a model for converting the water level into the water flow discharge in m3/s was created.
To determine the functional dependency between the waterflow discharge in the river and its water level within the forecasting horizon, a symbolic regression-based method implemented in HeuristicLab optimization framework has been selected. In order to train the model, historical data on water level forecasts were used. A web service for recalculation of the river water level into the water flow discharge was created providing hourly receipt of the water discharge in the river. In fact, forecasts of the water levels are transformed into forecasts for the water discharge values.
The sensor (automated hydrological stations - AHS) measurements from various sources and forecasts are visualized in a graphical web dashboard (Figure 16).

Figure 16 EWL observability dashboard representing combined AHS measurements and forecasts

The input data for floodplain simulation were obtained from several resources including bathymetric and geodetic measurements including application of drone.

For the floodplain simulation model, geodetic surveying was performed at the site. To create a 3D model of the riverbanks, aerial photography was performed with an unmanned aircraft. The real height and coordinates of the shore model were obtained using the global positioning method by measuring the support points on the riverbanks. The measurement of the riverbed and water surface was performed by global positioning. To obtain a high-precision water level surface, measurements were taken three times at different times of the year and in a short period of time along the entire length of the river section. As a result, it will be possible to model water volume flow and water inflow contours into floodplain lands.

Meanwhile the ice processes in the river were observed from Copernicus satellite data, both radar and optical (Figure 17).

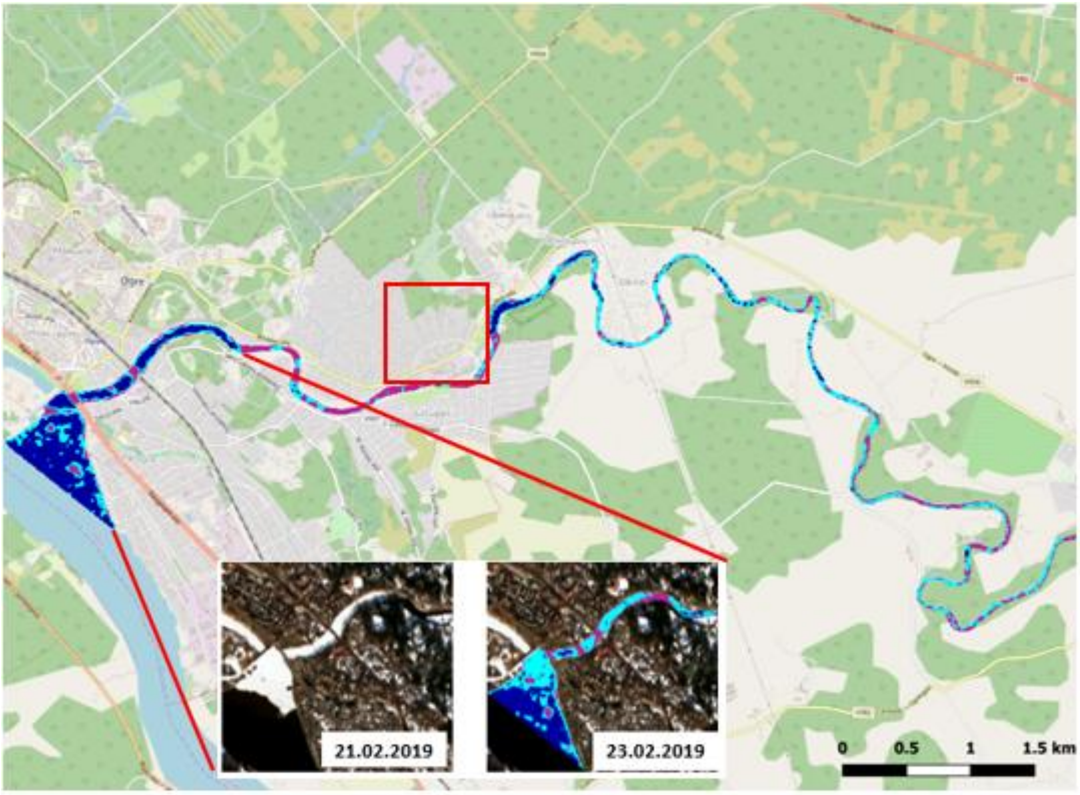

Figure 17 The example of map of Ogre River with radar and optical satellite data. With red rectangle indicated catchment area modelled with SWMM.

During winter and spring seasons information about ice conditions, is relatively hard to acquire manually, especially during freeze-up and breakup periods, which are characterized by ice jamming and extensive flooding. Installation of observation cameras in one of the solutions, although this method still provides only point observation rather than for longer river stretch.

Regarding the satellite data, the main concerns are revisiting time, resolution, and weather conditions. During the wintertime limited daytime and cloudiness limits the use of optical data, therefore freely available Sentinel-1 SAR data were chosen as the main data source. SAR satellites acquire images in all weather, day and night conditions. Revisit time for the Sentinel-1 satellites over Latvia is 1-1.5 days and images usually are acquired in early morning or evening.

Sentinel-1 IW GRD products with the 10 m spatial resolution were used for the river ice analysis. River ice analysis was performed on VV polarization data using Python programming tools. The analysis is based on changes in surface roughness and an increase in SAR backscatter values, for example when river ice is jammed in parts along the river stretch. Due to relatively small river size and satellite image resolution, Sentinel-1 image classification results were divided into 3 classes - low/medium and high backscatter. This corresponds to water or ice-free conditions, some type of river ice and ice jams respectively. The results of the analysis can be shared in many different formats suitable for GIS software to project the results on other thematical maps. Also possible to share as Google Earth *.kmz format for even easier data sharing, as the file size is very small.

From the practical use, there are some errors induced by the river characteristics and image resolution. The Ogre river is relatively small therefore river ice maps give general information about river conditions. Misclassification occurs at low water levels where riverbed characteristics crate turbulent water flow. Another misclassification is common on river stretches with extensive vegetation in the river channel, because plants are scatterers of SAR signal.

Sentinel-2 optical data can be used as reference information and to fill gaps between Sentinel-1 acquisitions. Clear images in the visible spectrum provide a good overview of river conditions which are also visually easier to comprehend. For the Ogre pilot area were Sentinel-2 Level 2 atmospherically corrected products to acquire information about river ice conditions. The Sentinel-2 data contain 13 spectral bands, but only 4 of them in the visible spectrum and NIR are in 10 m resolution, therefore regarding the river size other bands were not used.

6 Example of a step-by-step guideline for implementation of EWL

Step 0: Preparation, data acquisition
See the NOAH project output 2.1 Report on pilot areas and acquired data.

Step 1: Development of hydraulic model
See the NOAH project output 2.3 Report on modelling results.

Step 2: Defining catchments
Generate catchment areas for each inlet (gutter, curb opening) manhole that is included in the hydraulic model. Catchments and the parameters (permeability, infiltration, slope, shape etc.) are selected based on the Digital Elevation Models (DEM), land use classes etc.
For larger areas it is advised to use automatic generation of the catchment areas (e.g. GIStoSWMM5 software as described in A2.3 report)

Add the generated catchment areas to the UDS modelling software (in NOAH case, SWMM has been used).

Step 3: Defining and running climate scenarios in the hydraulic model
For defining the climate scenarios see report 2.2

Step 4: Identifying flood-prone manholes according to each used climate scenario
Use the SWMM reporting tool to deduce the manholes where flooding occurred under defined climate scenario. Export the data to Excel or similar database.

Step 5: Determine acceptance rates for flooding intervals
Add condition to the database based on the maximum flooding rate, maximum flooding volume or duration:
See example Figure 18.

	A	B	C	D	E	F	G	H	I
19	Node	Flooded	LPS	Flooding	Flooding	10^6 ltr	Meters		Condition
20	1560479	0.01	6.42	0	00:17	0	0		2
21	1560481	0.01	32.85	0	00:16	0	0		2
22	1562097	0.01	15.71	0	00:14	0	0		2
23	1562100	0.23	103.71	0	00:25	0.057	0		3
24	1562123	0.01	7.22	0	00:18	0	0		2
25	1562127	0.01	39.08	0	00:14	0	0		2
26	1562136	0.01	2.57	0	00:17	0	0		1
27	1562149	0.01	20.11	0	00:18	0	0		2
28	1562166	0.01	27.25	0	00:18	0	0		2
29	1562170	0.01	27.86	0	00:18	0	0		2
30	1562172	0.01	15.9	0	00:18	0	0		2
31	1562183	0.19	111.25	0	00:24	0.053	0		3
32	1562213	0.08	81.67	0	00:16	0.001	0		3
33	1562220	0.01	66.12	0	00:17	0	0		3
34	1562234	0.01	29.72	0	00:16	0	0		2
35	1562236	0.01	26.95	0	00:16	0	0		2
36	1562247	0.01	4.24	0	00:16	0	0		1

Figure 18 Adding conditions in spreadsheet. In the current case, conditions are based on maximum flooding and presented as follows: Q < 5 l/s -> 1; 5 l/s < Q < 25 l/s ->2; Q > 25 l/s -> 3. The conditions are case specific.

The flooding conditions could be also defined based on flood flow rate (tested in Slupsk):

- Green: Q < 15 l/s
- Yellow: 15 l/s ≤ Q < 50 l/s
- Red: Q ≥ 50 l/s

The threshold values between three classes were defined based on the 33rd and 67th percentile of the flood flow rate. The total number of flooded manholes was estimated to increase by 13.4% in the most severe climate change scenario of the 20-minute rainfall event with return period of 2 y. In the case of 20-year return period, the increase was estimated at 5.1%.

Numbers of manholes with various flooding flow rate classes are listed in the below:

Scenario			Flooding class			Sum
			1	2	3	
p 50%	Baseline		169	204	194	567
	RCP 4.5	2051-2060	189	201	197	587
		2091-2100	183	209	213	605
	RCP 8.5	2051-2060	185	214	225	624
		2091-2100	196	210	237	643
p 5%	Baseline		201	247	256	704
	RCP 4.5	2051-2060	208	243	259	710
		2091-2100	213	219	265	697
	RCP 8.5	2051-2060	227	248	257	732
		2091-2100	246	233	261	740

Step 6: Integrate predefined conditions to the attributes of catchments in GIS

Add the condition data to the GIS database catchment areas attribute tables (N.B. each catchment area should be connected to one manhole. The manhole grid code has to be included in the catchment areas attribute table).

Make three new sublayers in the catchment areas shape file describing conditions. Proposed color-coding: if condition is 1 – green; if condition is 2 – yellow; if condition is 3 - red.

Make 3 copies of the generated catchment areas shape file and add data about conditions for each climate scenario.

Step 7 Visualize the results

Congratulations, you have successfully generated static EWL maps for the pilot area.

Figure 19 On the left, project site and right catchments visualized in traffic-light manner.

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