DRIN CORDA

Enabling & Transboundary Cooperation & Integrated Water Resources Management in the extended DRIN RIVER BASIN

gef UNDP Global Water Partnership Mediterranean UNECE

GEF/UNDP/GWP-Med Project "Enabling Transboundary Cooperation and Integrated Water Resources Management in the Extended Drin River Basin

In the framework of the Memorandum of Understanding for the Management of the Extended Transboundary Drin Basin

Pilot activity "Preparation of Wastewater Management Decision Support Tool"

Wastewater management solutions in the Shkodra city

Report

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The Coordinated Action for the implementation of the Memorandum of Understanding for the management of the Drin basin (Drin CORDA) is supported by the GEF Drin Project. Thus, the latter constitutes an institutional project implemented by the United Nations Development Programme (UNDP) and executed by the Global Water Partnership (GWP) through GWP-Mediterranean (GWP-Med), in cooperation with the United Nations Economic Commission for Europe (UNECE). The Drin Core Group (DCG), being the multilateral body responsible for the implementation of the Memorandum of Understanding serves as the Steering Committee of the Project. GWP-Med serves as the Secretariat of the DCG.

Subject: Preparation of Wastewater Management Decision Support Tool

In the framework of

Memorandum of Understanding for the Management of the Extended Transboundary Drin Basin GEF Project "*Enabling Transboundary Cooperation and Integrated Water Resources Management in the Extended River Basin*"

Report on the Wastewater Treatment Decision Support Tool for Shkodra City Pilot Model

Data Project

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BOD5	Biochemical Oxygen Demand
CAPEX	Capital expenditures
CAS	Conventional activated sludge
COD	Chemical Oxygen Demand
CSO	combined sewer overflow
CW	Constructed wetland
DN	Diameter nominal
DoCM	Decision of Council of Ministers
DTM	Digital terrain model
EEA	European Environment Agency
EEC	European Economic Community
EPDM	Ethylene propylene diene monomer rubber
HM	Heavy metals
INSTAT	Civil Registry Office and Institute of Statistics
KfW	Kreditanstalt für Wiederaufbau
MBBR	Moving bed biofilm reactor
MBR	Membrane bioreactor
NPV	Net present value
O&M	Operation and maintenance
OPEX	Operating Expenses
PE	Population equivalent
Qn100	100 years return period
SBR	sequencing batch reactor
SDRB	Sludge drying reed beds
SStot	Total Suspended Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total suspended solids
UNECE	United Nations Economic Commission for Europe
UV	Ultraviolet
UWWTD	Urban Wastewater Treatment Directive
VTS	Volatile total solids
WEMDST	Wastewater management decision making support tool
WWTP	Wastewater treatment plant

1 Introduction

1.1 Project description

The project has been commissioned in the framework of Memorandum of Understanding for the Management of the Extended Transboundary Drin Basin GEF Project “Enabling Transboundary Cooperation and Integrated Water Resources Management in the Extended River Basin”.

In “Report on the Wastewater Treatment Decision Support Tool for Drin River Basin” methodology was described in detail (scenarios identification, modeling tool description) and Drin catchment model was elaborated.

In this report, the project task is the designing a wastewater and environment management decision support tool (DST) to address wastewater related problems in Shkodra city.

1.2 Expected outputs

In “Report on the Wastewater Treatment Decision Support Tool for Drin River Basin” decision support tool (WEMDST - Wastewater management decision making support tool) was developed and tested for Drin basin. In this report the Shkodra city (Albania) and the Shkoder/Skadar Lake and Buna/Bojana sub-basins served as the areas of reference for the development and testing of the tool.

Main goal of this report is to enable future sustainable decision-making process and to achieve effective wastewater treatment network that would improve the water quality in the Shkodra city. In order to achieve this, the WEMDST gives recommendations on WW Management and flood management in the city of Shkodra (presentation to the city authorities and this report) - identification of the most appropriate wastewater treatment system (centralized and decentralized scenarios) in combination with management of stormwaters/flood protection measures. An action plan for the improvements of the wastewater collection system and stormwater management in the city of Shkoder is also part of this report.

2 Drin Wastewater Management Decision Support Tool (Drin WEMDST) for Shkodra city

2.1 WEMDST for Shkodra city

The WEMDST tool, in this case, is a decision support tool that helps with the planning of new wastewater treatment plants and stormwater solutions on Shkodra city level. It can help city planners identify how and where should the city of Shkodra be equipped with wastewater treatment technologies to secure the positive effect on water quality on the Drin river.

It offers information on the current state of river quality in the Drin river and the possibility of predicting river quality and indicative WWTP infrastructure costs (both investment and operating) for various pre-set or custom scenarios. The tool itself was calibrated and validated against measured Drin river quality data, and it proved to be very accurate and consistent with the measurements.

2.2 Scenarios for Shkodra city

Shkodra city is a pilot case to test the scenarios for the Drin river basin. Two types of scenarios for Shkodra city were developed within this project. Scenarios A are intended for stormwater management in the city of Shkodra. Scenarios B are intended for future WWTP implementation in the Shkodra city. The scenarios are presented below.

2.2.1.1 Scenarios for stormwater management in the city of Shkodra

Stormwater in urban catchment of Shkodra city was examined in terms of flow quantity, under the effects of urbanization, and retention measures. The model considered the following factors: climate, catchment characteristics, land use, and management strategies. Climate affects storm characteristics such as frequency, duration, and intensity (design storm). Storm runoff is driven by the design storm and modified by land surface characteristics (terrain, soil type, cover, and imperviousness) affected by land use and catchment management strategies.[1] The output from the model is a flow rate, and retention areas flooded in the case of a specific return period event.

For each simulation, peak runoff was extracted and analyzed. This is defined as a baseline scenario. The baseline scenario represents the present land-use patterns and serves as a benchmark for comparison with potential future scenarios. Potential future scenarios guide stormwater management towards the sustainable (urban drainage system solutions – SUDS), especially surface measures, as infiltration and subsurface measures. Subsurface piping is of limited potential in Shkodra city.

The objectives of these scenarios are: 1.) to assess storm events and flow quantities 2.) to define possible retention areas 3.) to define retention measures to reduce the frequency of flooding.

2.2.1.2 Scenarios for future WWTP implementation in the city of Shkodra

The Shkodra city is a pilot case used for the testing of the Drin WEMDST. Scenario modeling was used to identify the most environmentally appropriate and cost-efficient wastewater treatment system in Shkodra. Scenarios were used to adjust the modeling tool appropriately.

The scenarios are summarized as follows:

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[1] https://www.researchgate.net/publication/319343413_Future_Scenarios_Modeling_of_Urban_Stormwater_Management_Response_to_Impacts_of_Climate_Change_and_Urbanization

Scenario (b.1) Shkodra city served by the WWTP (SBR technology) for tertiary treatment with mechanical dewatering with final disposal (e.g., incineration).

Scenario (b.2) Shkodra city served by the WWTP (SBR technology) for tertiary treatment with sludge drying reed beds with and without sludge reuse in agriculture.

The objectives of these scenarios were: 1.) to assess emission control costs for wastewater treatment plants related to waste treatment technology 2.) to assess emission control costs for sludge reuse and compare them with conventional disposal technology 3.) fine-tuning of the WEMDST.

3 Shkodra city wastewater and stormwater model

The pilot action in Shkodra represents a suggestion on how to address wastewater related problems in the Shkodra region. Considering the high flood risk experienced by the city, the question of wastewater is linked to flood management plans. The city served as the area of reference for the testing of the WEMDST for Drin catchment. The exercise was parallel to the WEMDST development on the Drin basin level and should confirm the model's values.

The present Shkodra wastewater solution was calculated bottom-up, using data from 2006 (KfW study) and confirmed by city utility operators in 2018.

The Shkodra scenarios were prepared after the technical consultation with city authorities in November 2018 (Mayor and members of the council), and the main output of the task is the wastewater treatment solution causing minimum operating and maintenance costs.

Once finalized, the solution is to be presented to the municipality (Mayor and council), operators (public utility employees), and other responsible stakeholders. The municipality is responsible for engaging projects and funding donors/sources; operators are a part of the consultation and knowledge transfer process so they would be able to maintain and operate any future facilities.

There are 5 municipalities in Shkodra Region, which have emerged after the Administrative Territory Reform in 2015. Three of them are downstream of Drin River: Shkodra, Malesi e Madhe Municipality and Vau Dejes. Each of them has its own Water Supply and Sewage enterprise (public utility), which are new and lack wastewater collection data.

3.1 Assessment of the current status (existing sewerage/stormwater system)

In 2006, an extensive feasibility study for Water and Sewerage Project Shkodra was funded by KfW. In the present wastewater treatment scenario elaboration, its data is used as input. Public utilities of Shkodra Municipality, Malesi e Madhe Municipality and Vau i Dejes Municipality provided additional information. **Recommendations are elaborated in Action plan (Annex 7).**

3.1.1 Existing sewerage system

3.1.1.1 Municipality of Shkodra

This chapter summarizes the situation of the sewerage system in Shkodra City described in KfW feasibility study Water and Sewerage Project Shkodra[2]. Since then, no significant supplements were done on sewerage system infrastructure in the municipality. Hydraulic analyses from 2006 are still valid but not in the aspect of sedimentation of particles in the system. That should be repeated. Shkodra District is presented in the figure below.

[2] KfW FEASIBILITY STUDY. WATER & SEWERAGE PROJECT SHKODRA. Project Concept Report. June 2016. 111 pg.

Figure 1: Shkodra District

The existing sewerage system in Shkodra (Figure *2*) is a separate system, which means there are two systems: one for urban wastewater and second for storm wastewater. It was designed and constructed as three main sewer lines (K1, K2, and K3) with secondary and tertiary sewers. The three main sewers combine and discharge by gravity via a DN 1000 main sewer (K0) to a pumping station containing 5 pumps, each with a capacity of 150 l/s. The station is located close to the bridge crossing the Buna River.

Outlet from the sewage system is into the Drin River. In the event of a power failure, there is an emergency outflow into the Buna River. There is no existing wastewater treatment plant for the city of Shkodra.

The total length of sewers in Shkodra and Bahcallek (about 5 km of sewers in Bahcallek) is approximately 145 km. All sewers use precast concrete pipes, which are butt jointed. The connection rate to the sewerage system is estimated to be approximately 73 % in the Shkodra City.

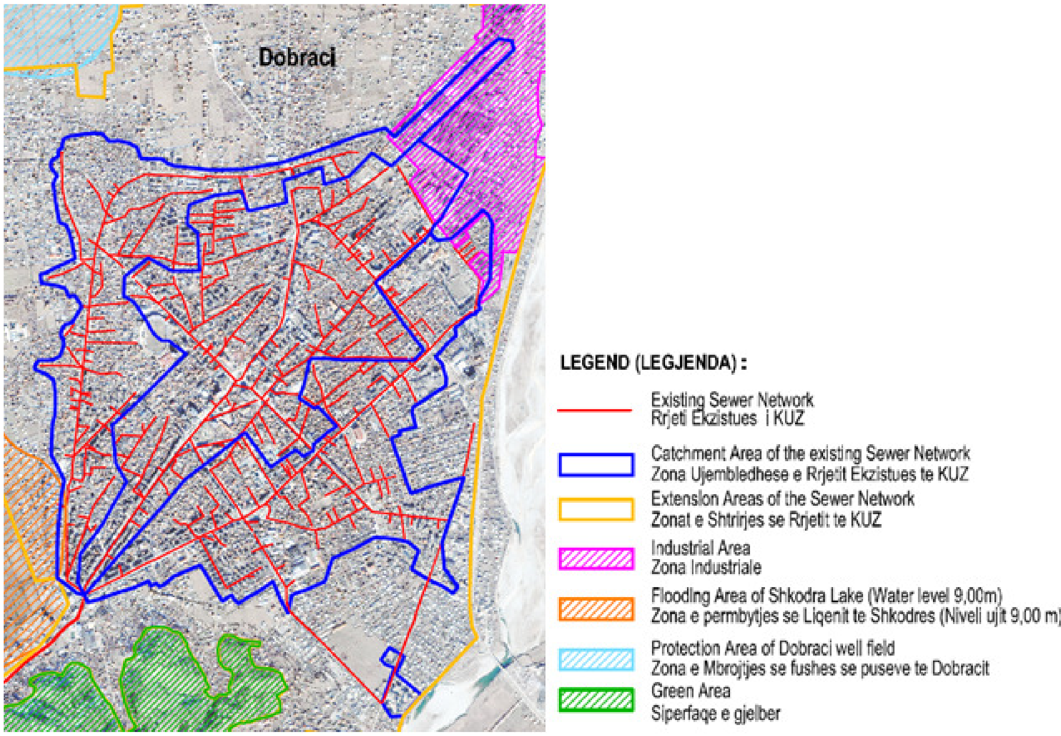

Figure 2: Extension area of existing sewerage system

Hydraulic analysis of existing sewerage system was made in Water & Sewerage Project Shkodra[3] (June 2006, KFW). he main conclusions for the analysis are that K0 (main collector to the pumping station) and the lower parts of K2 (Vasil Shanto street downstream of 5-heroes square) are operating close to full capacity and do not allow significant sewer extensions.

The remaining sewer network, and especially main sewer K1 and K3, generally have significant spare capacity (hydraulic load ratio < 0,5).

A CCTV-survey of the sewer network was carried out in May 2006. The majority of inspected sewer sections are constructed of prefabricated concrete pipes of circular profiles with various diameters. Pipes are generally 1,00 m long and mostly lack pipe socket and sealing gasket. Only house connections of smaller diameter are of other materials.

Almost all house connections are installed only in maintenance holes. Only very few direct connections to the pipes have been found during the survey. This is a common practice in many South-East European countries to avoid failed connections and allow access in case of problems. The following main defects have been noticed on most of the inspected sections:

- Badly jointed pipes, not abutting with gaps up to several centimeters in almost all inspected sections;
- Deposit of solid materials (stones, waste, etc.);
- Pipe misalignment with horizontal or vertical displacement up to several centimeters.

[3] Water & Sewerage Project Shkodra, June 2006, KFW

The pipes are in generally good condition; the main problem being is badly implemented pipe junctions. This leads to a high risk of sewage exfiltration and pollution of underground water. On the other hand, no significant direct infiltration/inflow of extraneous water into the pipes have been found during the survey. However, inflow of high quantities of extraneous water – mostly from the drinking water supply system – through house connections or connection of secondary and tertiary sewer in the manholes have been found.

The main problems of the sewerage system:

- Sewer partly or entirely blocked with solid material (sand, mud, stones, solid waste, etc.);
- Velocities in significant parts of the system, especially the secondary and tertiary sewers, are lower than desirable for prevention of settlement of solid material, due to low gradients and low flows;
- Direct connection of stormwater from roads to the sewerage system and stormwater discharges to the sewerage system in areas which have no unsurfaced roads and / or no stormwater drainage;
- Parts of the sewerage system (particularly K3) are not easily accessible due to the sewer being in private property or manholes covered;
- Manhole covers are missing and/or have been stolen and allow solid waste to be disposed into the sewer network;
- The pumping station is not operating most of the time, and emergency overflow is blocked. Wastewater is discharged to the Shkodra Lake / Buna River, and lower part of the system is operating in surcharged condition;
- Areas of the city (especially informal areas to the east, west, and north of the city) are not connected to the sewerage system. Rudimentary septic tanks generally serve these areas;
- Direct connection of sewage from some areas to the stormwater system;
- Lack of planning in the extension of the system;
- Lack of adequate operation and maintenance of the system due to limited equipment and resources for maintenance;
- Quality of construction of projects is poor;
- Uncontrolled emptying of septic tanks;
- Electromechanical equipment of the pumping station is outdated and in poor condition and has several serious deficiencies;
- Discharge of sewage to receiving waters without treatment (Figure *3*).

The main consequences of the above are the following:

- Environmental nuisance (odors, visual impact, mosquitoes, etc.) in summer due to wastewater discharge in Shkodra Lake / Buna River;
- High maintenance requirement due to deposit of solid material, with maintenance, made more difficult due to limited access to sewerage system;
- Hydraulic overloading and overflow of the sewer network by rain due to illegal connections of stormwater;
- Pollution of groundwater due to exfiltration of sewage from unsealed septic tanks and possibly from the sewer network (untighten pipe junctions);
- Pollution due to discharge of untreated wastewater and uncontrolled emptying of septic tanks to rivers and other locations (Figure *3*).

Figure 3: Location of WW discharge into the Drin River (Limnos, 2018).

There is no data regarding sewage losses, groundwater infiltration, or performance data of pumping stations.

The emphasized problem in the city of Shkodra is wastewater discharge into the Buna river, which is only operational when the main pumping station for pumping wastewater into the Drin River is not running. Regular operation is often disturbed because of frequent problems with network and equipment. In the case of high-water level, untreated wastewaters threaten Lake Shkodra. The consequences are nutrient and micro-biological loading of the lake. This pollution source is considered a high threat to the lake[4].

Additionally, discharge (wastewater and stormwater) from an urbanized area is released into the Buna river via an open channel. Surface water inflow into the sewage system causes operational problems when the water level in the channel is high (Figure *4*).

[4] LSIEMP transboundary project. 2012.

Figure 4: Wastewater discharge into Buna river[5]

There is no significant progress in ensuring compliance with the urban wastewater collection and treatment obligations since 2006 when the Kwf study was done.

3.1.1.2 Municipality of Malesi e Madhe, Shkodra Region

District Malesi e Madhe lies upstream of the Shkodra Lake and belongs to the catchment area (*Figure 5*). The district is relevant in terms of the prevention of wastewater pollution of the lake. Therefore, in the report, the state of wastewater collection and treatment was analyzed.

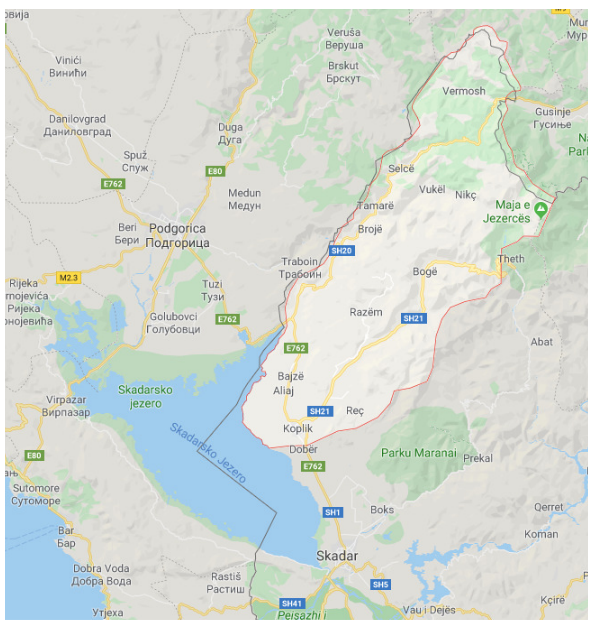

Figure 5: Malesi e Madhe District

Only the town of Koplik has a sewage system, and there are about 300 household connections. Sewage system ends without a wastewater treatment plant in the area called Dedgjone. The point of discharge is around 1.500 m from the city and 1.200 m away from Shkodra Lake (Figure 6). The rest of the town and other rural areas and villages use only improvised permeable septic tanks. Sewage system (Figure *7*) is gravitational (without pumps).

[5] LSIEMP transboundary project. 2012.

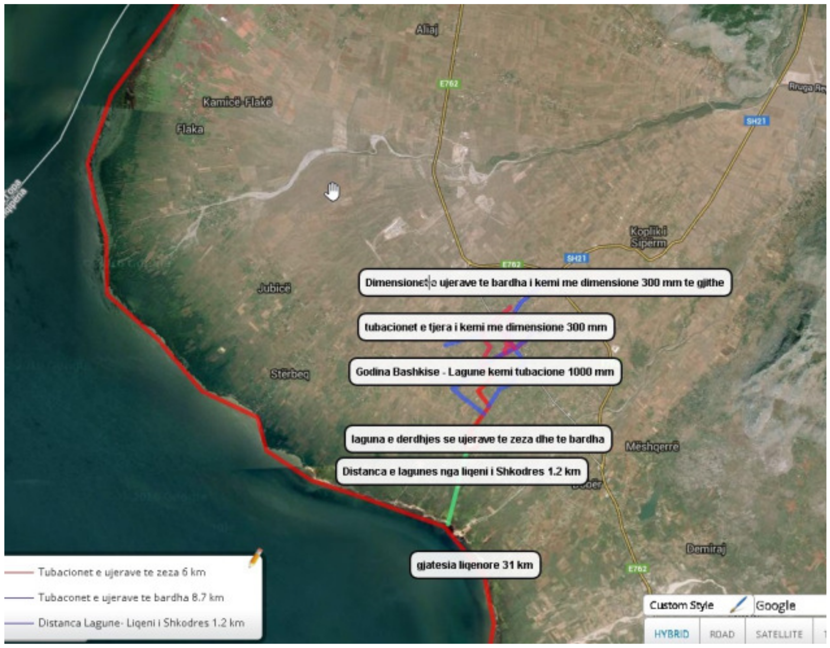

Figure 6: Wastewater discharge from Koplik – 1,2 km distanced from Shkodra lake

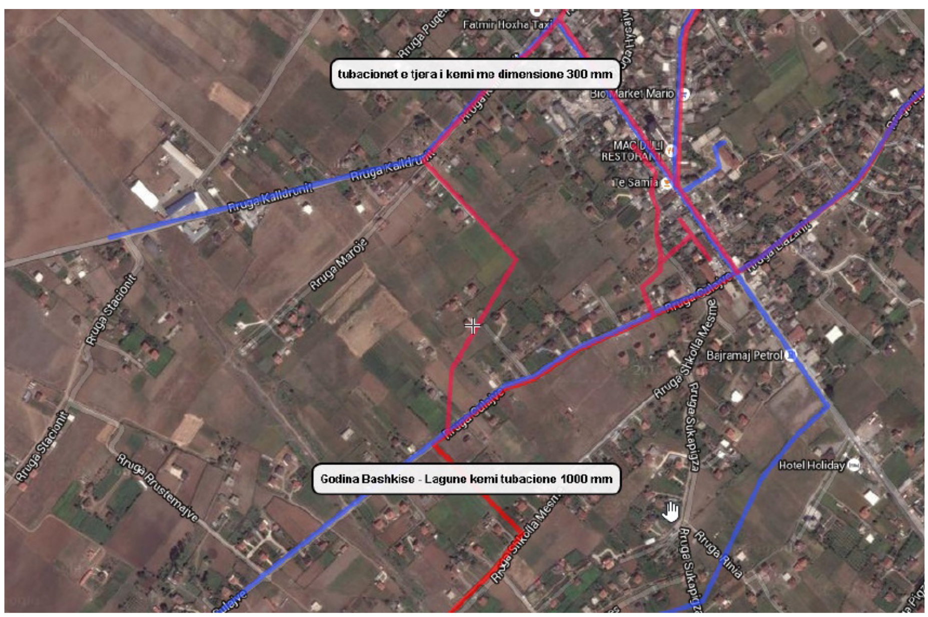

Figure 7: Sewer network in Koplik (blue line)

The most common problem affecting a sewer line, also a case in Koplik, are blockages. Cause of these blockages is the deterioration of old concrete pipes (Figure *8*), which are in operation since the 90`s. Problematic sections are not yet identified.

Figure 8: Manhole in Koplik

Koplik has a relevant transboundary impact. Domestic wastewaters present a source of pressure on the Shkodra lake. Wastewaters are not directly discharged into the lake; their negative impact is reduced with the natural buffer zone and soil purification functions.

3.1.2 Existing stormwater system

The existing stormwater system in Shkodra was designed and constructed as a separate stormwater system, with a separate sewerage system.

A system drains Shkodra of open channels, box culverts and pipes, with most drainage gravitating to the Shkodra Lake. Some areas, including the industrial area, drained to the Kiri River.

The total length of main drains is about 37 km, of which about 25 km are pipes, box culverts, and lined channels, with the remainder being open earth channels with relatively poor flow characteristics.

While the system covers the city's central and southern areas, there are many areas of the city, including those with paved roads that do not have or have minimal stormwater drainage. The main drainage system covers about 50-60 % of the city's formal areas, with much lower coverage in the informal areas.

Stormwater characteristics system:

Infiltration Coefficient:	qf	=	1,28	%
Hourly Average (infiltration):			24,00	h/d
Infiltration quantity:	QF,aM	=	4,63	l/s
		=	16,67	m3/h
Dry weather flow, yearly average:	QT,aM	=	367,43	l/s
			1.322,75	m3/h
			31.746,00	m3/d
Divisor for the daily peak:	xQmax	=	15,73	h/d
Daily peak dry weather flow, yearly average:	QT,h,max	=	558,33	l/s
			2.010,00	m3/h

Dewatering by Stormwater System

Factor of stormwater Inflow: $f_{S,QM}$ = 2,28

$$Q_M = f_{S,QM} * Q_{S,aM} + Q_{F,aM} \quad l/s$$

stormwater flow: Q_M = 830,28 l/s

2.989,00 m3/h

In the 2006 KfW Feasibility study, it is stated that “The assessment shows that generally most of the main drainage system has inadequate capacity for the above criteria…”. “The real situation is that due to lack of street inlets, poor quality roads surface (irregular surfaces), and lack of paved roads, stormwater does not enter the main drainage system as fast as it should do the quantities that should be discharged. As a consequence, the main drains are not operating as they should be; stormwater remains on the surface for long periods throughout the city and gradually infiltrates into the ground in many areas. Furthermore, most of the stormwater drainage system is partly or completely blocked with solid material and, therefore, not properly working.”

The situation has not changed since then, and the blocked drainage system is still limiting the effectiveness of the stormwater drainage nowadays. The source of the sediments and blocking material in the stormwater sewer is not identified. It is assumed that it is a combination of the general street waste consisting mostly of sand (different fractions) and solid waste removed via stormwater inlets.

After the analysis of the system of stormwater and wastewater collection in the Shkodra city, we came to the same conclusion as a previous study (KfW 2006) that rehabilitation and extension of the sewerage and stormwater drainage systems should be implemented so that the sewerage and stormwater drainage systems are separate. As a result of this concept plan similar overall design with direct discharges to receiving waters are proposed. Nevertheless, the 2006 study deviates from the existing spatial plan, planning a redevelopment of green corridors from Kiri River to lake Shkoder. As a part of green corridors, the open channel flow is proposed with different positive impacts (incl. amenities). On the other hand, one must consider spatial limitations for this solution, as existing spaces in the area do not enable clear identification of the canal layout.

3.2 Pathogen emissions during the flood events

Water-borne pathogen contamination in water resources and related diseases are a significant water quality concern throughout the world. Addressing the pathogens in the framework of wastewater management on the Drin river basin is also a straightforward issue. Therefore, providing a broader perceptive of pathogen contamination in freshwater, rivers, lakes, and reservoirs is a component of the report. Improved understanding of emissions and the impact of pathogens in water is the first step in understanding the domain and addressing it adequately.

Pathogens in water are a priority analyzed and managed in the case of drinking water supply. They are usually associated with the status of water supply in developing countries, where the combination of water resources status, demography, and economic conditions can result in contaminated water supply. Water-borne diseases (i.e., diarrhea, gastrointestinal illness) caused by various bacteria, viruses, and protozoanditions limit access to clean water and can be an issue to events also in developed countries. A study by Arnone and Walling (2007), who compiled data of outbreaks in the U.S. (1986 – 2000), reported 5.905 cases and 95 outbreaks. Nevertheless, authors stress the reality that the outbreaks are related not only to contamination of drinking water, but mainly to the recreational use of waters. This will also be addressed in the Drini river basin, as the water supply systems are mainly using other water resources as the water source for the water supply, not from the Drini river and tributaries. The Bathing water directive is the reference for the appearance of pathogens in the recreational waters.

Of the countries on the Drini river basin, only Albania has provided a report on the implementation of the EU Bathing Water Directive. In the season 2018, Albania identified and reported 108 bathing waters, which is 0.5% of all bathing waters in Europe. Six bathing waters in Albania have been newly identified for the season 2018. Six bathing waters in Albania have been newly identified for the season 2018. Of 108 bathing waters, only these 6 are identified as inland water bodies. Inland bathing waters are situated at rivers and lakes, featuring freshwater and respective parameter thresholds defined in Annex I of the Directive. In Albania, there are six bathing waters newly identified for the season 2018 that are still quality classified. All six were identified on the Ohrid lake. Other bathing waters of concern for the project are close to the mouth of the Drin/Buna river.

The monitoring results show that the water there is in the category of excellent or good water quality regarding the presence of pathogen contaminants in these waters (*Figure 9*).

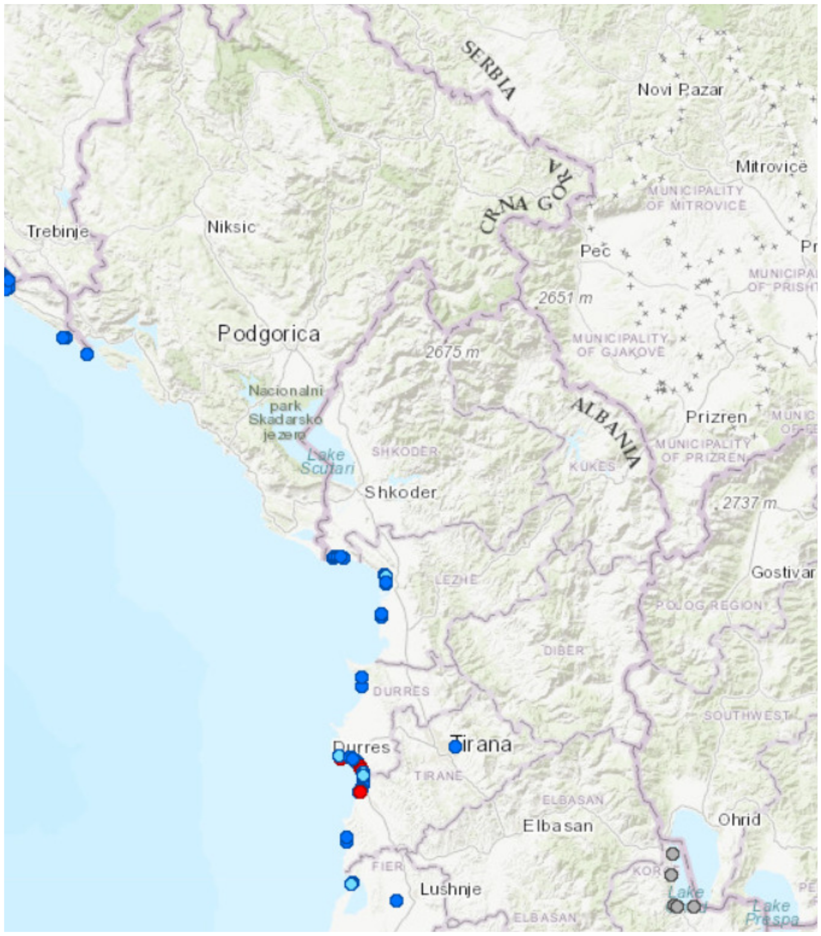

Figure 9: Monitoring of bathing waters – EEA 2018[6], (status November 2019)

The result generally shows that the issue of the pathogens in the waters of Drin river basin is not outstanding for drinking water (this does not imply that some of the drinking water sources do not have problems with water quality, but this is not related to wastewater treatment in target agglomerations). The issue of pathogens is not recognized for recreational waters defined by the EU Bathing waters directive. The relation between pathogens in water and use of inland freshwater bodies for recreational use based on the fact that the pressures of pathogens is usually not coinciding – the bathers do bath after prolonged period of dry, warm and sunny weather when water temperature, as well as air temperature, are suitable for bathing. This is not the case in the rainfall events when different flood events occur – river flooding, urban drainage, and combined sewer overflow (CSO). In the case of these events, it is quite clear that pathogens from different sources are emitted to water bodies, including increased pressure from natural background. Urban and suburban areas are dominated by impervious cover. During storms, rainwater flows across these impervious surfaces, mobilizing contaminants. The pollutants carried in runoff originate from a variety of urban and suburban nonpoint sources. Contaminants commonly found in stormwater runoff include fecal and pathogenic bacteria. Stormwater transports pollutants to water bodies such as lakes and streams[7]. However, practices aiming to reduce stormwater pollutants are quite limited because the discharges

[6] https://www.eea.europa.eu/themes/water/interactive/bathing/state-of-bathing-waters

[7] EPA (2009) Source Water Protection Practices Bulletin. Managing Storm water Runoff to Prevent Contamination of Drinking Water. United States Environmental Protection Agency (EPA); Washington, DC, USA: 2009. Office of Water (4606); [Google Scholar]

of urban drainage usually amount far beyond any treatment capacity. The main focus relative to the waterborne pathogens is therefore related to the protection of the drinking water sources and drinking water supply. In the case of bathing waters, treated urban wastewater might be subject to disinfection by different means (UV, ozonation, microfiltration) by which the identified bathing water in the impact area is protected.

Ultraviolet light in sunlight helps kill off bacteria. The necessary time required varies depending on the weather (Table *1*). A guideline from UK demonstrates how long people should keep off the flooded areas is presented below.

Table 1: The time needed to kill bacteria[8]

Season	Tirf/clay	Soil /sand /shingle /bark
Spring	13 days	20 days
Summer	6 days	9 days
Autumn	13 days	20 days
Winter	18 days	11 days

3.3 Discussion on the simultaneity of flood events and difference between the mainstream and stormwater flooding

Flood events occur relative to their specific spatial scale and cause. They are defined by their hydroclimatic perspective, which is related to the lifting mechanism and weather system. The complexity of the flood classification process is recognized by several authors, with thorough work on the subject performed by Tarasova (2019). They are defined by the main factors runoff coefficient, duration of rainfall, concentration-time, but also other parameters like retention capacities available (natural or man-made), snowmelt, etc.

Specific areas of flood analysis and hydrological studies address the coincidence of flood events where authors compare mainstream and tributaries and occur in flood peaks. In this analysis, the risk of flooding due to the combination of flood flows from different rivers is analyzed. Usually, multivariate functions are used - for example Chen (2012) defining conditional probabilities of flood events between the main river and its tributaries. However, these studies are always analyzing the tributaries of the mainstream and not stormwater drainage. Specific reason for that is that in the case of urban stormwater drainage, it is possible to identify two main differences regarding the flood mechanism:

1. Different concertation time and duration/intensity of the return period flood events. While the concentration-time in the case of urban drainage is usually measures in hours in large watersheds – like the Drin river basin, it is measured in days and weeks. This difference is even more exaggerated due to some natural (Lake Shkoder) and man-made retentions – Drin hydropower plants.
2. Different hydroclimatic perspective and convective storms are usually reference rainfall intensity events in the case of urban flooding; cold warm and stationary fronts are usually providing critical rainfall events of prolonged duration for larger river basin.

This is why short-term storms, precipitation, and resulting (urban) flooding are modeled on the local level for individual urban zone, independent from the river flooding event. However, in specific cases, border conditions of both have to be analyzed (i.e., location of the discharge of stormwater canal to the recipient) in order to provide a safe overall solution for all flood events. The same approach was applied for the modeling of the Drin/Buna flood for the positioning of the Shkoder WWTP and

[8] https://www.thameswater.co.uk/help-and-advice/drains-and-sewers/sewer-flooding-who-to-contact/sewer-flooding-what-to-do

stormwater management system. Extreme distinct concertation time and hydroclimate perspective could be identified, enabling separate analysis of both events.

An additional difference between these two types of flooding could also be recognized in the applied measures to confront them. While relatively accessible approaches could be applied in urban stormwater management (retention measures, constructive infiltration measures, green roofs, stormwater sewers, etc.) man-made interventions to confront the flooding from the main watercourses usually too complex, costly and time-consuming. They are from the physical point of view quite the same as those applied for the urban scale runoff, but their dimensions (i.e., river basin scale afforestation, multi-million m3 retention volumes, large diversion canals, a complex system of dykes) surpass them by many times.

3.4 Validation of modeling tool

For validation of the treatment model, design for WWTP for Shkodra city was elaborated. The simulation of the treatment model input parameters (size of 115.000 PE and tertiary level of treatment) was used. To determine how close the model simulation output and WWTP's real design from Chapter 3.5.8 WWTP for Shkodra city (115.000 PE) are, the CAPEX and OPEX were compared in Table *2*. Sludge handling is included.

Table 2: Option analysis of CAPEX for wastewater treatment for Shkodra city

Technology	**CAPEX WWTP [€]**
SBR	16.745.000 (WW treatment) + 1.990.000 (mech. dewatering) = **18.735.000,00**
WEMDST model simulation	15.700.000 (WW treatment) + 960.000 (mech. dewatering) = **16.660.000**
Deviation from the model [%]	-11 %

Deviation in CAPEX is relatively low (11%), it is a consequence of using a different technology (such as hours of aeration). Besides, SBR predicts anaerobic sludge digestion, which increases investment costs compared to simulation in the WEMDST model.

Due to different assumptions of technology, there are differences in OPEX cost. In Table 3 assumptions for the main categories are presented. OPEX costs for SBR are lower for 1,66 % compared to WEMDST simulation. The calculation for O&M costs for SBR is presented in Annex 1 (SBR for Shkodra city).

Table 3: Main OPEX costs for Shkodra city

Parameter	**SBR**	**WEMDST model simulation**	**Deviation from the model (%)**
Energy consumption (kWh/y)	4.080.749	3.085.000 (WW treatment) + 412.000 (mech. dewatering) = 3.497.000	+14,30
Sludge disposal (m^3/y)	10.129 + 2.070 (grit&grease) =12.199	12.000	+1,63
FeCl (kg/year)	200.610	242.000	-20,63
Staff (persons)	11 persons	10 persons	+ 9,1
TOTAL (EUR/y):	**1.576.488**	**1.602.600**	**-1,66**

The pilot on Shkodra implies that the WEMDST model simulation of OPEX and CAPEX costs are accurately predicted. Assessed costs deviate from the current state because they are not case-specific. The data can be used for prioritization to identify which of many demands are the key needs for environmental protection, emphasizing the financial aspect of investment.

3.5 Wastewater treatment scenarios for the city of Shkodra incl. sludge treatment

The existing sewerage system in Shkodra was designed and constructed as a separate sewerage system, with a separate stormwater system. The connection rate to the sewerage system is estimated to be approximately 73 % in Shkodra City. The wastewater collected by the sewerage system of the city of Shkodra is currently discharged without any (pre)treatment.

3.5.1 Discharge requirements for Albania

The main two legal documents for wastewater discharge requirements are:

- Law No. 9115 dated 24.07.2003 "On Environmental Treatment of Polluted Waters" (amended No. 34/2013),
- DoCM No. 177 dated 31.03.2005 "On the Allowed Norms for Wastewater Discharge to Receiving Waters.

In accordance with DoCM No. 177/2005 discharge effluent requirements for urban wastewater discharge (secondary treatment) are:

- Biochemical Oxygen Demand (BOD5) 25 mg/l
- Chemical Oxygen Demand (COD) 125 mg/l
- Total Suspended Solids (SStot) 35 mg/l for more than 10.000 PE
- Total Suspended Solids (SStot) 60 mg/l (2.000 – 10.000 PE)

In accordance with DoCM No. 177/2005 discharge effluent requirements for urban wastewater discharge in designated sensitive areas (tertiary treatment) are:

- Total Phosphorus (TP) 2 mg/l (10.000 – 100.000 PE)
  1 mg/l (more than 100.000 PE)
- Total Nitrogen (TN) 15 mg/l (10.000 – 100.000 PE)
  10 mg/l (more than 100.000 PE)

3.5.2 Discharge requirements for Shkodra City

Based on the predicted location options for the WWTP Shkodra, the treated wastewater's receiving water body will be the Buna River.
Shkodra agglomeration is bigger than 100.000 PE and thus should be designed for tertiary treatment. As no information on sensitive areas was available, it has been assumed that WWTP outflow can be considered sensitive. In line with the relevant regulations and laws in Albania, the effluent standard for the WWTP Shkodra are set as follows:

Table 4: Effluent requirements according to Albanian Standards

Parameter	Maximum Concentration
Biochemical Oxygen Demand (BOD_5)	25 mg/l
Chemical Oxygen Demand (COD)	125mg/l
Total Suspended Solids (TSS)	35 mg/l
*Total Nitrogen (TN)**	*10 mg/l*

Parameter	Maximum Concentration
*Total Phosphorus (TP)**	*1 mg/l*

**Discharge to sensitive areas subject to eutrophication and Agglomerations with more than 100.000 PE*.

3.5.3 Discharge requirements for industrial wastewater

Industrial wastewater often contains substances that need to be treated before being discharged into a WWTP and subsequent water bodies. Generally, this can be done close to the site of production itself.[9]

The release of industrial wastewater is regulated in Europe directly as part of the environment law on industry and indirectly by the EU policies that tackle water issues horizontally. The most relevant are the Urban Wastewater Treatment Directive (UWWTD, 91/271/EEC), the Groundwater Directive (2006/118/EC), and the Environmental Quality Standards Directive (2008/105/EC). Industry's direct or indirect releases of pollution to the environment are among the key aspects regulated by the Industrial Emissions Directive (IED, 2010/75/EU).

Article 11 of the UWWTD (91/271/EEC) requires Member States to ensure that competent authorities regulate and give prior authorization for industrial wastewater discharge into collecting systems and UWWTPs. Such authorizations must ensure that industrial wastewater entering the collecting systems and/or the treatment plants is pre-treated, where necessary, so that the functioning of the plant and the collecting system is not hindered and, thus, that discharges from the plants do not adversely affect the environment (Table *5*). However, the requirements of Article 11 are relatively general, and the specific interpretation of how to meet the requirements of this article are defined separately in each Member State.[10]

Table 5: Industrial wastewater types and their treatment requirements[11]

Category	Description of common features	Technique at UWWTPs	Pollutants	Example industrial sectors
Minimal contamination (can be land-spread)	Wastewater contains no pollutant that could harm an agricultural crop. Some nutrients (nitrogen compounds, phosphorus or potassium) can be present but these are useful for plant development. Levels of biocides or toxic substances should be very low.	No new/specific technology required, beyond secondary treatment.	Nutrients: nitrogen, phosphorus	**Food and drink**
Equivalent to domestic-type effluents	Wastewater streams with similar, mainly organic, pollutant content to municipal wastewater.	UWWTPs do not need major changes in their assets.	Degradable organic matter	**Food and drink**
Low flow and non-domestic-type pollutants at low concentrations	Wastewater contains small concentrations of other pollutants not present in urban effluents. The incoming load to UWWTPs may have a similar composition to municipal wastewater due to dilution.	No major investment required: more frequent inlet effluent monitoring. May require a buffer (e.g. tank/basin).	Different from common pollutants: e.g. pesticides, hormones, nano-plastics or endocrine disrupters.	**Chemicals**
Metals	Wastewater from metal processing, iron and steel plants or other	Sedimentation, flotation,	Metals	**Metal processing and mineral industry**

[9] https://www.sciencedirect.com/topics/earth-and-planetary-sciences/industrial-wastewater
[10] Industrial wastewater treatment –pressures on Europe's environment. 2019. European Environment Agency, 2019EEA Report. No 23/2018. ISSN 1977-8449: 66 p.
[11] Industrial wastewater treatment –pressures on Europe's environment. 2019. European Environment Agency, 2019EEA Report. No 23/2018. ISSN 1977-8449: 66 p.

Category	Description of common features	Technique at UWWTPs	Pollutants	Example industrial sectors
	industries containing metals and metalloids.	microfiltration, electrocoagulation		
High nutrient loading	Wastewater containing high nitrogen compounds, phosphates or substances that contribute to eutrophication. Higher inorganic content (i.e. higher conductivity).	Nitrification-denitrification, chemical precipitation	Substances increasing eutrophication	**Chemicals: fertilisers**
Effluent streams requiring pH adjustment	Wastewater streams with very high or very low pH.	Initial neutralisation step to reduce corrosion in the UWWTP.	Acids or alkalis	**Chemicals and mineral industry**
Persistent organics content	Wastewater contains not easily degradable organics such as persistent (xenobiotic) hydrocarbons or bioaccumulative organic toxic substances.	Specific and complex treatment technologies required (e.g. ozonation)	Persistent organics	**Textiles and chemicals**
Emerging substances	Wastewater contains new pollutants or has characteristics that are not currently monitored (because of high cost, high complexity or no legal obligations).	New monitoring methods and subsequent treatments techniques	New parameters and compounds not frequently measured, e.g. antibiotics	**Pharmaceuticals**

In Shkodra city, there is no industry producing heavy polluted industrial wastewaters, which would require a highly complex pre-treatment plant. **The treatment of industrial wastewaters before entering the public sewage system is the responsibility of industry owners.**

All industrial wastewater must be adequately pre-treated before discharge into the sewage system. Permitted limit values in industrial wastewater are presented in Annex 3 of the concurrent Council of Ministers Decision No. 177 (31.03.2005) on Norms for Wastewater Discharge to Receiving Waters. Annex 2 of the Decision contains effluent standards for various industries and municipal wastewater, which are based on the respective EU Guidelines.

Transfer from industry may require different and specific treatments; thus, many EU countries have implemented a system of discharge permits. Obtaining permit conditions in the process of elaboration of project documentation regulates industrial emissions at a national level and represents a mechanism for environmental protection. Pollutant register contains important data for planning of wastewater infrastructure. Pollutant Release and Transfer Register Albania published by the Ministry of Environment is not yet fully operational.

3.5.4 Sludge requirements for sludge reuse

The Sewage Sludge Directive 86/278/EEC was set up to encourage sewage sludge in agriculture and regulate its use to prevent harmful effects on soil, vegetation, animals, and humans. The Directive also required that sludge should be used in a way the nutrient requirements of plants and the quality of the soil and the surface and groundwater remains impaired.[12]

3.5.4.1 Limit values for heavy metals

While sewage sludge contains nutrients and organic matter beneficial for the soil, it can also contain contaminants such as heavy metals, organic compounds, and pathogens. [13] The Decision Nr. 127/2015 on Requirements for the use of sludge in agriculture sets limit values for seven heavy metals (cadmium, copper, nickel, lead, zinc, mercury, and chromium), both in soil and in sludge itself (Table *6*).

[12] https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_iii_report.pdf
[13] https://ec.europa.eu/environment/archives/waste/sludge/pdf/part_i_report.pdf

Table 6: Limit values for concentrations of heavy metals (HM) in soil, in sludge for use in agriculture and amounts, which may be added annually to agricultural land, based on a 10-year average[14]

Parameter	*HM IN SOIL (mg/kg of dry matter)	**HM IN SLUDGE (mg/kg of dry matter)	***HM ANNUALLY ADDED AMOUNT (kg/ha/yr)
Cadmium	3	20-40	0,15
Copper	100	1.000	12
Nickel	75	400	3
Lead	200	800	15
Zinc	300	3.500	30
Mercury	1,5	20	0,1
Chromium	-	-	-

* Limit values for concentrations of heavy metals in soil (mg/kg of dry matter in a representative sample, as defined in annex ii c, of soil with a pH of 6 to 7);

** *Limit values for heavy-metal concentrations in sludge for use in agriculture (mg/kg of dry matter);*

*** Limit values for amounts of heavy metals which may be added annually to Agricultural land, based on a 10-year average (kg/ha /yr).

3.5.4.2 Limit values for pathogens in sludge

The Directive 86/278/EEC does not include specific requirements for pathogens content in sludge used in agriculture. The Albanian legislation also does not include limitations on pathogens content in sludge quality. [15]

3.5.4.3 Limit values for organic compounds in sludge

Directive 86/278/EEC does not provide any limit values or requirements for organic compounds in sewage sludge. In this case also, Albanian legislation does not include limitations on organic compounds in sewage sludge.[16]

3.5.4.4 Obligations for treatment

Directive 86/278/EEC specifies treated sludge as sludge, which has undergone biological, chemical or heat treatment, long-term storage, or any other appropriate process to significantly reduce its fermentability of the health hazards resulting from its use. However, Member States may authorize, under conditions, the use of untreated sludge if it is injected or worked into the soil.[17]

Chapter 5 of the Decision Nr. 127/2015 on Requirements for the use of sludge in agriculture defines that (art. 13) sludge should be treated before use in agriculture and that untreated sludge cannot be used in agriculture. Before using treated sludge, the sludge should be analyzed according to the requirements (see limit values for heavy metals).

Chapter 3 of the same Decision defines the obligations of the producer of sludge used in agriculture to report on sludge treatment method, composition, and properties, according to the environmental permit and license approved by the competent authorities.

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31986L0278&from=EN
[15] https://ec.europa.eu/environment/archives/waste/sludge/pdf/sludge_disposal2.pdf
[16] https://ec.europa.eu/environment/archives/waste/sludge/pdf/sludge_disposal2.pdf
[17] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31986L0278&from=EN

The Decision follows the Law 10463/2011 "On integrated waste management" where in Art. 34 the use of sewage sludge in agriculture is allowed upon authority permission.

3.5.4.5 Surfaces on which use of sludge is prohibited

Article 7 of the Directive 86/278/EEC provides restrictions concerning the spreading of sludge on grazing and pastureland, and on land on which vegetables and fruits are grown.

Chapter 5 of Decision Nr. 127/2015 on Requirements for the use of sludge in agriculture defines that (art. 14) the use of sludge in agriculture is not permitted on grazing lands where livestock will graze less than six months after the sludge use and in pasture land or where fodder plants are grown, if the land used for pasture is harvested within three weeks after sludge use.

3.5.5 General description of wastewater treatment technology

Basic technology of all kinds of wastewater treatment is biological treatment. The technical concept solution consists of a wastewater treatment plant for Shkodra city for achieving tertiary treatment level.

The concept design for WWTP for Shkodra city is prepared for 115.000 PE The consultant defined two possible alternatives of water treatment technologies:

- Conventional wastewater treatment with activated sludge process,
- Wastewater treatment with sequencing batch reactor (SBR).

3.5.5.1 Wastewater treatment with activated sludge process

The activated sludge processes have become the most versatile biological processes available for designing wastewater treatment plants and have been applied successfully for many decades worldwide. All components can be controlled and adjusted to the WWTP's pollution load, which makes this process extremely flexible, and if well designed and operated, extremely efficient.

The main components are:

- An aeration tank in which the wastewater is in contact with the bacteria and other organisms responsible for the degradation of the carbonaceous compounds. These organisms are suspended in the wastewater in the form of so-called activated sludge flocks. Since the process is to be kept aerobic and the bacteria have to be kept suspended, and in dispersed contact with the wastewater, the activated sludge tanks require aeration units and mixing devices which are frequently combined. Aeration and mixing can be provided by surface aeration (turbines or rotating brushes with horizontal axis) or blowing air into the tank with air diffusers.

- A final sedimentation unit in which, prior to discharge, the purified wastewater is separated from the activated sludge. To keep a sufficient concentration of activated sludge in the aeration tank, a part of the mixed liquor (mix of treated wastewater and activated sludge or of the settled sludge) has to be returned to the aeration tank via a return sludge pumping unit. The excess sludge has to be removed and treated in the sludge treatment unit.

WWTP is planned as follows:

- Inlet pumping station
- Screens
- Aerated grit chamber

- Primary settling tank
- Aeration tank
- Secondary settling tanks
- Pre-thickener

Inlet pumping station lifts inlet wastewater to a proper level; different types of pumps can be used. Screens stop all particles bigger than 10 mm and have an automatic screen cleaner, which removes particles automatically.

In the aerated grit chamber, fat and grit are carried out based on floating/sinking. The primary settling tank is the primary phase of water treatment. Here particles settle down, and also primary sludge is added through pumps. Water, free of particles, flows into an aeration tank, where the main water treatment process occurs. With the help of active sludge, dissolved organic, nitrogen, and phosphorus substances are removed from wastewater.

Active sludge from aeration tank settles down in secondary settling tanks. Redundant active sludge is pumped in pre-thickener. Part of active sludge is returned into aeration tank to revive active sludge.

3.5.5.2 Wastewater treatment with sequencing batch reactor (SBR)

In 3.5.5.1 classical principle of wastewater treatment is described. In SBR technology, aeration tank and secondary settlement tank are joined in one. Because inflow and outflow of water happens sequentially, the technology is named SBR.

Wastewater treatment plant contains the following parts:

- Mechanical pre-treatment
    - rough rake,
    - compact device with fine rake and grit and grease chamber (sand, fat and oil extraction,
    - septic receiving station,
    - primary settling tank.
- Biological treatment
    - Biological basins – SBR,
    - Pump units for cleaned water,
    - Pump units for recirculation,
    - Pump units for sludge,
    - Mixers for aeration stage,
    - Blowers for aeration.

The main processes are:

- **Mechanical pre-treatment**

  The raw wastewater contains coarse material und mineral substances. To minimize the abrasion of the WWTP systems and support the biological treatment step, these biological not removable suspended substances have to remove for a trouble-free operation of the WWTP.

  Furthermore, it is important to remove biologically, not degradable components to get an excess sludge of good quality.

  The wastewater contains mineral components which cannot be treated respectively decomposed in the biological treatment process. They also increase the inert matter in the activated sludge. Therefore, mineral components are removed in the grit chamber. The aeration is used to enable the breakdown of grease and oil from sand and other sediments.

The sand sediments to the bottom and the floating substances are removed by automatic skimmers and sludge scrapers to the grit chamber's intake and the collecting shaft for the floating substances. The wastewater contains mineral components which cannot be decomposed in the biological treatment process. They also increase the inert matter in the activated sludge. In order to remove the mineral components, they will precipitate in the grit chamber.
The sand is collected in an inflow zone and transported automatically into the sand classifier by mammoth pumps. The collected grease is removed by special suction vehicles. A large part of the water is separated along with the grease. This separated water will be returned to the beginning of the process.

The purpose of preliminary sedimentation is the preliminary treatment of wastewater. From wastewater, we eliminate waste loads. In the primary settling tank is one zone primary sludge and one zone of partially cleaned water. Partially cleaned wastewater goes to biological treatment, primary sludge goes to dehydrator, and then to the digester.

- **Biological treatment**
  In the SBR-process, the biological treatment and the separation of sludge and cleaned water occur in one chamber. There the process steps have to work with temporary differences.

  The first step is the inflow of the wastewater into the reactor and the aeration of the water. The chamber volume will be dammed with the increase of water inflow. After reaching the maximum high, the inflow will cease.
  The aeration is shut off in the sedimentation phase, and the activated sludge will separate from the cleared water.

  After the sedimentation of the sludge, the cleared water's remove phase will start, and the water will take off into the river. If the minimal filling level is reached, the pumps will be stopped, and the reactor is ready for the next treatment cycle.

  Rotary compressors supply the activated sludge with oxygen by blowing-in environmental air into the chamber. The blower units are covered to reduce noise.

  Sufficient air exchange in the blower room is required due to the motors' production of waste heat. A fan for the used air and a fresh air grate are installed. The air inlets and outlets are sound insulated.

  The compressed air is transported through collecting and distributing pipes to the aerators. Fine-bubble membrane aerators disperse the compressed air into the activated sludge chamber.

  The aerators can be closed and lifted separately for maintenance works without interrupting the plant operation.

  Fast-revolving mixers are used for the recirculation in the denitrification zone.

  An excess sludge pump is placed in the return sludge pumping station and transports the excess sludge to the sludge treatment plant or to the sludge silo. The pump can be operated manually or by an automatic time-controlled program. A centrifugal pump is used to transport the excess sludge.

The excess sludge is stored in a sludge silo. Drained water will be released by a manual operating device and transported to the screen inflow. A mixer homogenizes the thickened sludge for further treatment.

3.5.6 Sludge treatment

The suspended solids removed from the wastewater and those produced by the biological treatment lead to sewage sludge production consisting of organic and inorganic solids. Sludge from municipal treatment plants is likely to contain pathogenic micro-organism and parasites (which may contribute to the transmission of disease) and contaminants (which may be hazardous to humans or the environment). Furthermore, due to the high organic matter content, sewage sludge is likely to undergo anaerobic digestion if not stabilized. Therefore, proper handling of the sludge is an essential component of a wastewater treatment plant to avoid resulting nuisances and adverse impact on the environment. The choice of the wastewater treatment process must thus be influenced by anticipated problems with sludge handling and sludge disposal options.

The character and amount of sewage sludge depending on the population and type of industry connected to the treatment plant and, to some extent, the type of primary, secondary and tertiary treatment employed for the wastewater treatment.

The sludge treatment processes aim at two main objectives:

- **The stabilization of the sludge to reduce the nuisance potential.** Stabilization means reducing the organic - or volatile – fraction to avoid that the sludge undergoes further digestion when stored, reused in agriculture, or disposed of in landfills. Furthermore, the stabilization process also aims to reduce or even more the removal of pathogenic organisms and micro-organisms. Stabilized sludge is no more decayable and can be dewatered naturally or mechanically. It can also be stored without generating disagreeable odors.

- **Sludge dewatering** to reduce the moisture content and reduce the volume of the sludge and make it easy to be handled and transported to the final disposal place.

Two possible alternatives of sludge treatment technologies are defined:

- Mechanical dewatering,
- Sludge drying reed beds.

3.5.6.1 Mechanical dewatering

Mechanical treatment of sludge consists of:

- Pre-thickener,
- Mechanical sludge pre-thickening,
- Anaerobic digester,
- Gas storage, torch
- Post-thickener,
- Sludge dewatering.

Pre-thickener is a simple object, where the primary sludge and waste sludge are combined and thickened by gravity. Sludge is more thickened (up to 6 %) in mechanical sludge pre-thickening. In an anaerobic digester, the waste sludge is anaerobically stabilized. The by-product of the digestion process, methane, is used for electricity generation. The electricity can cover about 30 % of the energy consumption of the WWTP. The waste heat is used for the heating of the digesters. The retention time will be about 22 days at a temperature of 33 °C. In post-thickener, sludge is thickened by gravity before it goes into sludge dewatering centrifuges or belts. Centrifuges are used for the dewatering of the stabilized sludge. 5 working days/week and 16 working hours/day are considered for the centrifuges' sizing. The expected final sludge concentration is 22-25 %. Dewatering with centrifuges consume polymers and electricity.

3.5.6.2 Sludge drying reed beds

The sludge drying reed beds is a passive technology that combines both sludge stabilization and sludge dewatering. A sludge treatment reed bed system is designed for dewatering and mineralizing sludge from wastewater treatment plants. At least partially stabilized (extended aeration is enough), the sludge passively dewaters with drainage through a filter and evaporation. Plants and the microbial activity contribute to the dewatering, ventilation, and mineralization. The environmentally sustainable treatment leaves a residue of treated sludge, resulting in a high quality "bio soil" as the final product. This bio soil can be used as a fertilizer and for soil improvement. The natural processes in the treatment and the sludge's dewatering represent a sustainable, energy effective and affordable method of sludge drying reed bed system compared to a more conventional mechanical dewatering of sludge.
The sludge treatment reed bed system contains several basins built as either concrete or soil basins with a waterproof membrane at the bottom. In the basins, there is a filter containing a system for sludge supply line and for drainage. In the filter, a (local) reed vegetation is planted. The drain system's function is to drain the reject water from the sludge dewatering before it is pumped into the inlet at the wastewater treatment plant and to ventilate filter and sludge.

Key benefits of using reed beds to manage sludge:

- OPEX costs estimated to be 70% lower than belt press or centrifuge technology;
- Energy consumption is 90% lower than belt press or centrifuge technology;
- Final dry solids content of 25–40%; such is the volume for transportation compared to other dewatering technologies;
- No chemicals used for dewatering – reduced operational handling risks;
- Significant opportunities for sludge reuse given that no flocculation chemicals contaminate sludge and higher dry solids content allow better handling;
- Mineralisation of hazard organic compounds; sludge treatment reed beds offer treatment and dewatering, whereas belt presses/centrifuges only provide dewatering;

- A higher filtrate quality of the water is produced from sludge treatment reed beds than filtrate produced from belt presses; reducing internal load on WWTP Sludge loading if recirculated;
- Design life >30–40 years (most mechanical systems have a maximum 15–20 years of life-time).

3.5.6.3 Resource recovery

The management of sewage sludge, which is the sludge originating from the treatment of wastewater, is a problem of great concern in Europe.[18] Sludge disposal methods (Figure *10*, Table *7*) vary from one country to another.[19] Statistics for sludge production in 2016 showed that 89 % of the total volume of treated sewage sludge was used as fertilizer for agricultural in 8 EU Member States: Germany, France, Poland, Czech, Sweden, Norway, Austria, and Ireland. *

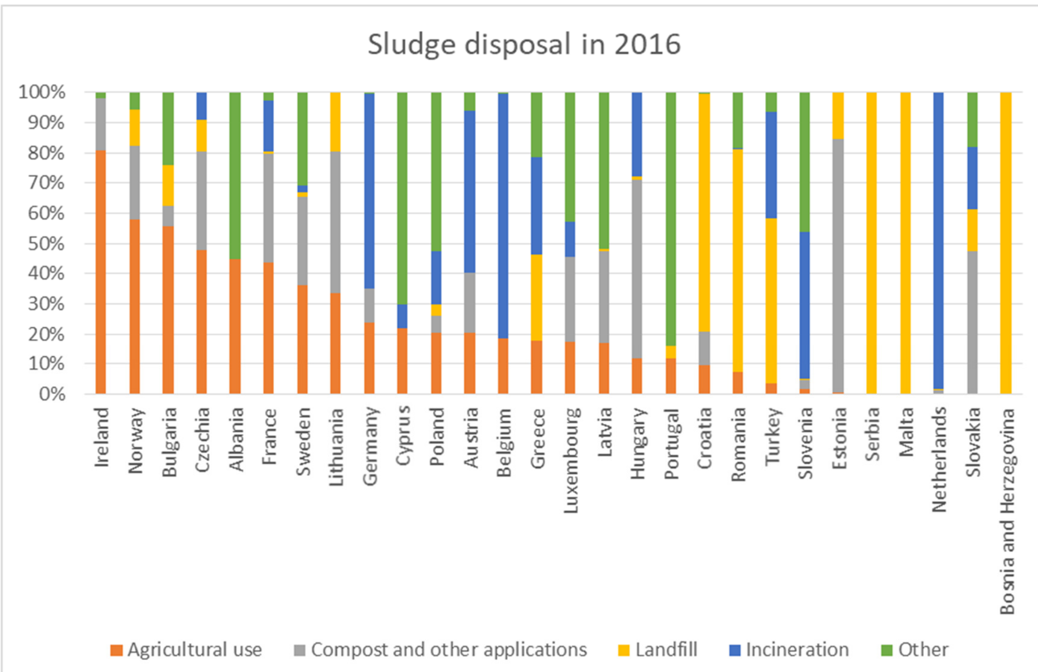

Figure 10: Disposal from urban wastewater treatment in 2016[20]*

*Note: Data not available for Denmark, Italy, Spain, Finland, UK, Iceland, Switzerland.

Table 7: Overview of sludge disposal in 2016[21]*

Type of sludge disposal	Agricultural use	Compost and other applications	Landfill	Incineration	Other
% of total mass	26	17	6	39	12

[18] https://www.researchgate.net/publication/311273547_Sewage_sludge_management_in_Europe_a_critical_analysis_of_data_quality
[19] http://extranet.novacomm-europa.eu/environment/waste/sludge/index.htm
[20] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_spd&lang=en
[21] https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

* Data available for Germany, France, Poland, Czech, Sweden, Norway, Austria, Ireland, Belgium, Bulgaria, Hungary, Greece, Romania, Portugal, Lithuania, Latvia, Cyprus, Luxembourg, Croatia, Slovenia, Estonia, Malta, Netherlands, Slovakia.

Sludge incineration seems to be the leading practice when observing the % of the total mass of sludge. However, when observing the practices used in 24 EU Member states, all practices except landfilling are represented evenly. Solutions for safe sludge reuse are a global requirement, and we need to move further and faster toward resource recycling. Sewage may not look like a particularly precious resource, but it is a source of phosphorus and other products.[22] Resource recovery is a site and contexts specific solution and can benefit society by turning waste into a valuable and renewable resource. EU Member States are on the road to economic nutrients recycling.

Phosphorus recovery from sludge is already mandatory in Switzerland and Germany. The terms of the Swiss Waste Avoidance and Disposal Act (VVEA), which was passed in 2016, require the operators of wastewater treatment plants in Switzerland to recover the phosphorus from their sewage sludge before sludge disposal. Given a 10-year grace period, phosphorus recovery will have to be implemented until 2026.[23] In Germany, the central element of the new Sewage Sludge Ordinance is the obligation to recover phosphorus (P) from sewage sludge or sewage sludge incineration ash.[24] The WWTP above 100,000 PE will have to fulfill the new phosphorus recovery requirements by 2029, after a 12 years transition period. The WWTP of 50.000 to 100.000 PE gets three additional years for implementation. All effected WWTP have to develop phosphorus recovery concepts by 2023.[25] Until then, sewage sludge from these wastewater treatment plants may continue to be used as a fertilizer on soil in compliance with the criteria of waste and fertilizer legislation. Sewage sludge from smaller wastewater treatment plants (≤ 50.000 PE) may continue to be used indefinitely on soil in the future.[26] It has to be noted that in 2016 in Germany 64 % of sludge was incinerated, and thus it makes sense to recover incineration ash, while countries that do not have incineration plants will probably focus more on other methodologies on how to recover nutrients from sludge. Albania is one of the countries that do not have a sludge incineration plant yet. Thus, the aspect of sludge reuse should be considered when designing WWTP for Shkodra city.

[22] https://ec.europa.eu/programmes/horizon2020/en/news/new-life-sewage-sludge
[23] https://www.ebp.ch/en/projects/phosphorus-recovery-wwtp-glarnerland-switzerland
[24] https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/190116_uba_fb_klaerschlamm_engl_bf.pdf
[25] https://phosphorusplatform.eu/scope-in-print/news/1395-new-sewage-sludge-ordinance-passed
[26] https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/190116_uba_fb_klaerschlamm_engl_bf.pdf

3.5.6.4 Sludge reuse in Shkodra city

3.5.6.4.1 Introduction

With the combined effects of population growth, economic development, and expanding cities, our water sources' pressure will increase in the future. Producing more crops will become increasingly demanding due to water and nutrient demand and shortages to meet them. With negative effects on natural ecosystems that provide essential services (including soil and water), every resource recovery aspect must be explored. Integrated approaches are needed while simultaneously tackling water, agriculture (nutrients), and population needs.

Sludge drying reed beds are a nature-based solution, which means that provide an approach where engineered natural ecosystems can be integrated to address targeted challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits. The challenges include climate change, water security and pollution, food security, human health (from IUCN definition[27]).

The common point of these aspects is the wastewater treatment process and resource recovery resulting in water and particularly nutrient reuse in agriculture. Sewage sludge resulting from the wastewater treatment process is regarded as a potentially useful resource if adequately processed. Its treatment process is relevant for Phosphorus reuse. It is a critical raw material, an essential ingredient of nutrients (mineral fertilizers), and an irreplaceable natural resource. Being a pillar of intensive agriculture, the threats of depletion of its natural reserves (phosphate rock) is realistic to occur in the future decades.

Sludge management, on the other hand, is highly complex and has a cost ranging from 10 to 60 % of the total operating costs of the wastewater treatment plants (WWTP) depending on the sludge treatment technology (although sludge represents only 1 % to 2 % of the treated wastewater). The adequate final destination of 'biosolids' is a fundamental factor for a sanitation system's success. Nowadays, it is not limited to treatment and disposal. We need to look at sustainable sewage sludge management, which means "the resources in sludge are recycled, while pollutants are destructed or removed".[28] It has been neglected in many countries and disregarded in the design of wastewater treatment plants.

3.5.6.4.2 Problem description

With the construction and expansion of municipal infrastructure (sewage and wastewater treatment plants), the amount of sludge in wastewater treatment plants increases. Sewage sludge is the leading waste byproduct of the wastewater treatment process. The excess sludge presents biomass and microorganisms that contain organic matter, nutrients, and persistent pollutants that originate from wastewater. Usually, it has a low density and low concentrations of inorganic matter. The sludge produced during biological treatment is called secondary (biological) sludge. It can be fermented in aerobic digesters to gain biogas; however, the sludge from anaerobic digesters still has to be further processed or appropriately disposed.

Besides activated sludge from biological treatment and anaerobic digesters, wastewater treatment plants also produce primary sludge, which originates from primary sedimentation tanks designed to remove inorganic particles (sand or gravel) as some heavier organic particles that can precipitate from

[27] https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions
[28] http://site.iugaza.edu.ps/rkhatib/files/2015/02/Sludge-Managemant-Chapters-1-and-2.pdf

raw wastewater. The amount and characteristics of primary sludge depend on the sedimentation tank's capacity, hydraulic performance, and the quality of the influent.

Primary and secondary sludge have different characteristics due to do the nature of the solids they contain. In any case, sludge contains valuable nutrients such as phosphorous and nitrogen used in agriculture and can partially substitute fertilizer imports. Reuse of treated sewage sludge in agriculture contributes to the local supply of nutrients and, thus, nutrient recycling.

If the wastewater derives mainly from households, high concentrations of heavy metals and toxic pollutants are not expected, so generated sludge can be used for agricultural purposes. In the case of industrial wastewaters, other pollutants may be present, and sludge management should be tackled with special attention.

Sewage sludge must be treated due to health, environmental, and economic reasons. Sludge contains different pathogens and toxic pollutants that can cause health problems to the persons exposed to it.

Raw sludge also has unpleasant smells and is a potential source of vectors. Therefore, it is necessary to deactivate pathogens and transform substances. Volume reduction is advisory to reduce costs and turns reuse economically feasible.

Management of sewage sludge in Albania is defined by the The Decision Nr. 127/2015 on Requirements for use of sludge in agriculture. The decision was adopted based on European sewage sludge Directive 86/278/EEC. The limit values are presented in Chapter 3.5.4 Sludge requirements for sludge reuse.

Safe and long-term solutions for the destination of sludge produced by the urban wastewater treatment are vital elements of the sustainable functioning of the wastewater treatment plants implemented all over Europe by applying the UWWT Directive. The recycling of sludge, containing useful organic matter and nutrients in agriculture, is considered by the Commission as the best solution, provided that the quality of the product and the way of its use are harmless for human health and environment.[29]

In Shkodra city, wastewater planning has been focused on developing wastewater infrastructure to meet the water (effluent) requirements of economic and social development. Biosolids' reuse is a strategic decision and should be taken into account before WWTP design. Such a process requires an understanding of all aspects of system functioning and leadership to drive implementation and allocate resources so that all stakeholders adopt the necessary changes. Now is the right time to make strategic decisions (WWTP Shkodra is not designed yet) and fill all information gaps to support long-term planning. Spatial development and land planning of Shkodra city is particularly important for wastewater infrastructure siting. It is also vital to ensure that significant spatial development is not planning in locations, provisioned for WWTP. In the case of biosolids' reuse, the vicinity of agricultural land for biosolids reuse in agriculture would further reduce costs. However, sludge reuse in agriculture is not the only option. Material can replenish organic matter and nutrients in soil. The organic matter can improve the water-retaining capacity and structure of some soil. Thus, it can also be used as a soil amendment to improve soil characteristics or prevent erosion. It can also be used in other areas of interest (green areas and parks, construction material, etc.).

3.5.6.4.3 Predictions

Assumptions made for biosolids' reuse in Shkodra city:

[29] https://ec.europa.eu/environment/archives/waste/sludge/pdf/workshoppart1.pdf

- **Sludge characteristics before dosing sludge to reed beds:**
  - Anaerobic biological sludge – stabilized
  - Sludge type: primary and secondary mixed together
  - Mechanical properties of sludge: fluid sludge
  - Water content: 98-99 %
  - Dry solids content: max 5 %
  - VTS content: 85 – 90 %

- **Sludge treatment on sludge drying reed beds**:
  - Sludge loading rate: 60 kg TSS/m^2*year
  - No. of beds: 16 beds
  - Required area for filter layer: 54.000 m^2
  - Required gross area (including embankments, maintenance roads, …): cc. 76.500 m^2
  - Operational (loading) cycle: 10 or more years
  - Lifespan: 30 years or more

- **Final product:** biosolids (dewatered, mineralized and stabilized sludge)
  - 2 scenarios, depends on the maintenance and conditions of operation:
    - Optimal scenario: Dry solid content (dry matter) 50% and 40% degree of mineralization
    - Regular scenario: Dry solid content (dry matter) 30% and 40% degree of mineralization

- **Quality of the final product:**
  - It should meet the standards for agricultural land disposal (no relevant industry)
  - Limit values set in The Decision Nr. 127/2015 on Requirements for use of sludge in agriculture
  - Required regular monitoring and sludge analysis before final decision on sludge disposal/biosolids' reuse
  - In case sludge does not meet limit values for biosolids' reuse, it can be excavated and transported to the nearest incineration plant. The excavated material has lower volume compared to mechanical dewatering and thus, manipulation costs are cheaper.

- **Biosolids' application:**
  - Sludge on reed beds accumulates for 10 and more years. Thus, biosolids' reuse is available only every 10 or more years.
  - Application is feasible after resting period before biosolids' excavation. During this period, natural air-drying on the open air of reed beds continues to accelerate pathogen die-off.
  - Biosolids' quantity before reuse:
    - Optimal scenario: 38.900 tonnes will accumulate on sludge drying reed beds in 10 years
    - Regular scenario: 64.830 tonnes will accumulate on sludge drying reed beds for 16 years
  - Use as soil amendment according to national legislation
  - Reuse in agriculture depends on crop needs and land use and national regulations accepted according to Nitrate Directive 91/676/EEC (maximum annual limit of nitrogen per hectar)
  - Nitrogen balance

- Percentage of nitrogen in biosolids: from 3 to 5 %
    - 3 % of 38.900,0 or 64.830 ton = 1.167.000,0 or 1.945.000,0 kg of nitrogen
    - 5 % of 38.900,0 or 64.830 ton = 1.945.000,0 or 3.241.500,0 kg of nitrogen
- 1 Scenario: extensive agriculture
    - N input per ha agricultural land: 170 kg N/ha
    - Required agricultural land: from 1.459,0 ha to 2.432,0 ha
- 2 Scenario: intensive agriculture
    - N input per ha agricultural land: 800 kg N/ha
    - Required agricultural land: from 2.432,0 ha to 4.052,0 ha

3.5.7 Analysis of pressures

3.5.7.1 Design Parameters

In the process of designing, the WWTP capacity is determined. The municipality of Shkoder and the consultant, who is currently making the Shkodra feasibility study update, were consulted. The concept design takes into account the planning horizon till 2045. The proposed capacity of WWTP Shkodra City is 115.000 PE. For capacity determination, the following data were used.

3.5.7.1.1 Population

The population for the city of Shkodra and the surrounding villages has been estimated (Table *8*), based on the analysis of the demographic data:

- Population growth rate for Shkodra city 2001 – 2011: -0,77 % / year
- Population Shkodra[30]

Table 8: Population in Shkodra

Name	Status	Population Census 1979-01-07	Population Census 1989-04-14	Population Census 2001-04-01	Population Census 2011-10-01	Population Prediction 2045
Shkodër	Administrative unit			147,633	135,612	104,421*
Shkodër	City	65,000	79,920	83,598	77,075	71,145*

*if annual growth rate remains the same

The gathered population data is presented in Annex 4 (Table 26 and 27). The data used in this report was collected from the Municipalities, Civil Registry Office and Institute of Statistics (INSTAT). The table demonstrates that population in the administrative unit of Shkoder is decreasing, in years from 1989 to 2019 by 28%, I.e. 80.264 people.

Additional share of population due to tourism: 25% (2045)

Table 9: WWTP design criteria

Designation	Unit	Values
Population prediction 2045	Inhabitants	71.145
Connecting rate to the sewer system	%	100
Connected population to the sewer system	Inhabitants	71.145
Additional fraction of population for Industrial WW	%	25

[30] Instituti i Statistikës, Tiranë (http://www.instat.gov.al/)

Industrial Population-Equivalent (based on industrial survey)	Inhabitants	17.786
Additional fraction of population for tourism	%	30
Tourism Population-Equivalent	Inhabitants	21.344
TOTAL:	**Inhabitants**	**110.275**

Design capacity of WWTP Shkodra City is 115.000 PE

3.5.7.1.2 Drinking water consumption

The future evolution of the drinking water consumption for domestic use and small-scale industries, commerce and institutions has been estimated as follows (Table *10*):

Average water consumption in household from 120 to 180 lit / person (PE) / day.

Table 10: Drinking water consumption forecast 2006 – 2045

Name	**Unit**	**2006**	**2020**	**2030**	**2045**
Domestic water consumption	l / PE day	250	150	130	120
Small-scale industry, commerce and institutions	l / PE day	40	30	25	20

Wastewater flow, yearly average:			159,72	l/s
			575,00	m3/h
Spec. Infiltration Coefficient:	qf	=	50,00	%
Hourly Average (infiltration):			24,00	h/d
Infiltration quantity:	QF,aM	=	79,86	l/s
		=	287,50	m3/h
Dry weather flow, yearly average:	QT,aM	=	239,58	l/s
			862,50	m3/h
			20.700,00	m3/d
Divisor for the daily peak:	xQmax	=	16,00	h/d

$$QT,h,max = QF,aM + \frac{24 * QS}{aM;xQmax}$$

Daily peak dry weather flow, yearly average:	QT,h,max	=	319,44	l/s
			1.150,00	m3/h

3.5.7.1.3 Tourism

In the last decade, the tourism in the city Shkodra is growing. There is an increase in the number of tourists visiting the Shkodra Municipality by 30% during the past 4 years.[31] When dimensioning the wastewater treatment plan loadings tourist population must be considered.

Additional share of population due to tourism: 25% (2045)

3.5.7.1.4 Industrial wastewater

In Shkodra city, there is no particular industry. The industrial area is not connected to the sewer network yet. A new separate sewage network will be constructed for the industrial area, to be connected to the central sewer network of Shkodra City.
Based on the industrial survey and forecasted development of the industrial activities from kWf study from 2006, the estimated industry load is 25 % for the planning horizon till 2045.

3.5.7.1.5 Wastewater loads and concentrations

According to the ATV-DWK-A 198E, one (1) PE generates the following daily loads:

- COD = 120 g/(PE*d)
- BOD_5= 60 g/(PE*d)
- Suspended Solids = 70 g/(PE*d)
- Total Nitrogen = 11 g/(PE*d)
- Total Phosphorus = 1,8 g/(PE*d)

Based on these calculations, the following pollution loads are calculated:

- COD = 13.800 kg/d
- BOD_5= 6.900 kg/d
- Suspended Solids = 8.050 kg/d
- Total Nitrogen = 1.265 kg/d
- Total Phosphorus = 207 kg/d

For these parameters, calculated concentrations in the inflow of wastewaters are as follows:

- COD, c = 667 mg/l
- TSS, c = 389 mg/l
- TN, c = 61 mg/l
- TP, c = 10 mg/l

The hourly values are calculated with the hour index for domestic and infiltration.

Regarding the microorganisms in wastewater, the following table (Table *11*) represents reference values of microorganism in municipal wastewater per 100 ml.

Table 11: Reference values of microorganism in municipal wastewater per 100 ml[32]

Parameter	Raw sewage
E. Coli	10^7
Cl. perfringes	10^4

31 Action plan for fostering innovation in sustainable tourism –SHKODRA Municipality, ALBANIA: **https://fostinno.adrioninterreg.eu/wp-content/uploads/2018/12/PP7_Action-plan-UNISHK.pdf**

32 https://ocw.un-ihe.org/pluginfile.php/463/mod_resource/content/1/Urban_Drainage_and_Sewerage/5_Wet_Weather_and_Dry_Weather_Flow_Characterisation/DWF_characterization/Notes/Presentation%20handouts.pdf

Fecal streptococcae	10^7
Salmonella	200
Enterovirus	5.000
Rotavirus	50

Although these are common values, according to Henze, et al. (2008[33]), the concentration of pathogens in raw wastewater might vary significantly between different geographical regions depending on the current amount of people infected, socio-economical characteristics and per-capita water consumption. The more people get infected, the lower their socio-economical level and per-capita water consumption, the higher is the concentration of pathogens in domestic wastewater. All of these characteristics are associated with developing countries, and therefore, it can be stated that wastewater has a higher concentration of pathogens in developing countries than in developed countries (Henze, et al., 2008). At the same time, this increases the risk of human infection with pathogens in developing countries.

3.5.7.1.6 *Specific water consumption*

Hydraulic load is defined in existing terms of reference for elaboration of concept design for the WWTP Shkodra city, and adopted European standards of consumption, and is as follows:

- Spec. wastewater quantity: wS,d = 120,00 l/(P*d)

$$QS,aM = \frac{EZ * wS}{d;86400}$$

3.5.7.2 Impact on water quality in the receiving waters with different levels of treatment

Produced loads and loads released into water recipient for various treatment scenarios of Shkodra agglomeration have different impact on water quality in the receiving waters. Different scenarios were elaborated:

- 0: Current state
- A: Current state with WWTP (secondary level of treatment)
- B: Current state with WWTP (tertiary level of treatment)
- C: New sewage, all current inhabitants are connected to WWTP (secondary level of treatment)
- D: New sewage, all current inhabitants are connected to WWTP (tertiary level of treatment)
- E: New sewage, predicted inhabitants are connected to WWTP (secondary level of treatment)
- F: New sewage, predicted inhabitants are connected to WWTP (tertiary level of treatment)

Currently, the wastewaters from Shkodra city are discharged directly into the Buna river or through dispersed sources (e.g., septic tanks). If all current inhabitants were connected to the WWTP's sewerage, the release into the Drin river would be only 13 % of BOD5 released into the river at the current state (A, B, C, D scenarios). For scenario E and F, the release into the Drin river would be 20 %, due to increasing numbers of inhabitants and not due to the treatment plant's efficiency. Regarding the nutrient's removal, there is a big difference in the impact on the river with different treatment levels. With a secondary level of treatment, the nutrient release is even higher than at the current

[33] https://saniup.org/wp-content/uploads/2018/01/UWS-SE-2017-02-Carolina-Bettinelli_EXAM-VERSION.pdf

state due to increased numbers of inhabitants and concentrated sources of nutrients (WWTP). The treatment plant's efficiency with a secondary level of treatment is 20 % for TN removal and 10% for TP removal. If the WWTP has a (proposed) tertiary level of treatment, the release into river % of the current state (scenario 0) is 26% for scenario D and 40% for scenario F. The results are presented in the Table *12*.

Table 12: Produced loads and loads released into water recipient for various treatment scenarios of Shkodra agglomeration

scenario	*0) current*	*A) wwtp*	*B) wwtp*	*C) wwtp + sewage*	*D) wwtp + sewage*	*E) wwtp + sewage*	*F) wwtp + sewage*
treatment type	*none*	***secondary***	***tertiary***	***secondary***	***tertiary***	***secondary***	***tertiary***
population							
dispersed PE	18.876	18.876	18.876	0	0	0	0
connected PE	56.000	56.000	56.000	74.876	74.876	115.000	115.000
treated PE	0	56.000	56.000	74.876	74.876	115.000	115.000
total PE	**74.876**	**74.876**	**74.876**	**74.876**	**74.876**	**115.000**	**115.000**
BOD5 [kg/day]							
produced by households	4.493	4.493	4.493	4.493	4.493	6.900	6.900
released into river							
from dispersed sources	113	113	113	0	0	0	0
from untreated sewage	3.360	0	0	0	0	0	0
from treated sewage	0	336	336	449	449	690	690
released into river	**3.473**	**449**	**449**	**449**	**449**	**690**	**690**
release into river % of cur.		**13%**	**13%**	**13%**	**13%**	**20%**	**20%**
N total [kg/day]							
produced by households	899	899	899	899	899	1.380	1.380
released into river							
from dispersed sources	23	23	23	0	0	0	0
from untreated sewage	672	0	0	0	0	0	0
from treated sewage	0	538	134	719	180	1.104	276
released into river	**695**	**560**	**157**	**719**	**180**	**1.104**	**276**
release into river % of cur.		**81%**	**23%**	**103%**	**26%**	**159%**	**40%**
P total [kg/day]							

produced by households	225	225	225	225	225	345	345
released into river							
from dispersed sources	6	6	6	0	0	0	0
from untreated sewage	168	0	0	0	0	0	0
from treated sewage	0	151	34	202	45	311	69
released into river	**174**	**157**	**39**	**202**	**45**	**311**	**69**
release into river % of cur.		**90%**	**23%**	**116%**	**26%**	**179%**	**40%**

To determine the impact of WWTP on water quality in the receiving waters, the WEMDST was used. The results show that the WWTP with a tertiary level of treatment has an impact on the river quality. The BOD_5 in the river is reduced from 5,79 mg/l to 1,5 mg/l, TN from 0,97 mg/l to 0,21 mg/l and TP from 0,16 mg/l to 0,02 mg/l (Figure *11*). Therefore, class of the quality for BOD_5 of the river changes (from class II to class I).

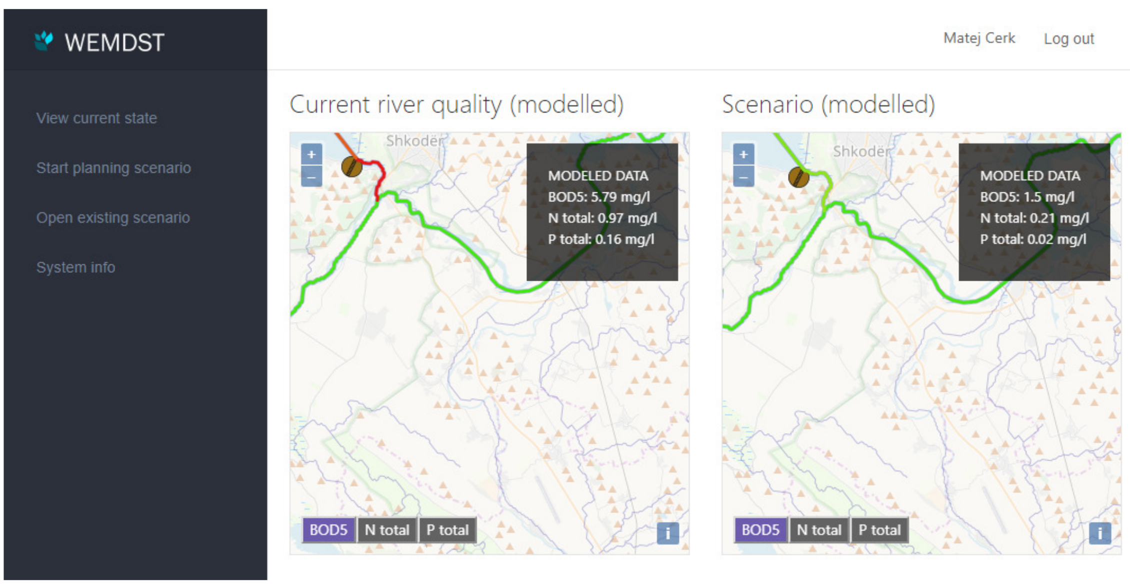

Figure 11: The WEMDST model of the WWTP impact on river quality

Albania's river water quality is based on the classification criteria defined by UNECE. The classification system is based on the number of parameters analyzed and compared with the biological, physical, and chemical quality of river water in different countries. The parameters are P_{total}, NO_3, O_2 dissolved, BOD_5, COD, and NH_4^+. The UNECE river water quality criteria are given in Table *13*.

Table 13: UNECE river water quality criteria (Report on environmental situation in Albania 1997-1998, NEA)[34]

Category	P_{total} (mg/l)	NO_3 (mg/l)	Dissolved O_2 (mg/l)	BOD_5 (mg/l)	COD (mg/l)	NH_4^+ (mg/l)

[3434] https://ec.europa.eu/environment/archives/international_issues/pdf/report_albania.pdf

Class I	<10	<5	>7	<3	<3	<0.1
Class II	10-25	5-25	7-6	3-5	3-10	0.1-0.5
Class III	25-50	25-50	6-4	5-9	10-20	0.5-2
Class IV	50-125	50-80	4-3	9-15	20-30	2-8
Class V	>125	>80	<3	>15	>30	>8

The quality classification of Buna river, according to these UNECE criteria, is given in (Report on Environmental State 2003-2004)[35] *Table 14*.

Table 14: Quality classification of Buna river

Category	**Code**	**P_{total} (mg/l)**	**NO_3 (mg/l)**	**BOD_5 (mg/l)**	**COD (mg/l)**	**NH_4^+ (mg/l)**	**Overall quality**
Drin	D1	V	I	I	I	II	III
	D2	V	I	I	I	II	III
Drin Lezhe	Le3	V	I	III	III	III	III

It was not possible to assess the precise effect of WWTP implementation with different levels of treatment on river quality. It has been assumed that the implementation of WWTP would positively affect the water quality in all watercourses resulting in an upgrade of Water Quality Objective class I or II. This seems a reasonable assumption, as the leading cause of not meeting the WQO is the discharge of various substances by sewage and industrial discharges, and these discharges would be dealt with by the WWTP.

3.5.7.3 Pathogens removal efficiency

Pathogens removal should be considered, when effluent has an impact on bathing waters[36], or in the case the water reuse is predicted[37]. Some pathogens in untreated wastewater are already removed using secondary or biological treatment (Table *15*).

Table 15: Efficiency of pathogens removal[38]

Parameter	**Raw swage**	**Biol. treated**	**Efficiency [%]**
E. Coli	10^7	10^4	99,90%
Cl. perfringes	10^4	10^2	99,00%
Fecal streptococcae	10^7	10^4	99,90%
Salmonella	200	1	99,50%
Enterovirus	5.000	500	90,00%
Rotavirus	50	5	90,00%

Rivers discharging into recreational water areas may carry a heavy load of microorganisms from diverse sources, including municipal sewage (treated or not) and animal husbandry. After every rainfall, microbial loads may significantly increase due to surface runoff, urban and rural stormwater overflows (including natural watercourses - torrents - that only drain stormwater) and resuspension of

[35] https://ec.europa.eu/environment/archives/international_issues/pdf/report_albania.pdf
[36] https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/state-of-bathing-water/bathing-water-directives
[37] https://ec.europa.eu/environment/water/pdf/water_reuse_regulation.pdf
[38] https://ocw.un-ihe.org/pluginfile.php/463/mod_resource/content/1/Urban_Drainage_and_Sewerage/5_Wet_Weather_and_Dry_Weather_Flow_Characterisation/DWF_characterization/Notes/Presentation%20handouts.pdf

sediments. Coastal pollution levels may, therefore, be elevated following rainfall and periods of high risk in some coastal areas may be found to correlate with such climatological data[39].

Table 16: Relative risk potential to human health through exposure to sewage through outfalls (including stormwater runoff and combined sewer overflows)[40]

	Discharge type		
Treatment	**Directly on beach**	**Short outfall[a]**	**Effective outfall[b]**
None[c]	Very high	High	NA[d]
Preliminary	Very high	High	Low
Primary (including septic tanks)	Very high	High	Low
Secondary	High	High	Low
Tertiary	Moderate	Moderate	Very low
Lagoons	High	High	Low

[a] The relative risk is modified by population size. Relative risk is increased for discharges from large populations and decreased for discharges from small populations.

[b] This assumes that the design capacity has not been exceeded and that climatic and oceanic extreme conditions are considered in the design objective (i.e., no sewage on the beach zone).

[c] Includes combined sewer overflows if active during the bathing season (a history of total non-discharge during the bathing season can be treated as "Low").

[d] NA = not applicable

In areas where there are bathing waters or where disinfection is continuously required, it is advisable to treat wastewaters with treatment plants equipped with disinfection systems.

3.5.8 WWTP for Shkodra city (115.000 PE)

3.5.8.1 Design capacity

For Shkodra city WWTP of with the capacity of 115.000 PE is proposed including N and P removal (tertiary treatment level).

Retention time pre sedimentation: t_D = 1,00 h

3.5.8.2 Wastewater technology selection

The 2006 feasibility study by KfW considered three different technologies for wastewater treatment:

- Option 1: Anaerobic ponds followed by aerated lagoons;
- Option 2: Anaerobic ponds followed by trickling filters and
- Option 3: Extended aeration.

[39] https://www.who.int/water_sanitation_health/bathing/srwe1-chap4.pdf
[40] https://www.who.int/water_sanitation_health/bathing/srwe1-chap4.pdf

Considering this study's outcome, Option 1 (Anaerobic ponds followed by aerated lagoons) was proposed for further elaboration. However, due to extensive land cost requirements and related long and difficult acquisition, land exchange, or expropriation procedures, Option 2 (Anaerobic ponds followed by trickling filters) was selected as a potentially the most appropriate.
Considering the municipality's expressed desire to minimize O&M costs, consultant`s experience in WB Region and site specifics of proposed WWTP location, the following technologies were considered:

- Conventional activated sludge;
- SBR;
- MBBR technology.

Overview of option analysis for WWTP for Shkodra city is presented in Table 17.

Table 17: Option analysis for WWTP in Shkodra city

Parameter	**Option 1: Conventional activated sludge (CAS)**	**Option 2: Sequencing batch reactor (SBR)**	**Option 3: Membrane bioreactor (MBR)**
Investment costs (EUR)	1	2	3
O&M costs (EUR/year)	2	1	3
(1)Land requirements	3	2	1
(2)Ease of operation	1	2	3
(3)Maintenance	1	2	3
(4)Energy consumption	1	2	3
(5)Environmental impact	3	2	1
(6)Water reuse	2 (no)	2 (no)	1 (yes)
(7)Treatment efficiency	2	2	1
TOTAL:	16	17	19
RANKING:	**2**	**1**	**3**
CONCLUSIONS:	- adopted for large scale applications	- commonly used technology in WB - good relation between price-performance and land requirements	- applicable for required high quality effluent

(1) **Land requirements**: 1-smallest land requirements (third the land area required for an SBR), 3-biggest land requirements

(2) **Ease of operation:** 1-easy to operate (low process complexity), 3-complex high-tech operation

(3) **Maintenance:** 1-require less maintenance, 3-high maintenance needs

(4) **Energy consumption:** 1- consumes less energy consumption, 3-consumes more energy

(5) **Environmental impact:** 1- small footprint (more eco-friendly option), 3-greater environmental impact

(6) **Water reuse:** 1-possible water reuse, 2- water cannot be reused without additional treatment (UF, UV)

(7) **Treatment efficiency:** 1-high quality effluent (better than required by legislation), 2-lower quality effluent

Based on the evaluation, the most appropriate technology options are Option 1 (CAS) and Option 2 (SBR). Complex wastewater decision-making require difficult trade-offs between economic, social and ecological objectives. It requires clear insight into how different options would perform in the long term and on a seasonal basis. Apart from an efficient WWTP operation, the relations between price-performance-land requirements are equally important when choosing the technology for Shkodra city. In addition, the wastewater planning process is closely linked to the spatial and urban planning both to be adapted to the local circumstances. Wastewater resource recovery (wastewater and sludge reuse) requires a strategic planning of the Municipality and is reflected in the technology selection. Formulation of the vision and its goals involves the participation of several public decision-makers and authorities and their alignment with local wastewater management. However, not all wastewater planning processes should be as comprehensive: in other contexts, wastewater planning processes may focus on a particular topic, for example, only on effluent quality. The formulated options are the basis for discussion and negotiation through the planning process.

Croatia is currently the liveliest market for constructing municipal WWTPs in the region since they are undertaking an extensive investment program to ensure compliance with the UWWT Directive. Thus, the consultant has collected data on selected/implemented technologies presented in the table below.

Table 18[41]: Public tenders for WWT construction in Croatia in the period 2016 – 2019

Location	Capacity (PE)	Technology
Nova Gradiška	22.100	MBR + sludge dehydration
Jastrebarsko	15.000	extended aeration, BIOCOS or SBR + sludge drying reed beds
Virovitica	26.000	SBR or CAS + sludge drying reed beds
Donja Dubrava	13.000	SBR or CAS + sludge drying reed beds
Mursko Središće	12.000	SBR or CAS + sludge drying reed beds
Pleternica	15.300	SBR or CAS + mechanical sludge dehydration
Požega	33.500	SBR or CAS or combination + sludge drying reed beds
Grgur (Nin-Privlaka-Vrsi)	26.000	SBR or CAS or MBR or MBBR + mechanical sludge dehydration
Poreč	137.500	MBR + solar drying and composting
Krk island	Summer: 85.000 Winter: 17.600	MBR+ sludge composting and sludge dehydration
Rovinj	64.900	MBR + solar drying
Zabok i Zlatar	51.630	SBR or CAS or MBBR + solar drying
Brod Moravice	1.800	SBR + mechanical sludge dehydration
Fužine	2.400	SBR + sludge dehydration
Vodice-Srim-Tribunj	20.000	CAS or SBR or combination + sludge dehydration and lime treatment
Varaždinske toplice	6.500	SBR or CAS + sludge flocculation, dehydration
Petrinja	24.000	SBR, CAS, MBR, MBBR + sludge dehydration
Varaždin	127.000	SBR + mechanical dehydration
Vukovar	42.000	SBR + sludge dehydration and lime treatment

Key conclusions of the analysis of proposed wastewater technologies in Croatia:

- MBR technology is commonly used in touristic coastal areas where land availability is scarce, expensive to purchase, and high-quality effluent is required due to bathing waters. Additionally, coastal areas are under pressure from draught during the summer.
- Both CAS and SBR are well-established technologies in the Western Balkan Region.
- Croatia, like Albania, does not have an incineration plant yet. According to European national guidelines, every country is responsible for the disposal of its own sludge quantities; therefore, incineration capacities are fully engaged and can dispose of only limited quantities of sludge from abroad. Croatia and Slovenia used to collect and transfer sludge for final disposal to neighboring countries (Austria, Hungary), but recently countries limited sludge imports significantly. Alternative sludge management approaches are being increasingly used, also aiming to accumulate or reuse sludge until incineration plant would be implemented.

Selected Option 2 (SBR) is further supported by the cost analysis in the next chapter.

3.5.8.3 Cost analysis of wastewater treatment

To reach the required effluent standards, nutrient removal, and a sustainable energy balance, SBR treatment technology is proposed. **Concept solution for WWTP Shkodra city is presented in Annex 1, while the summary of cost analysis is found in the chapters below.**

3.5.8.3.1 Investment cost

The WWTP of SBR technology investment costs are summarised in *Table 19*. The costs do not include sludge treatment and handling.

Table 19: Summary of investment costs of wastewater in Shkodra city

Description	Cost [EUR]
Investigation on site	45.500,00 €
Project documentation	560.000,00 €
Civil works	5.800.000,00 €
Electrical works	1.414.000,00 €
Measuring and regulation equipment	980.000,00 €
Mechanical works – piping, armatures etc	813.500,00 €
Technological works	5.228.000,00 €
Laboratory equipment	35.000,00 €
Cold test	25.000,00 €
Starts up	40.000,00 €
Trial period	105.000,00 €
Construction side organization	115.000,00 €
Unforeseen works	1.489.000,00 €
Guarantees and insurance	95.000,00 €
TOTAL:	**16.745.000,00€**

3.5.8.3.2 Operation and maintenance cost

The WWTP (SBR technology) operation and maintenance costs are summarised in Table *20*. Detail calculation is presented in Annex 1. The costs do not include sludge treatment and handling.

Table 20: O&M costs of wastewater treatment in Shkodra city

Descriptions		Unit price	Cost [EUR/y]
Energy consumption	3.538.505,00 kWh	0,1 EUR/kwh	353.850,5
Workforce	11 persons	*16.570 EUR/year	182.270,0
Precipitant Costs	802,44 m^3/year	100 EUR/m^3	80.244,0
Grit and Grease removal	2070 m^3/year	100 EUR/m^3	207.000,0
Maintenance for wastewater	*according to % of investment costs*		*192.500,0*
Monitoring-formal	*24 samples*	*800 EUR/sample*	*19.200,0*
Monitoring-intern	*56 samples*	*200 EUR/sample*	*11.200*
Heating oil	*2.100 l/year*	*1,0 EUR/l*	*2.100,0*
Process water	*22 m3/day*	*0,6 EUR/m3*	*4.800,0*
		TOTAL:	**1.053.164,50**

**average cost of manager, process engineer, maintenance – mechanical and electrical*

3.5.8.4 *Cost analysis of sludge treatment*

In this chapter cost analysis of two different scenarios are presented:

- Mechanical dewatering
- Sludge drying reed beds.

3.5.8.4.1 Mechanical dewatering and digestion

The simplified process flowchart of WWTP with mechanical dewatering is presented in *Figure 12*.

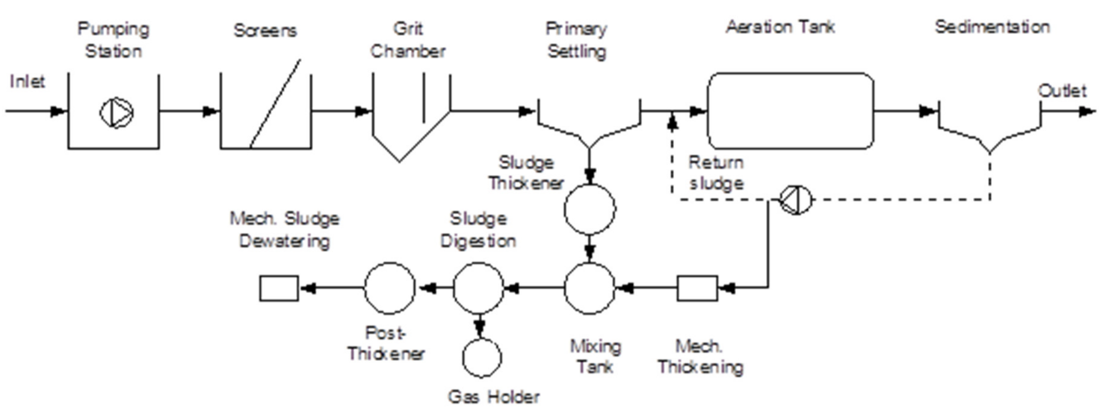

Figure 12: The simplified process flowchart of WWTP for Shkodra city with mechanical dewatering.

3.5.8.4.1.1 Investment cost

The investment costs for sludge treatment with mechanical dewatering are summarised in *Table 21*.

Table 21: Summary of investment costs of mechanical dewatering of sludge in Shkodra city

Descriptions	Cost [EUR
Civil works & other services	210.000,00
Mechanical equipment and installations	1.460.000,00
Electrical equipment and installations	320.000,00
TOTAL:	**1.990.000,00**

The investment cost does not include land purchasing.

3.5.8.4.1.2 Operation and maintenance costs

The assessment of operation and maintenance costs for mechanical dewatering of sludge is given in *Table 22*.

Table 22: O&M costs for mechanical dewatering of sludge in Shkodra city

Descriptions	Cost [€/y]
Energy - electricity	54.224,40
Chemicals	81.000,00
Maintenance	29.350,00
• *Civil works*	1.050,00
• *Mechanical equipment and installations*	21.900,00
• *Electrical equipment and installations*	6.400,00
Sludge disposal	698.899,
TOTAL:	**863.473,60**

The amount of sludge to be disposed of after mechanical dewatering is estimated to 11.648,32 t/y of sludge (22 % DS) tons per year. The predicted disposal method for the sludge after mechanical dewatering is incineration. In operational cost these amounts to 698.899,2 € per year. Total annual costs for Shkodra city for sludge treatment and disposal are 863.473,60 €.

3.5.8.4.2 Sludge drying reed beds

The simplified process flowchart of WWTP with reed beds is illustrated in Figure 13. **Conceptual design of sludge drying reed beds is presented in Annex 2.** The annex contains a general description, principle of operation, basic dimensioning of reed beds for Shkodra city, cost analysis, sludge quantities, and land requirements for the sludge use.

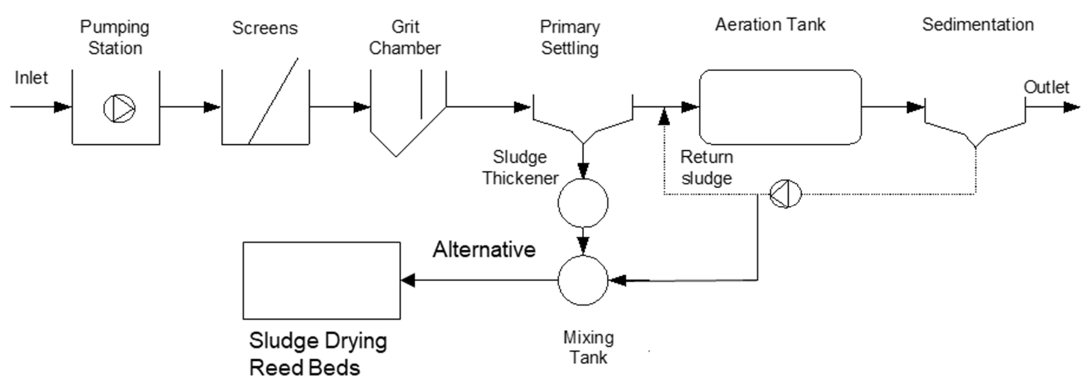

Figure 13: The simplified process flowchart of WWTP for Shkodra city with reed beds.

3.5.8.4.2.1 Investment cost

Investment costs for reed beds for sludge treatment are presented in Table *23*.

Table 23: Summary of investment costs of mechanical dewatering of sludge in Shkodra city

Descriptions	**Cost [EUR]**
Civil works & other services	3.252.139,00
Mechanical equipment and installations	812.176,00
Electrical equipment and installations	105.000,00

TOTAL**:**	**4.115.315,00**

The investment cost does not include land purchasing, project documentation, operation staff training and dissemination

3.5.8.4.2.2 Operation and maintenance costs

Operation and maintenance costs for reed beds for sludge treatment are presented in Table *24*.

Table 24: The assessment of operation and maintenance costs for sludge drying reed beds

Descriptions	**Unit**	**Cost [€/y]**
Energy - electricity	159.100	15.900,00
Workforce	1,6	17.300,00
Maintenance		46.804,10
• *Civil works*	*1% of investment*	*32.521,40*
• *Mechanical equipment and installations*	*1,5% of investment*	*12.182,70*
• *Electrical equipment and installations*	*2,0% of investment*	*2.100,00*
Monitoring		6.900,00
• *Formal*	*1/10*	*500,00*
• *Intern*	*64*	*6.400,00*
Sludge reuse (regular scenario)	6.483 tons/year	97.245
TOTAL:		**184.149,10**

After an average operative period of 10 years, the biosolids (treated sludge) are dug up and disposed of or reused, e.g., fertilizer in agriculture. There are two possible scenarios about when and how much of biosolid must be removed from the RB for disposal or reuse. Experience has shown that the final product's quantity depends on wastewater characteristics, dynamics of household's connectivity to the sewer system, supervision of the RB, climate conditions, chemical, and biological processes in RB. The amount of biosolid is dependent on the degree of mineralization and dry matter content, which are dependent on the conditions listed above. Detailed information about sludge amount is hard to predict due to uncertainties; therefore, two scenarios were predicted, regular (normal conditions) and optimal (optimal conditions) scenario. The main characteristics are presented below.

Table 25: Two scenarios for quantity of biosolid after treatment on RB

Scenario	**Loading**	**% of mineralization**	**% of dry solids**	**Sludge disposal (t/year)**	**Year of emptying RBs**
Optimal scenario	60 kg TSS/m^2	40	50	3.890	15,97
Regular scenario	60 kg TSS/m^2	40	30	6.483	9,58

In the optimal scenario, conditions are very good (e.g., high temperature, long vegetation season, low precipitation); we can achieve volume reduction due to a 40% degree of mineralization and around 40 % of dry solids. In regular scenario conditions not so optimal for biological processes, we can achieve a 40% degree of mineralization and up to 30 % of dry solids. It is expected that in the Mediterranean region (mild climate), the optimal scenario is more realistic than a regular scenario.

Table 26: Costs for disposal or reuse for different scenarios

Scenario	Optimal scenario		Regular scenario	
	Disposal	Reuse	Disposal	Reuse
Sludge disposal (t/year)	3.890,0		6.483,0	
Cost per unit (EUR/t)	60	15	60	15
Cost per year (EUR/year)	233.400	58.350	388.980	97.245

Total annual costs for Shkodra city for sludge treatment on the sludge drying reed beds (including disposal) amounts to 320.304,1 € with optimal, and 475.884,0 € with regular conditions. The predicted disposal method for the sludge after stabilization on sludge drying reed beds, is incineration. In case sludge is used in agriculture, the total annual costs for sludge treatment are 145.254,1 € for optimal and 184.149,1 € for regular conditions, including reuse costs.

3.5.8.5 A comparison of sludge scenarios for future WWTP implementation in the city of Shkodra

Table 27 displays the investment cost comparison of different sludge treatment technology. The difference in investment cost for sludge treatment is considerable, but considering smaller operational costs of the reed beds and sludge reuse in agriculture, this is an economically favorable option. Sludge drying reed beds optimize annual operational costs for more than 80 %.

Table 27: Option analysis for sludge treatment for Shkodra city

Parameter	Scenario 1: mechanical dewatering	Scenario 2: reed beds			
		optimal scenario		regular scenario	
Sludge alternatives	disposal	disposal	reuse in agriculture	disposal	reuse in agriculture
CAPEX [€]	1.990.000	4.169.315	4.169.315	4.169.315	4.169.315
OPEX [€/y]	863.473,60	320.304,10	145.254,10	475.854,10	184.141,60
NPV O&M [€/y]	-14.931.214	-5.538.709	**-2.511.739**	-8.229.004	-3.184.312
NPV INVESTMENT [€]	-1.990.000	-4.169.315	**-4.169.315**	-4.169.315	-4.169.315
NPV TOTAL [€]	-16.921.214	-9.708.024	**-6.681.054**	-12.398.319	-7.353.627
Ranking	**5**	**3**	**1**	**4**	**2**

3.5.8.6 Price for collection and treatment of wastewater in Shkodra city

Typical operating costs items of water investments include energy, materials, services, technical and administrative personnel, maintenance, and sludge management costs. Projections of O&M costs shall be split into fixed and variable costs, and by category. [42]

[42] https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

The source of financial revenues in the Integrated Water Supply (IWS) project comes from the application of charges to users for the services rendered, e.g., revenues for drinking water supply, drainage water collection and wastewater collection and treatment, sludge management, sale of purified water for industrial and agricultural purposes, etc. The public/private water agencies/companies/entities that run the water management should, in the first instance, ensure the financial sustainability of the whole water management system, including investments in maintenance of infrastructure. Thus, adequate tariffs have to bet set up to ensure an adequate level of recovery of the cost of providing the service, as well as financial sustainability of operations once the project is implemented, while at the same time respecting affordability constraints that might apply.[43]

Price for collection and treatment of wastewater consists of:

- Part representing public infrastructure costs (network charge) - fixed part
- Part representing costs of the public service – variable part.

The network charge is charged according to the capacity or size of the water supply connection (connection load) and is expressed as DN (diameter of the water meter in millimeters). The collected funds of network charges for collection and treatment are paid in rent to the Municipality and are revenues. The network charges include the costs of public infrastructure (depreciation of infrastructure facilities or devices or rent, infrastructure insurance, costs of possible damages) and are intended for investments in renovations and new constructions of the public sewerage system and treatment plants.

There are several methodologies on which basis the calculation of public service of wastewater collection and treatment can be made. The basis for calculating the variable part is the quantity of drinking water supplied, expressed in cubic meters or population equivalent (PE) or something else.

Costs of the public service include:
- direct costs of materials and services;
- direct labor costs;
- other direct costs;
- general (indirect) production costs, which include the costs of materials, depreciation of business required fixed assets, services, and labor;
- general purchase and sale costs, which include the costs of materials, depreciation of business required fixed assets, services, and labor;
- general administrative expenses, including material costs, depreciation of business required assets, services, and labor, etc.[44]

For the Shkodra city, we could not predict the price per m^3 of collected and treated wastewater because the O&M costs for the sewer system cannot be defined. There were only theoretical assumptions about the length of the new sewer system; the pumping stations were not included, causing the highest maintenance costs of the sewer system, and data about water supply connections are known. Therefore, the direct costs for performing the public utility service of wastewater collection cannot be estimated, and therefore the price per m^3 cannot be defined.

[43] https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf
[44] Decree on the methodology for determining prices of obligatory municipal public services for environmental protection (Official Gazette of the Republic of Slovenia, no. 87/12, 109/12, 76/17 in 78/19)

3.5.9 Analyses of WWTP location

The following location scenarios were analysed for Shkodra city:

- Scenario 1 A: Bahcallek, as proposed in the previous Feasibility Study from 1997;
- Scenario 1 B: On the territory of the Commune of Berdica, south-east of Location 1A, in the vicinity of the village of Berdica e Madhe on the bank of Buna River;
- Scenario 2: On right bank of the Buna River, south of the village of Zues.

Scenarios were defined within "Water & sewerage project Shkodra feasibility study, Project concept report" (June 2006). Locations are illustrated in the figure below.

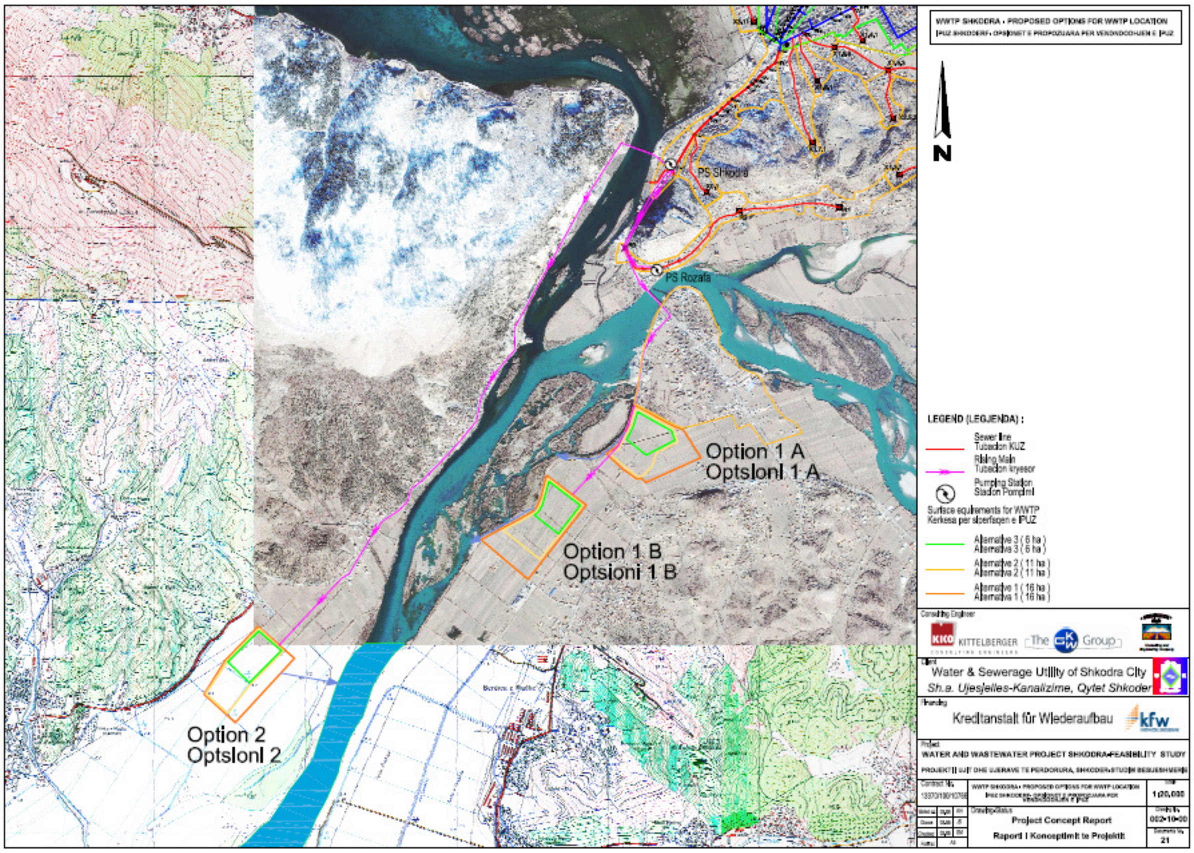

Figure 14: Options for WWTP placement (Option 1A, 1B and 2)[45]

Additional assessment for WWTP positioning was done within the scope of this project with an emphasis on flood risk assessment and is presented in the following chapters.

3.5.9.1 Flood impact assessment

Results of the hydraulic modeling are showing that the proposed locations for UWWTP: Option 1A and Option 1B are very unfavorable.

There are two reasons for that:

1) Location of both UWWTPs are located on flood discharge active floodplain area downstream Bahcallek, which was flooded and discharging also during the floods of 2006 as shown on Figure 15.

[45] Water & sewerage project Shkodra feasibility study, Project concept report" (June 2006)

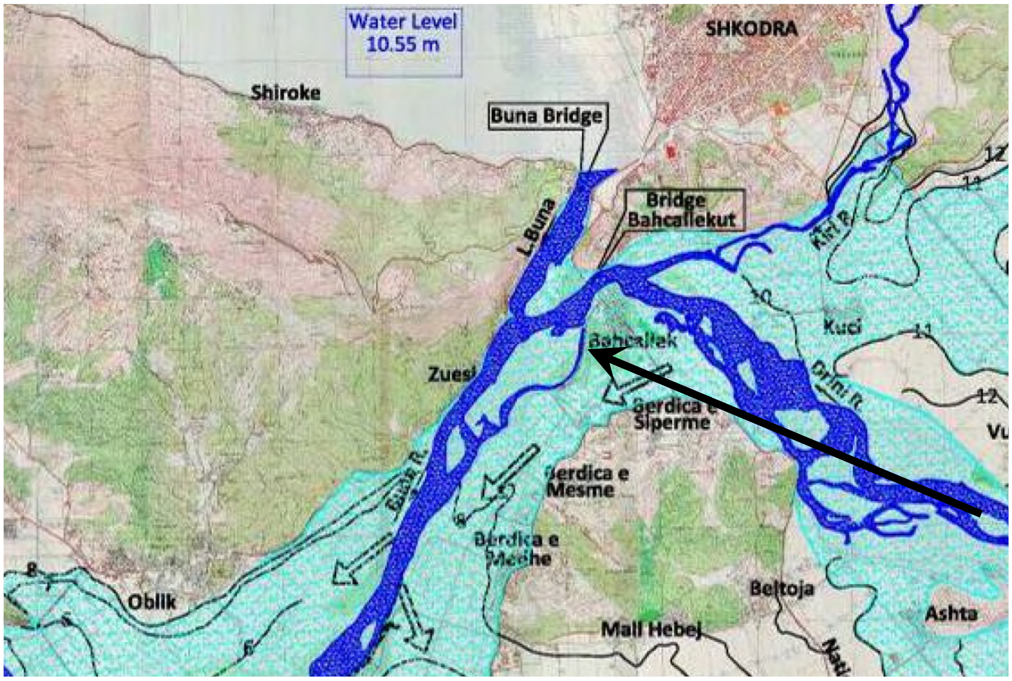

Figure 15: Map of Shkodra 2010 flood event (Mott McDonald 2012), arrows indicating main flood flows.

2) Locations are potentially hindering the future development of alternative flood routing over the road Berdice – Bahcallek.

Resulting flood depth on location of the Option 1A is between 1.0 m and 1.5 m, with velocities between 0,4 m/s and 0,6 m/s for modelled Qn100 as shown on following figures:

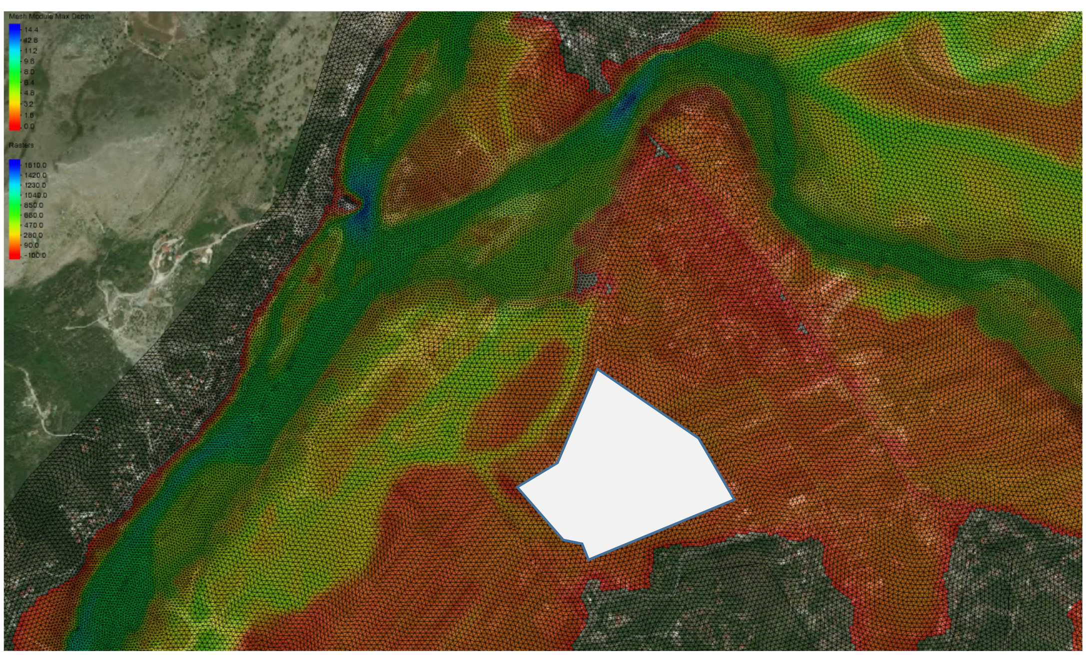
Figure 16: Modeling results flood depths Qn100 for the location of WWTP – Option 1A between 1.0 m and 1.5 m.

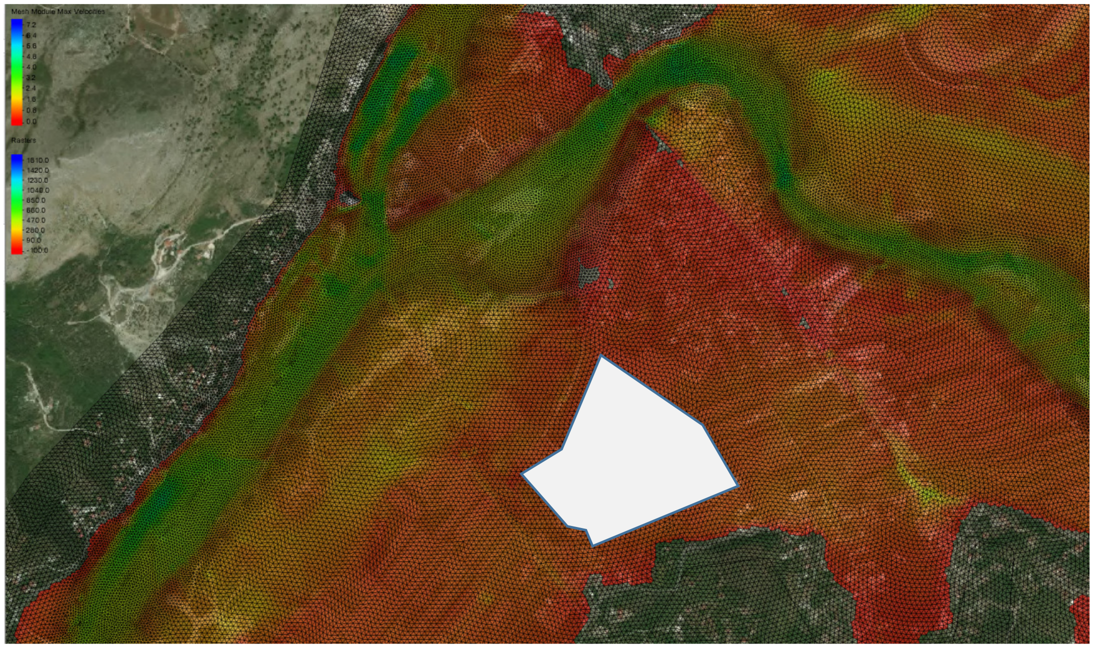

Figure 17: Modeling results water velocities for Qn100 for the location of WWTP – Option 1A between 0.4 m/s and 0.6 m/s.

Resulting flood depth on location of the Option 1B is between 0.8 m and 1.3 m, with velocities between 0,4 m/s and 0,5 m/s for modelled Qn100 as shown on following figures (Figure 18, Figure 19):

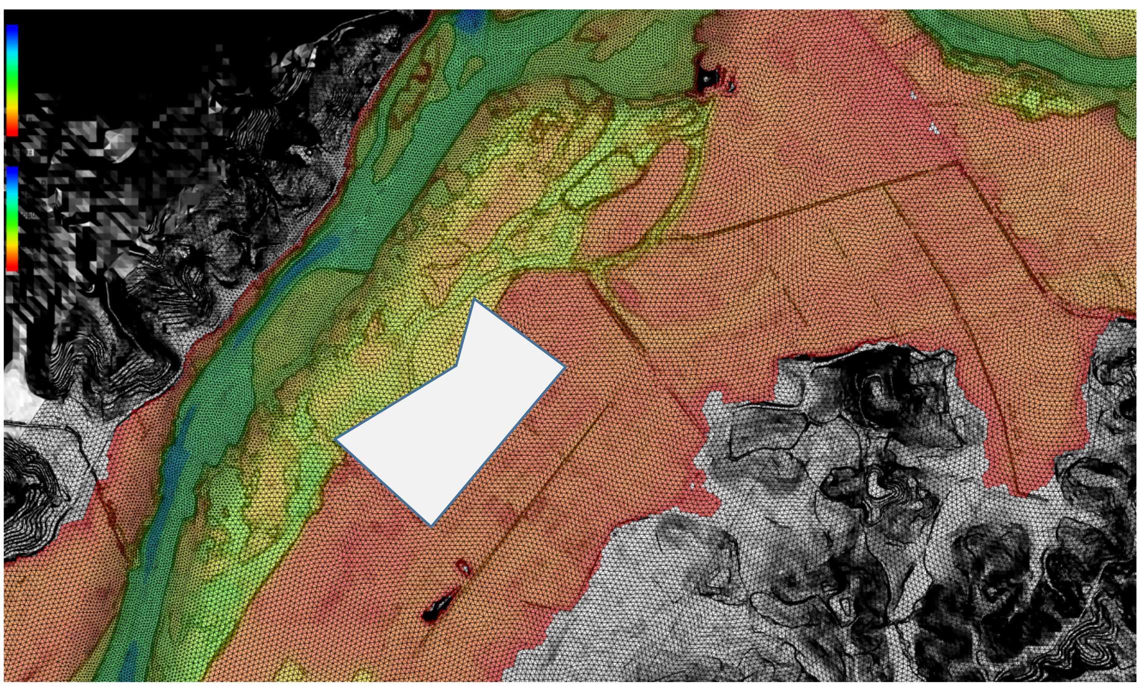

Figure 18: Modeling results flood depths Qn100 for the location of WWTP – Option 1B between 0.8 m and 1.3 m.

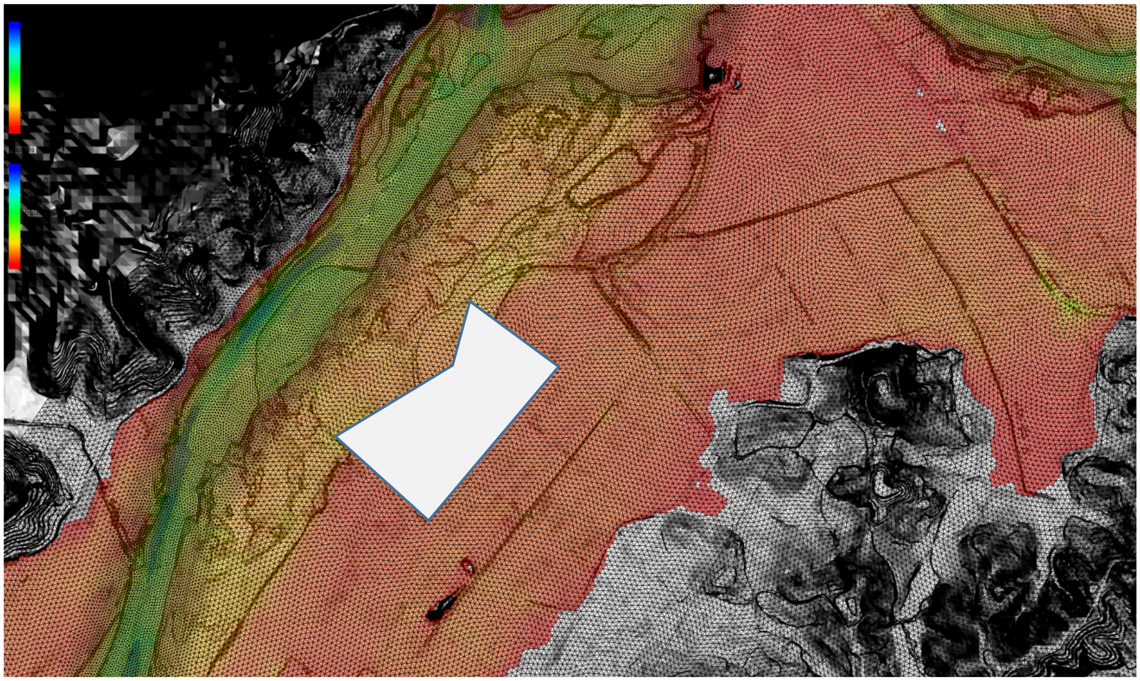

Figure 19: Modeling results flood velocities at Qn100 for the location of WWTP – Option 1B between 0.4 m/s and 0.5 m/s.

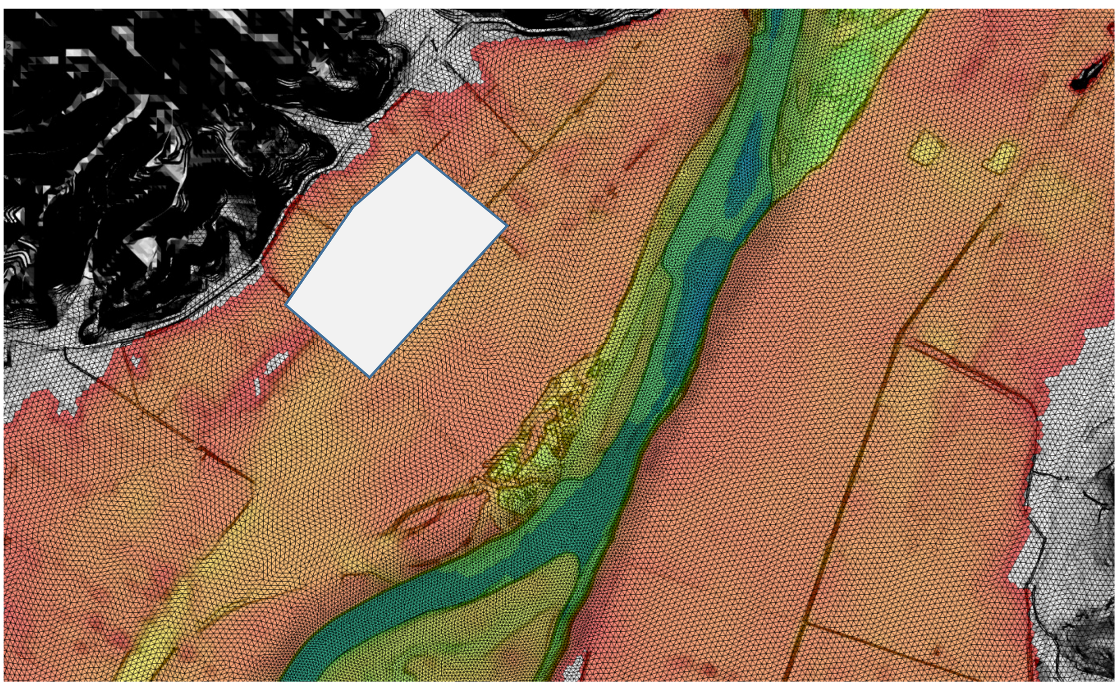

Figure 20: Modeling results flood depths Qn100 for the location of WWTP – Option 2 between 0.0 m and 1.3 m.

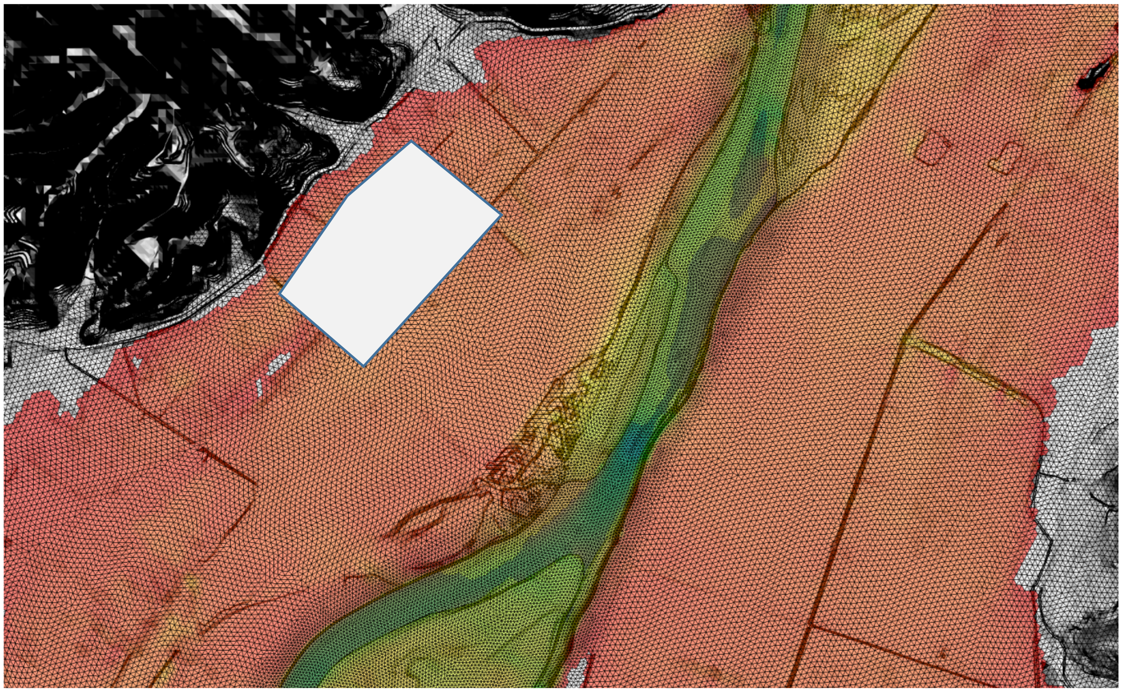

Figure 21: Modeling results flood velocities at Qn100 for the location of WWTP – Option 2 between 0.0 m/s and 0.5 m/s.

Option 2 location was inserted into the hydraulic model with the same discharge characteristics. The result shows that closing the location with an alternative 3 extent (16 ha), the increase of water depth on the flood plain is very small (FFF cm). Flood depth at the Qn100 event is between 0.1 and 1.9 meters and velocities between 0.3 and 0.6 m/s. While the comparable difference with the other two options (1A and 1B) regarding the depth and velocity is not so notable, the remaining width of the flood plain plays an important role in the favorable assessment of Option 2.

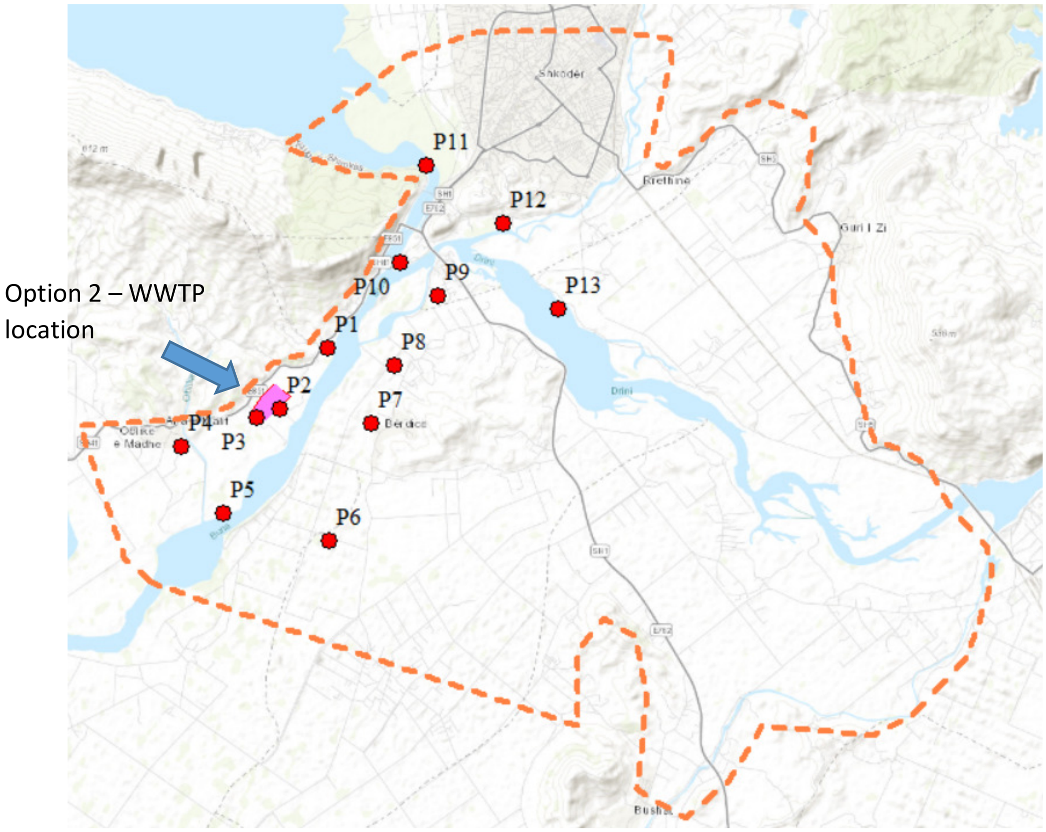

Figure 22: Selected locations where comparison between the modeling results for Qn100 – current status and Qn100 with the construction of WWTP at the location Option 2

Table 28: Qn100 with the construction of WWTP at the location Option 2

Point	Q100					
	*H existing (m.a.s.l.)	**H option 2 (m.a.s.l.)	dH (m)	V existing (m/s)	V option 2 (m/s)	dV (m/s)
P1	8.85	8.88	0.03	0.4	0.4	0.0
P2	7.97	8.00	0.03	0.7	0.8	0.1
P3	7.79	7.69	-0.10	0.5	0.2	-0.3
P4		/			/	
P5	7.09	7.09	0.00	0.7	0.7	0.0
P6	7.01	7.02	0.01	0.5	0.5	0.0
P7	8.27	8.30	0.03	0.2	0.2	0.0
P8	8.88	8.91	0.03	0.5	0.5	0.0
P9	9.48	9.50	0.02	0.3	0.3	0.0
P10	9.49	9.50	0.01	0.5	0.5	0.0
P11	9.87	9.88	0.01	1.5	1.5	0.0
P12	10.77	10.78	0.01	0.3	0.3	0.0
P13	10.97	10.98	0.01	0.9	0.9	0.0

* Without WWTP

**Impact of WWTP on flood

The results (Table *28*) show an expected small increase in the water level in the vicinity of the Option 2 -WWTP location – an increase of 3 cm. The increase is expected, but also very close to the computational error of the mathematical model. The only decrease in the point P3 is protected (shadowed) by the WWTP location and results in the decrease of the water level by 10 cm.

Option 1A and Option 1B are very unfavorable due to flooding of parcels.

3.5.9.2 Analysis of the viability regarding the positioning of WWTP Shkoder

This chapter analyses the distance of the WWTP from the nearest settlements and its impact.

Distance from the existing settlements is usually an important criterion when selecting the optimal location of the WWTP. Vicinity of the settled areas implies potential conflict with the local population for which both the construction stage and operation stage are disturbing. While the construction stage is disturbing for a shorter time (increased traffic, noise, dust, etc.), the operation of WWTP is probably more difficult to accept. It results in noise, odor, and visual disturbance, which often result in a decreased value of the real estate in the WWTP vicinity. While the main direct components of this disturbance (i.e., noise, odor) can be successfully managed (there are cases of successful WWTPs even in a very strict urban environment), the overall perception of the vicinity of the treatment plant and its psychological effects are difficult to confront.

Figure 23: Option 1 A

Analysis of the location 1A (max extent scenario): Distance from the settled houses is almost zero, some new houses were constructed in the area foreseen for the construction of the WWTP, which will be subject to the demolition in this scenario. Changes in the period 2006 (KfW) and 2019 orthophoto are notable. The location is therefore recognized as less suitable.

Figure 24: Option 1B

Analysis of the location 1B (max extent scenario): Distance from the settled houses is approx. 30 meters from the outer perimeter of the WWTP (three houses) and approx. 100 meters on the eastern rim (one house), there are no significant land-use changes in the period 2006 to 2019. The location is recognized as more suitable in comparison to location A1.

Figure 25: Option 2

Analysis of the location 2 (max extent scenario): Distance from the settled houses is approx. 200 meters from the WWTP's outer perimeter (three houses across the state road E851) and approx. 70 meters on the northern rim (non-residential building – farming), there are no significant changes in land use in the period 2006 to 2019. The location is recognized as suitable compared to both locations A1 and A2 regarding the vicinity of settled areas.

3.5.9.3 Land purchase costs

Three principal alternatives for the wastewater treatment plant's location were taken out of the KWf study from 2006 and analyzed. Figure 26 display a required area for SBR for wastewater treatment and sludge drying reed beds for sludge treatment.

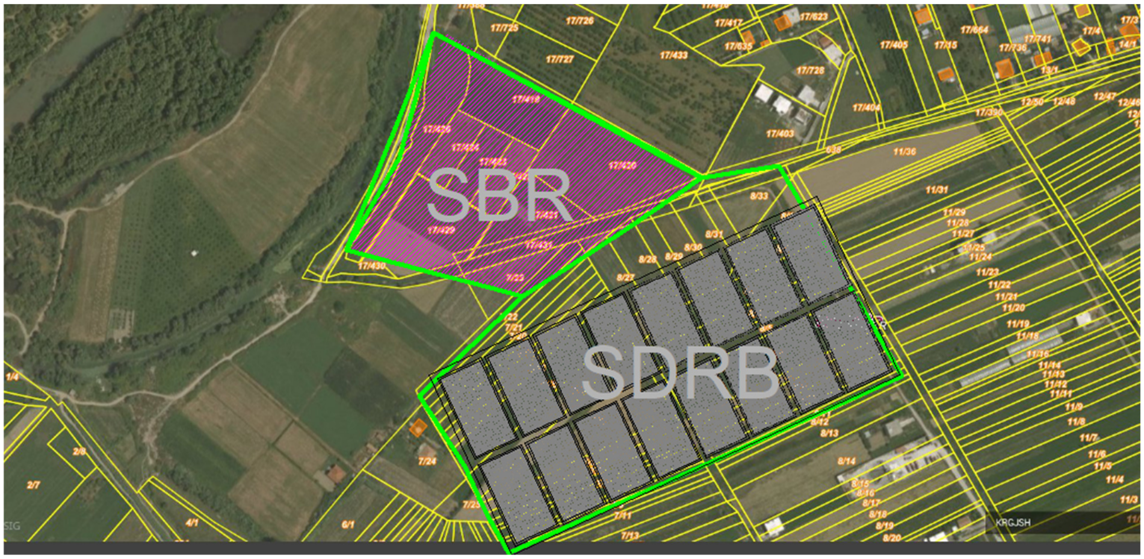

Figure 26: Location of WWTP in Bahcallek (option 1A)

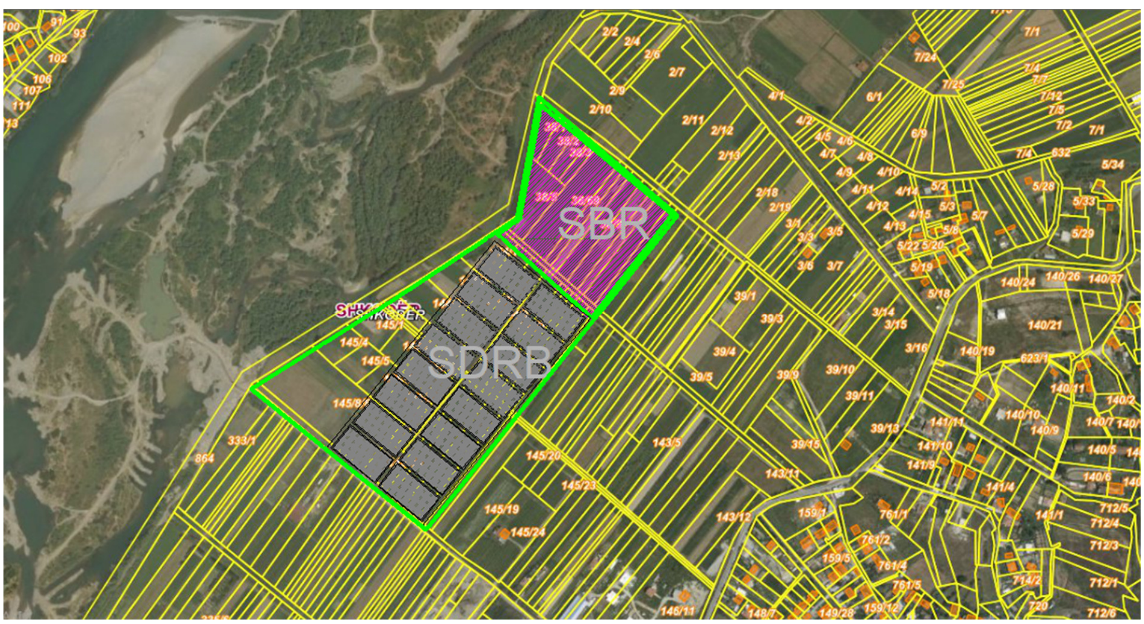

Figure 27: Location of WWTP on the territory of the Commune of Berdica, in the vicinity of the village of Berdica e Madhe on the bank of Buna River (Option 1B)

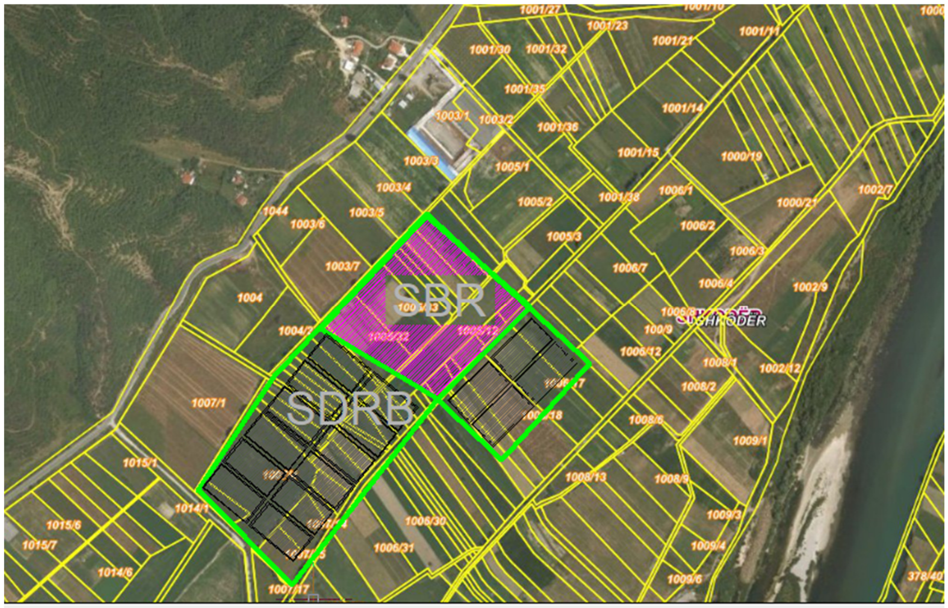

Figure 28: Location of WWTP on right bank of the Buna River, south of the village of Zues (Option 2)

The figures above show the optional location of WWTP and needed Cadastral Parcels for its implementation. In option 1A and 1B, most parcels are private, while in option 2 almost all of them are state-owned. Therefore, the land purchasing in option 2 is more feasible, due to the shorter and simpler process of obtaining land to construct WWTP.

In the table below, the official prices for land purchases are presented. The market prices are much higher, especially for options 1A and 1B.

Table 29: The reference prices for the land on sites where the WWTP is planned to be constructed[46]:

Option	Description	Town, village	Cadastral Zone Number	Price [lek/m2]	Price[47] [l€/m2]
Option 1A	Bahcallek, as proposed in the previous Feasibility Study 1997	Berdice e siperme	1159	321	2,62
Option 1B	On the territory of the Commune of Berdica, south-e ast of Location 1A, in the vicinity of the village of Berdica e	Berdice e mechme	1158	293	2,39

[46] Decision Nr. 89, dated 3.2.2016 approval of the map of the land value in the Republic of Albania

[47] https://www.bsi.si/statistika/devizni-tecaji-in-plemenite-kovine/mesecna-tecajnica-banke-slovenije-valute-za-katere-ecb-ne-objavlja-referencnih-tecajev-in-cene-plemenitih-kovin/16.12.2019

Option	Description	Town, village	Cadastral Zone Number	Price [lek/m2]	Price[47] [l€/m2]
	Madhe on the bank of Buna River				
Option 2:	On right bank of the Buna River, south of the village of Zues.	Oblike	2817	396	3,23

The required area of land for the construction of the WWTP is 6 ha. Investment costs include land purchasing costs based on the land requirement for WWTP and a unit price of (EUR/m2) according to the locations and official prices.

The land requirement for SBR is approximately 40.000 m2.

The minimal area (filter surface area) of SDRBs for effective sludge dewatering and mineralization is 54.000 m2. With included operation and maintenance paths, the total needed area for sludge drying reed beds is approximately 76.250 m2. In this option, the beds would be executed with embankments; there is also an option with a concrete wall, which requires a little bit less area (-6.750 m2).

The WWTP investment costs are summarised in the table hereafter.

Table 30: Land purchase prices for three main alternatives for the location of the wastewater treatment plant for two sludge scenarios

Location	Scenario 1: SBR + mechanical dewatering	Scenario 2: SBR + sludge drying reed beds
Option 1A	= 40.000 * 2,62 =104.800 €	(40.000 + 76.500)* 2,62=305.230
Option 1B	= 40.000 * 2,39= 95.600	= (40.000 + 76.500) * 2,39=278.435
Option 2	= 40.000 * 3,23 = 129.200	= (40.000 + 76.500) * 3,23=376.295

3.5.9.4 Summary of WWTP location analysis

Scenario analysis was used to address the placement of future WWTP into the geographical setting. The location analysis provides systematic criteria, which the consultants consider to have relevance. Option analysis of WWTP location is summarized in Table 31.

Table 31: Summery of WWTP location analysis

Assessment parameter	Option 1A	Option 1B	Option 2
Vulnerable to flooding	yes	yes	yes
Flood depth (Q100)	1,0-1,5 m	0,8-1,3 m	0,2-0,8 m

Water velocities	0,4-0,6 m/s	0,4-0,5 m/s	0,5-0,7 m/s
Distance from existing settlements	only few meters away from first houses	30 -100 meters	200 meters
Distance from existing sewage outflow (Kwf, 2006)	1.870	2.600	4.600
River crossing	Drin river crossing	Drin river crossing	Buna river crossing
Land use	agricultural land	agricultural land	agricultural land
Cadastral plots	fragmented	fragmented	fragmented
Land owners	mostly private	mostly private	mostly state
SBR land requirements (4 ha)	feasible	feasible	feasible
Sludge drying reed beds (7,6 ha)	feasible	feasible	feasible
*Land purchase (SBR + reed beds)	305.230 EUR	278.435 EUR	376.295 EUR
Option ranking:	**2**	**2**	**1**
		Elevation of flood treath for Q100:	**8,00 m.a.s.l.**

Option analysis showed that Option 2, WWTP positioning on the territory of the Commune of Berdica, south-east of Location 1A, in the vicinity of the village of Berdica e Madhe on the bank of Buna River, is the most favorable location considering the flooding threat. However, location is the farthest from the existing urbanized area of Shkodra city and requires crossing the Buna river. Investment costs increase with distance from effluent discharge. Land cost for WWTP Shkodra represents a typical administrative risk (land cost will probably be higher than predicted), causing procedural delays. The availability of land is a crucial aspect when selecting the location for WWTP Shkodra. In order to avoid lengthy procedures, it is better to place WWTP on public land.

3.5.9.5 Analysis of the effects potential flood corridor on the location of the Option 1A and 1B WWTP

We have stipulated the effective corridor with a width of 50.00 meters and excavated to 2.00 meters in the existing terrain for the analysis. The changed geometry is shown in the following figures (Figure 29, Figure 30, Figure 31).

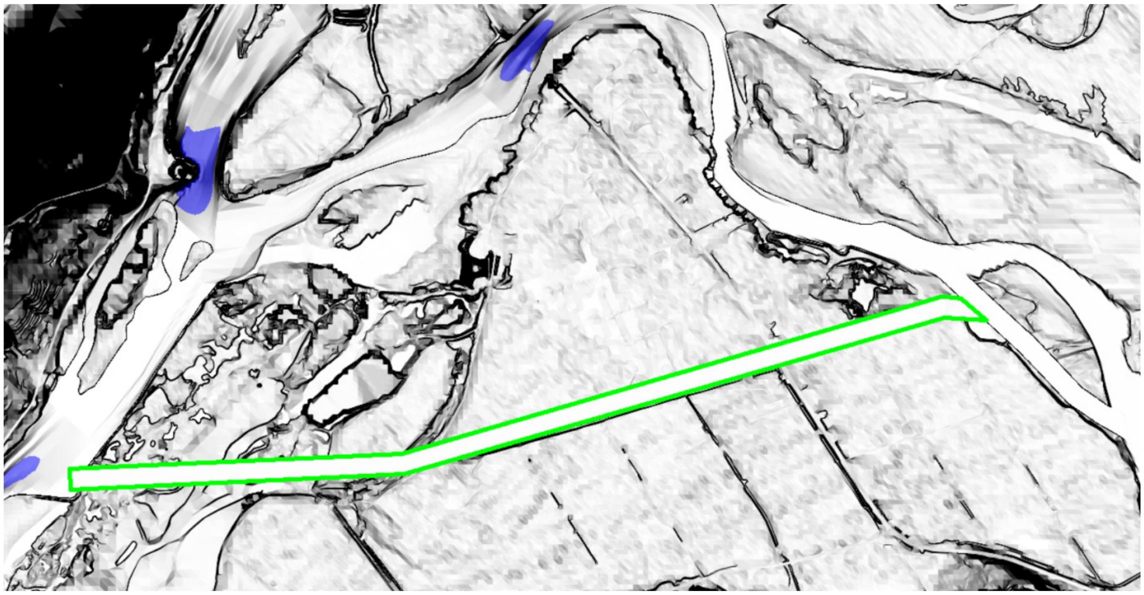

Figure 29: Analysed scenario flood mitigation measure for improved flood safety of Bahcallek bridge – additional diversion canal for flood routing.

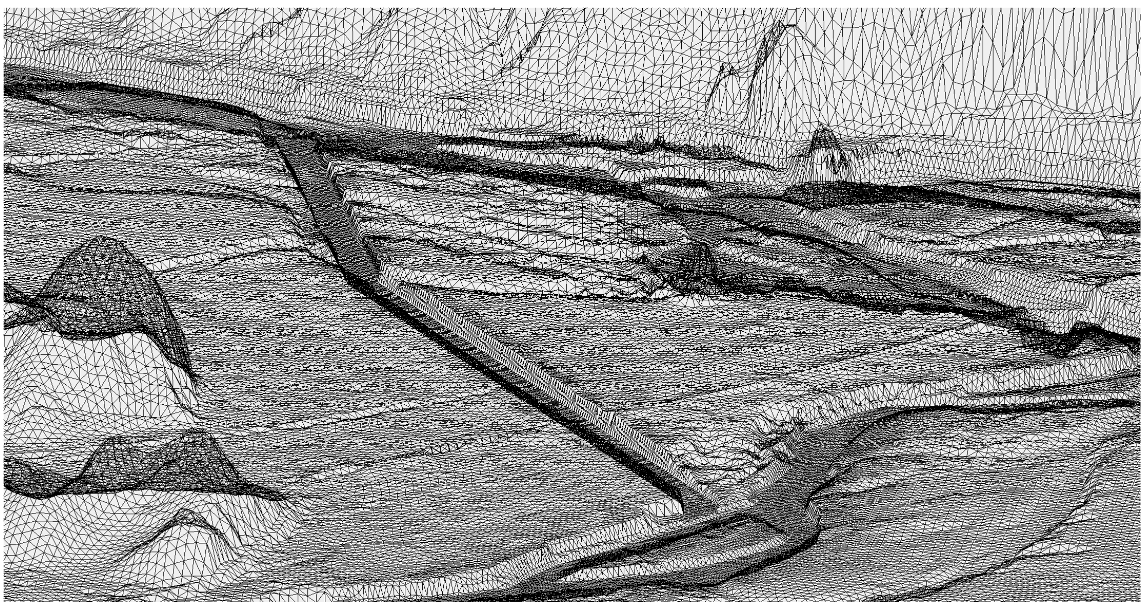

Figure 30: Changed geometry in 2-d mesh for the hydraulic analysis of the effects of the flood risk reduction measure – flood diversion canal.

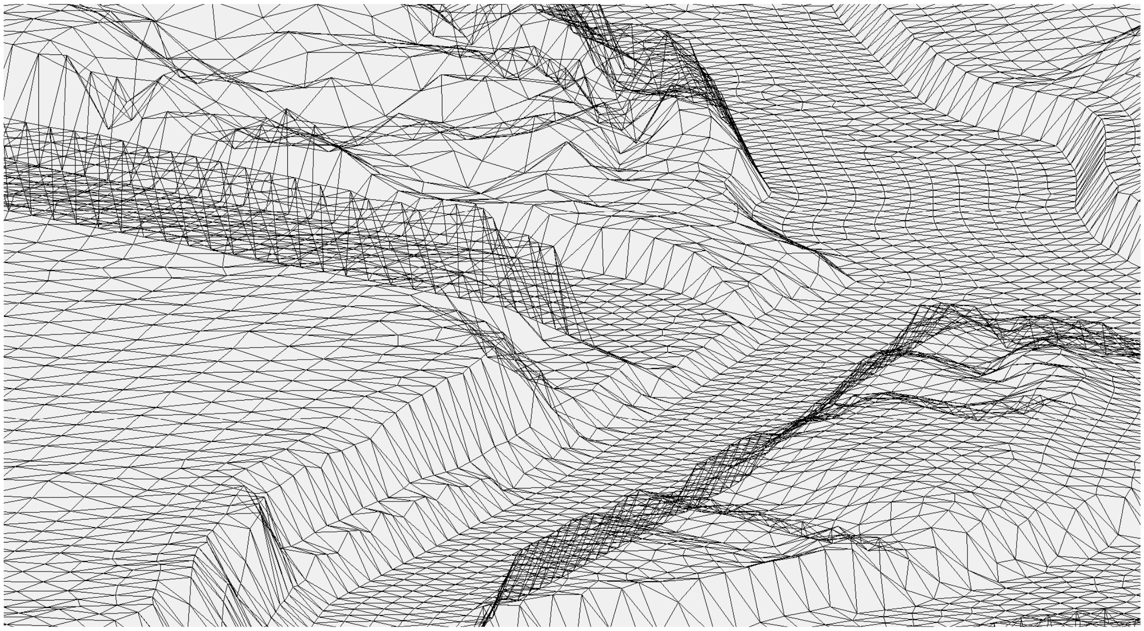

Figure 31: Changed geometry in 2-d mesh for the hydraulic analysis of the effects of the measure – intake.

The modeling results display the effect of the additional flood diversion canal would have in the change of the water level on the analyzed point (Table 32).

Table 32: Analyses of the effect of the additional flood diversion canal

Point	(m.a.s.l.) – Existing 2D model	(m.a.s.l.) – Diversion canal	Difference water level (m)
P9	9.53	9.42	-0.11
P10	9.45	9.41	-0.04
P11	9.61	9.57	-0.04
P12	11.07	10.62	-0.45
P13	11.27	10.92	-0.35

The result is confirming the hypothesis, that Option 1A and option 1B, which are limiting the development of flood diversion canal, are not a favourable choice.

3.5.10 WWTP for dispersed agglomerations surrounding the Lake Shkodra in Albania

3.5.10.1 Sewer systems surrounding the Lake Shkodra in Albania

The centralized, water-based sewer systems are applied to attain considerable public health improvement in industrialized countries' urban areas. However, the cost of such a sewer-based system is enormous and is unaffordable to many of the developing countries. Centralized systems require conventional (intensive) treatment systems, which are technologically complex and financially expensive. Many communities of the developing countries cannot afford the construction and operation of conventional treatment systems. For these communities, alternative natural treatment systems that are simple in the construction and operation, yet inexpensive and environmentally friendly, seem appropriate.[48] The current 'Western' concept of high-quality water supply and centralized high-tech wastewater treatment needs thorough re-thinking.[49] Different aspects of centralized and decentralized wastewater systems are shown in Table *33*.

Table 33: Different aspects of centralised and decentralised wastewater systems[50]

Aspect	Centralised		Decentralised	
	+	-	+	-
	• high treatment efficiency of conventional treatment systems	• high energy consumption • substantial pumping required • larger solutions less flexible	• easier to pilot new technologies • reuse of wastewater and sludge easier to manage • adaptation to local conditions possible • small (natural) treatment systems use less energy and less energy for pumping	• newly developed technologies may be less reliable • sludge handling more difficult in many small systems
	• economies of scale	• expensive for remote areas	• low population density: smaller solutions may be more economical	• economies of scale • duplication of infrastructure (e.g. labs, storage) in small systems
	• Located away from human settlements	• public resistance		• located near or within human settlements → odor, overflow, aesthetic issues

[48] United Nations Human Settlement Program: Constructed Wetlands Manual, 2008, 89 p

[49] UNEP/WHO/UN-HABITAT/WSSCC, 2002. Water Supply and Sanitation Coverage in UNEP Regional Seas: Need for Regional Wastewater Emission Targets? Section I: Regional Presentation of Data. UNEP-GPA, The Hague.

[50] https://events.development.asia/system/files/materials/2013/01/201301-centralized-vs-decentralized-sewerage-systems-which-which-you.pdf

Aspect	Centralised		Decentralised	
	+	-	+	-
				• public resistance
	• possibility of „staged development“	• large investment required • remote areas last to be connected	• smaller solutions affordable and faster to implement	
	• small number of treatment plants easier to manage • management conducted by organizations with high capacity			• many small treatment plants difficult to manage • remote unmanned facilities prone to theft and vandalism

Various investigations have been made in different countries for cases of dispersed settlements. Connection of several settlements to a standard treatment plant, or individual solutions is an important question - whether each settlement should be equipped with an individual treatment plant, or connection of several settlements to a standard treatment plant, or individual solutions. This is quite a complex topic, depending on many factors/criteria, usually subject to detailed feasibility study/variant analysis.

Collecting wastewater via sewerage systems is not valid under all circumstances. In particular, it is not valid when a “settlement”/”area” is not sufficiently concentrated, i.e., “dispersed/scattered” (“area with low population density”), meaning that the distances between houses are considerable, or if individual houses are “remote.” Various investigations have been made in different countries for cases of “remote houses.” There are many factors (topography; recipient; energy connection; accessibility; etc.) which influence the decision whether in such cases it is more economical to construct a sewer line to those house(s), or it is more economical to consider other solutions (septic tank and collection via cesspool cars; individual small treatment plants; small treatment plants, e.g. combining two or three neighboring houses; etc.). In Tables 26 and 27 in Annex 3, settlements in the catchment area of the Lake Shkodra in Shkoder Municipality and Malësi e Madhe Municipality are listed.

3.5.10.1.1 WWTP selection in the surrounding the Lake Shkodra in Albania

Appropriate WW technologies for small agglomerations:

- conventional (traditional wastewater technologies)

    - SBR (sequencing batch reactor)
    - EXTENDED AERATION
- nature-based solutions
    - CONSTRUCTED WETLANDS

3.5.10.1.2 General description of treatment technologies for agglomerations below 2.000 PE

3.5.10.1.2.1 Sequencing batch reactor (SBR)

Short description: Fill-and-draw activated sludge system where all the operations (fill, react, settle, and draw) is achieved in a single batch reactor.

In SBR, oxygen is bubbled through the wastewater to reduce biochemical oxygen demand (BOD) and chemical oxygen demand (COD), producing a high-quality effluent with a low turbidity and nitrogen levels capable of meeting effluent quality standards. The SBR accomplishes equalization, aeration, and clarification in a timed sequence in a single reactor basin. By varying the operating strategy, aerobic, anaerobic, or anoxic conditions can be achieved to encourage the growth of desirable micro-organisms.

While there are several configurations of SBRs, the basic process is similar. The installation consists of one or more tanks that can be operated as plug flow or completely mixed reactors. The tanks have a “flow-through” system, with raw wastewater (influent) coming in at one end and treated water (effluent) flowing out the other. In systems with multiple tanks, while one tank is in settle/decant mode, the other is aerating and filling. In some systems, tanks contain a section known as the bio-selector, which consists of a series of walls or baffles that direct the flow either from side to side of the tank or under consecutive baffles. This helps to mix the incoming Influent and the returned activated sludge (RAS), beginning the biological digestion process before the liquor enters the central part of the tank.

There are five stages in the treatment process:

1. Fill
2. React
3. Settle
4. Decant
5. Idle

The inlet system opens, and the tank is being filled in, while mixing is provided by mechanical means (no air). This stage is also called the anoxic stage. Aeration of the mixed liquor is performed during the second stage by using fixed or floating mechanical pumps or by transferring air into fine bubble diffusers fixed to the floor of the tank. No aeration or mixing is provided in the third stage, and the settling of suspended solids starts. During the fourth stage, the outlet valve opens, and the treated supernatant liquor exits the tank.

3.5.10.1.2.2 Extended aeration

Short description: includes capabilities for aeration & mixing, settling, the return of activated sludge and solids removal with two-compartment tanks or separate tanks.

The extended aeration process is one modification of the activated sludge process that provides biological treatment to remove biodegradable organic wastes under aerobic conditions. Air may be supplied by mechanical or diffused aeration to provide the oxygen required to sustain the aerobic biological process. Mixing must be provided by aeration or mechanical means to maintain the microbial organisms in contact with the dissolved organics. The pH must also be controlled to optimize the biological process, and essential nutrients must be present to facilitate biological growth and the continuation of biological degradation.

Wastewater enters the treatment system and is typically screened immediately to remove large suspended, settled, or floating solids that could interfere with or damage equipment downstream in the process. Wastewater may then pass through a grinder to reduce large particles not captured in the screening process. If the plant requires the flow to be regulated, the effluent will flow into equalization basins that regulate peak wastewater flow rates. The wastewater then enters the aeration chamber, where is the crucial part where 90% of the treatment occurs. Aeration, the mixing of air and a liquid, is used to speed the reactions involved. Extended aeration treatment system works by providing ideal conditions for aerobic bacteria and other micro-organisms; these micro-organisms then decompose the biological contaminants in the raw sewage to form a suspended sludge. The mixed liquor then flows to a clarifier or settling chamber where most micro-organisms settle to the bottom of the clarifier, and a portion is pumped back to the incoming wastewater at the beginning of the plant. This returned material is the return activated sludge (RAS)[51].

3.5.10.1.2.3 Constructed wetland

Short description: Pre-treatment of wastewater by filtration and settling, followed by bacterial decomposition in a natural-looking lined marsh.

Constructed wetland (CW) is a natural solution for wastewater treatment (from households or industry) using plants. This is an alternative to conventional sewage systems and septic tanks. The functioning of CW is based on natural self-cleaning capacities. Basic processes occurring in the CW are adsorption, mineralization, aerobic and anaerobic degradation. The main part of the treatment process is done by bacteria living in the plants rhizosphere. Plant roots introduce oxygen into the substrate, thus creating aerobic zones. Around aerobic zones, anaerobic zones occur. Within this mosaic of aerobic and anaerobic zones, organic matter degradation and incorporation of wastewater into microbial mass occurs. The presence of oxygen determines bio-degradation processes (nitrification, denitrification). Plant roots also play an essential role as carriers of microorganisms, which digest wastewater to more simple compounds incorporated into plant biomass.

Possible variants of a constructed wetland:

- Constructed wetland with vertical flow;
- Constructed wetland with horizontal flow;
- Constructed wetland with vertical and horizontal flow.

Typically, a constructed wetland functions with no machine and electrical equipment, enabling significant energy, maintenance, and effort savings. The system consists of several beds, isolated with non-permeable foil, filled with a substrate where water flows gravitationally below the surface. Water is treated to requested purification standards with microorganisms and wetland plants, taking advantage of physical and chemical processes.

[51] https://www3.epa.gov/npdes/pubs/package_plant.pdf

The general description, treatment steps, and cost analysis of constructed wetland technology are presented in Annex 3.

3.5.10.1.2.4 Advantages and disadvantages

Advantages and disadvantages of different technologies for small WWTPs are presented in Table *34*.

Table 34: Advantages and disadvantages of technologies

Technology	Advantages	Disadvantages
SEQUENCING BATCH REACTOR	• High treatment efficiencies possible for BOD5, COD, TSS, N, P • High flexibility in operating conditions • Less land requirement	• Low pathogen removal • Dependence on power supply • Automation required • High maintenance requirements • High operation and maintenance costs
EXTENDED AERATION	• Plants are easy to operate • Relatively low sludge yield due to long sludge ages, can be designed to provide nitrification, and do not require a primary clarifier.	• Do not achieve denitrification or phosphorus removal without additional unit processes • Require more energy • Systems require a larger amount of space and tankage than SBR
CONSTRUCTED WETLAND	• High treatment efficiencies possible for BOD5, COD, TSS • High pathogen removal • High hydraulic and loading flexibility (appropriate for tourism areas) • Normally no electricity and machine elements are needed for their operation (if water flows gravitationally through the system) • Low costs of operation and maintenance • Landscape attractiveness (green area)	• Big land requirements (2 m2/PE) • Sometimes limited P removal • Can clog (bad selection of substrate or inappropriate construction and maintenance)

3.5.10.1.3 Concept solutions for WWTP Jubice (590 PE)

As an example of a WWTP solution for dispersed settlements surrounding Shkodra the settlement Jubice was selected. According to the "Komuna Qendër, Rrethi Malësi e Madhe", the settlement of Juice has 572 inhabitants (2011).

Detailed concept solution is elaborated in Annex 4.

Hydraulic parameters:

– Estimated capacity: 590 PE
– Daily quantity of wastewaters: V_{otp} = 88,5 m^3/d
– Maximum hourly flow: Q_{max} = 3.07 l/s

Wastewater loads:

- BOD_5: 35 kg/d
- COD: 71 kg/d
- SS : 41 kg/d
- TN: 1 kg/d
- TP: 6 kg/d

Required surface area:

- for implementation of a constructed wetland (variant 1) at least 1.500 m^2 is required.

When selecting a WWTP technology for dispersed agglomerations < 2.000 PE, different aspects should be considered:

- Technical aspects (ease of operation, suitability of technology, ease of spare parts acquisition etc.);
- Environmental aspects (risk of odor, noise, certainty of achieving targeted effluent quality);
- Financial aspect (investment costs, costs of operation and maintenance).

3.5.10.1.3.1 Technical aspects

Considering the technical aspects of device, the following comparison is made using criteria of ease of operation, suitability of technology, ease of spare parts management and required space for implementation. In Table *35*, technical aspects of variant solutions are compared.

Table 35: Technical aspects of single variant solutions

Pros/Cons	Variant 1 Constructed wetland	Variant 2 Extended aeration
Advantages	No energy and mechanical equipment are usually required for operation Energy built in plant biomass may be reused (briquettes, compost, animal feed, etc.) The construction is simple and does not require large intervention to the environment Maintenance is low-cost and simple Multipurpose use of treated water is possible (watering, irrigation of green surfaces…) Fluctuation of water quantities caused by seasonal increase of population has no effect on operation	Minimal space requirement Area is accessible Independency from weather conditions Construction of a septic tank for primary treatment is not necessary Sludge stabilisation is taking place in the same reactor (aeration tank)

Pros/Cons	Variant 1 Constructed wetland	Variant 2 Extended aeration
Deficiencies	Larger need for land surface Greater sensitivity for anaerobic conditions	Huge energy consumption High level of mechanisation Sludge treatment and disposal is necessary (but not sludge stabilisation)
Rank	**1**	**2**

Variant 2 is not suitable for the treatment plant of this size (590 PE) due to the complex drive and more complicated maintenance regime.

Taking into consideration technical aspects, Variant 1 – constructed wetland, is optimal.

3.5.10.1.3.2 Environmental aspects

Considering the environmental aspects of the device, the following comparison is made using criteria of risk of odor, noise, certainty of achieving targeted effluent quality, environmental impact in case of malfunction etc. In Table *36*, environmental aspects of variant solutions are compared.

Table 36: Environmental aspects of single variant solutions

Pros/Cons	Variant 1 Constructed wetland	Variant 2 Extended aeration
Advantages	1. High treatment efficiency 2. In the decomposition, 10 - 20% of nutrients (phosphorus, nitrogen, carbon, etc.), heavy metals, pesticides and other toxic substances are taken up into plant biomass. At other devices, without additional chemicals they penetrate into the environment. 3. No odors and insects develop because the water flows underground 4. Green areas contribute to urban surroundings biological diversity – representing sustainable ecosystems for birds and amphibians 5. Device improves the landscape	1. High treatment efficiency (BOD_5), 2. Possible biological removal of N and P 3. Low risk in emergence of odors and insects, degradation
Deficiencies		1. In the case of failure and repair of mechanical part of WWTP, microbial population needs a few days to recover; wastewaters are released into the environment during this period
Rank	**1**	**2**

All analysed variants satisfy the treatment demands (achieving targeted effluent quality).

Taking into consideration environmental aspects, Variant 1 – constructed wetland, is optimal.

3.5.10.1.3.3 Financial aspects

Financial aspects of variant solutions are considered through investment costs and operation/maintenance costs. The duration of cost observation is 30 years. For calculation of net present value (NPV) of costs the discount rate of 4% is used. Amortisation is calculated as follows:

- Construction works 50 years,
- Machine works 15 years.

Table 37: Economic aspects of single variant solutions

Cost analyses	**Variant 1** **Constructed wetland**	**Variant 2** **Extended aeration**
INVESTMENT COSTS (EUR)	- 159.945,50	- 472.000,00
INVESTMENT COSTS – RANKING	**1**	**2**
COST OF OPERATION AND MAINTENANCE (EUR/year)	- 5.914,00	- 20.928,00
COST OF OPERATION AND MAINTENANCE - RANKING	**1**	**2**
NPV OF INVESTMENT COSTS	- 165.386,00	- 420.600,00
NPV OF INVESTMENT COSTS AND REPLACEMENT OF EQUIPMENT	- 74.675,00[1]	- 366.398,00[2.]
NPV OF THE REST OF THE VALUE	Not known	Not known
NPV TOTAL	- 224.060,00	- 838.398,00
NPV OF INVESTMENT AND COSTS – RANKING THE VARIANTS	**1**	**2**

1. Necessary replacement of substrate in the first bed every 10 years.

2. After 15 years, the replacement of hydro mechanical equipment is expected in the amount of minimum 60% of investment cost.

Comment: The price (market value) of plots (land) for wastewater treatment plant is not taken into account.

From Table *37* it is evident that the Constructed wetland (Variant 1) is financially favourable and has minimal energy (drive) and maintenance (yearly) costs.

Based on the analysis of costs for both variants for a period of 30 years, taking into account a 4% discount rate, it is estimated that the Variant 1 – Constructed wetland is most acceptable.

3.5.10.2 Concept solutions for Village Kaldrun, Village Koplik i Sipërm and Village Drisht

We assessed wastewater infrastructure for three agglomerations in the vicinity of the Shkodra city; whether it is preferable and more sustainable to have a centralized WWTP or to have autonomous small WWTP constructed for each one of the agglomerations. **The assessment is presented in Annex 5.**

3.5.10.3 Collection system in Shiroke in Zogaj

Simplified cost estimation of 1 m of sewerage amounts to approximately 250 EUR. This estimation should facilitate the decision. Generally, a long sewerage system that connects villages or cities to one central WWTP is more expensive than building a smaller WWTP for separate villages.

In the case of settlements Shiroke and Zogaj it is questionable whether settlement Zogaj should be equipped with an individual treatment plant or rather connected to the existing treatment plant in Shiroke. This topic was part of the study's detailed analysis entitled "Water & sewerage project Shkodra feasibility study, Project concept report" (June 2006). It's content consists of the introduction, problem analysis and presentation of options, conceptual design and cost estimate for wastewater collection, water drainage and wastewater treatment, options for wastewater and waste sludge disposal and reuse, comparison of options and conceptual design for Shiroke and Zogaj recommendations for the project implementation.

The distance between settlements is more than 5,2 km. Between Buna Bridge and Shiroke, there are six individual houses. For most of these houses and restaurants, the wastewater connection – through an individual pumping station and pressure pipe to a wastewater treatment facility in Shiroke or Zogaj is not considered a suitable and economical solution. For these buildings, individual on-site solutions with improved septic tanks and complementary treatment should be adopted. An economically viable assumption is to connect remote houses to a sewerage system in case of their max. 100 m distance to a sewage collection system.

Considering the situation for the villages of Shiroke and Zogaj, a decentralized system is to be applied, at least a secondary treatment system shall be used in order to protect the Lake of Shkodra.

3.5.11 Hydrology/hydraulic model for stormwater

The objectives of these scenarios were:

1.) to assess storm events and flow quantities,
2.) to define possible retention areas,
3.) to define measures to reduce frequency and intensity of urban flooding with improved urban drainage and retention.

Inadequate handling of wastewater, together with stormwater, has serious consequences for human health, environment, and economic development. It contaminates the water supply, increases the risk of infectious diseases, and deteriorates groundwater and other local ecosystems. This is also related to stormwater management, where stormwater, directly and indirectly, impacts flood damage.

Reference framework for the stormwater management in the Shkodra city was: Water & sewerage project Shkodra feasibility study prepared by the GKW Group and KICO Kittelberger and financed by the KFW in 2006 (KICO 2006). The project is addressing in detail the issues related to wastewater collection and treatment as well as stormwater issues for the Shkodra city.

The project was and still is a reference framework for the status and objectives in the development of both services in the Shkodra city; therefore, it was important to verify this analytical document's status as per today.

Shkodra city drainage diagram is presented in Figure 32.

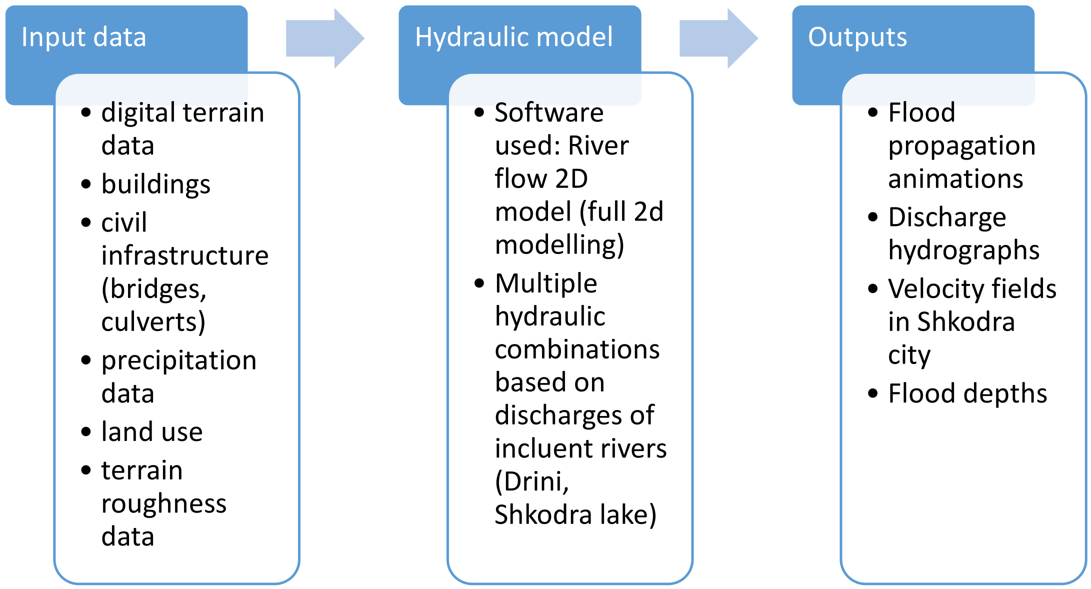

Figure 32: Shkodra city drainage diagram (hydraulic model)

3.5.11.1 Analysis of the Shkodra stormwater drainage system

A hydraulic analysis of the existing stormwater drainage system, using a computerized hydraulic model, has been made in 2006 to assess the existing system's capacity.

This calculation has been based upon the following hypothesis:

- A rainfall intensity of 180 l / s·ha (rainfall duration of 15 minutes with a return period of 2 years);
- Free discharge in the receiving waters;
- No hydraulic restriction or blockage in the system (free-flow section without deposit of solid material or solid waste);
- Run-off coefficient defined according to the current and forecasted urban development;
- Definition of catchment areas including the currently drained and areas likely to be drained to the main collector according to the topography;
- Assuming that the areas connected to the system are paved (for example, roads) and there are sufficient inlets to the system, which are operational and not blocked. (In practice this is not the case but it is essential that the main drainage system has adequate capacity for the future when the infrastructure in the city becomes fully functional).

The assessment results showed that generally most of the main drainage system has inadequate capacity for the criteria mentioned above with the undersized main stormwater sewers being in the following sub-systems:

- The lower part of sub-system 1 (Industrial Area), which discharges to the Kiri River;
- Sub-system 2 (center-east of the city), discharging into the Fermes Channel;
- Sub-system 6 (north and north-east of the city), which discharges to the Shkodra Lake.

In reality, the lack of street inlets, poor quality of roads surface (irregular surfaces), and lack of paved roads cause insufficient infiltration to the main drainage system at the time of storm events. Consequently, the main drains are not operating as they should; stormwater stays on the surface for extended periods throughout the city and gradually infiltrates into the ground in many areas.
Furthermore, most of the stormwater drainage system is wholly or partly blocked with solid material and not properly working.

The analysis shows that the status has not significantly changed since 2006 as the main drainage functionality is still provided by the surface flow in 2018. The status could be observed in the rainfall event of 23.7.2018 shown in Figure *33*.

Figure 33: Urban flooding – Shkodra – Rruga Studenti – Shesi Demokracia 23.7.2018, at 12.18

The rainfall event was predicted, but not the actual intensity. According to the bulletin on natural hazards[52] issued on 22.07.2018, the intensity should be 14-45 mm in 24 hours. According to the information on available precipitation stations from the Climate bulletin[53] we can assess that more

[52] BULETINI MBI RREZIQET NATYRORE (Bulletin on Natural Hazards) Qendra Kombëtare për Parashikimin dhe Monitorimin e Rreziqeve Natyrore, Buletini Nr. 477 / 2018, 23-07-2018
[53] Universiteti Politeknik i Tiranes (2018) Buletini Mujor Klimatik Nr. 19, Korrik 2018, ISSN 2521-831X

than 45 mm of precipitation in 90 minutes probably resulting in a 10-year return period event, but the data are uncertain.

This is confirming existing issues of Shkodra city regarding stormwater management.

The main problems with the stormwater system are as the following:

1. The primary system is incomplete and to a large extent hydraulically inadequate;
2. Many sections are not working properly because they are wholly or partially blocked with solid material and/or solid waste;
3. The secondary and tertiary system is limited in extent and capacity, completely missing in several parts of the city, including along unsurfaced roads;
4. Inlets to the system are generally too small, too far apart, and often blocked. Sand traps are missing;
5. The lower part of the stormwater drainage network operates in a surcharged condition when the Shkodra Lake level is high. The period of high level in the lake coincides with the period when rainfall is highest;
6. Roads surface is in many places uneven and irregular;
7. Extensions to the system are not always constructed in priority areas;
8. Limited equipment and resources are available for maintenance of the system;
9. The quality of construction of ongoing projects is poor.

The main consequences of the above are as follows:

a. flooding occurs in many parts of the town;

b. stormwater discharges to the sewerage system cause surcharging of the system (mainly when the sewage pumping station is not operating), deposition of solid material is increasing maintenance requirements and pumping costs (if the sewage pumping station is operational);

c. damage to roads resulting in higher maintenance requirements;

d. the economic development of the city is limited.

The observations resulted in the development of 2D model of the surface flow of the Shkodra city which is recognizing some issues and guidelines for the development of the stormwater drainage system in Shkodra.

First, the 3D terrain model was developed with the Shkodra surface runoff features as shown on the following figures (Figure 34, Figure 35):

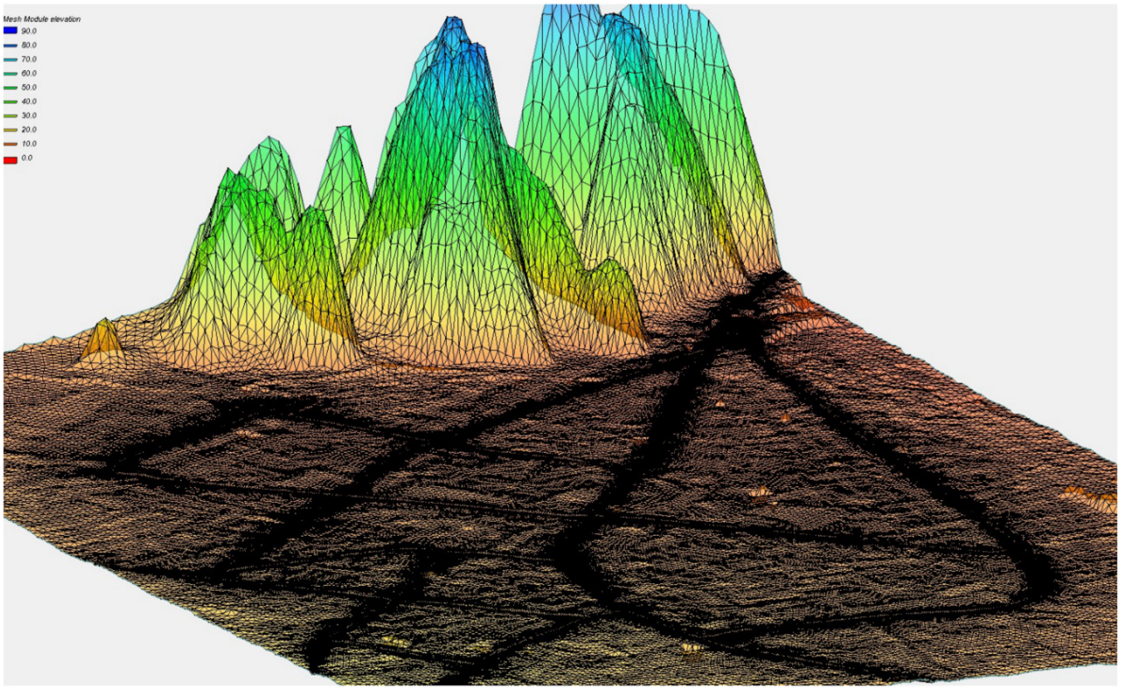

Figure 34: Digital elevation model applied for hydrological and hydraulic modeling with elevation corrections of the main runoff corridors along main streets.

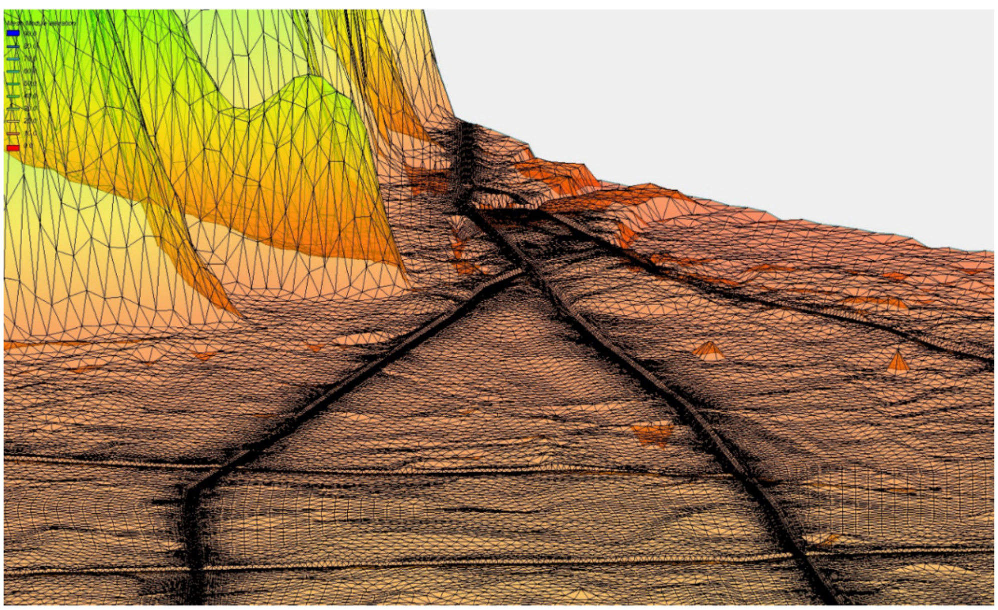

Figure 35: Digital elevation model with elevation corrections of the main runoff corridors along main streets.

In this way, the finite element mesh was developed for the dynamic calculation of hydraulic propagation as well as hydrological rainfall-runoff parameters for the entire area shown in Figure 36:

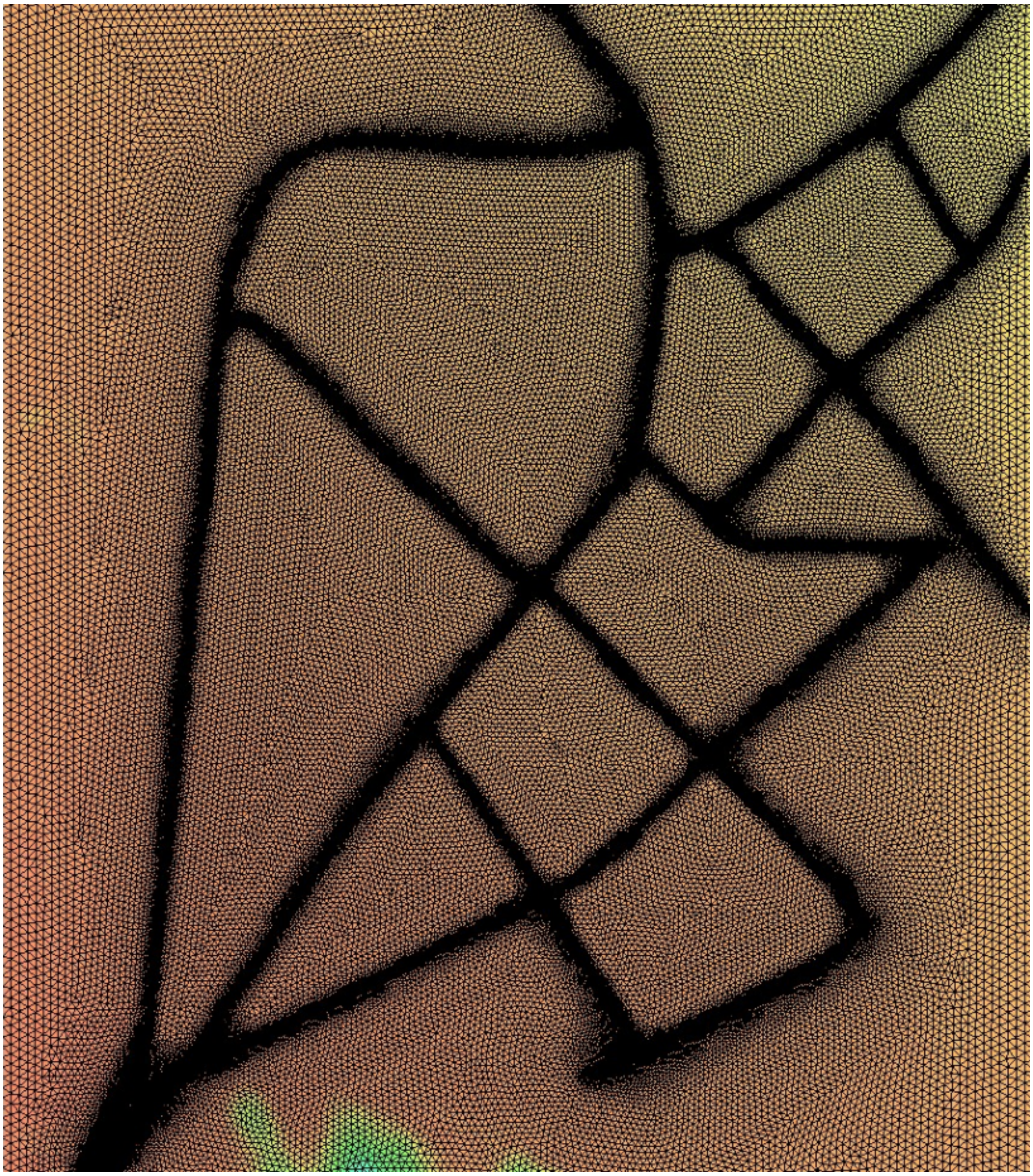

Figure 36: Finite element mesh for the modeling of Shkodra storwater runoff (145.000 cells).

The model has hydraulic characteristics defined by the Manning – Strickler roughness parameter (ng) of 0,03 for the defined roads and 0,055 for the remaining urban zone. Higher ng for the urban zone compensates for the complex runoff and propagation mechanisms without defined streams and buildings.

Runoff was defined with the SCS model of losses, where the SCS Runoff Curve Number Method (CN) value of 95 was used. This results in the runoff volume coefficient between 0,77 and 0,90, which is expected for the comparable urban zones. Higher CN value (98) would result in a higher runoff, which is probably not the Shkodra city's case.

Following precipitation intensity/return period/duration were data used (Table *38*):

Table 38: Precipitation per return period and duration in mm

Precipitation duration	Return period (years)				
	100	50	25	10	5
24 hours	175	158	140	123	105
12 hours	138	124	110	97	82
6 hours	109	98	87	77	65
2 hours	75	68	60	53	45
1 hour	59	53	47	41	35
30 min	46	41	37	32	28
20 min	40	36	32	28	24
10 min	32	29	26	22	19

The data is based upon the precipitation of the Tirana hydrometeorological station, for which the consultant was able to obtain the relevant information. The return period – duration – intensity data are most reliable for Tirana hydrometeorological station having the longest observation period and similar precipitation pattern as Shkodra.

The following figures are providing the modeling results for the duration of different precipitation events. Models for the 30 minutes (Figure *37*), 60 minutes (Figure 38), 2h (Figure 39), 6 h (*Figure 40*), and 12 hour (Figure 41) – events were deployed for return periods of 10 years, 100 years and 500 years. The return period of 500 years was extrapolated based on technical practice for the catchments smaller than 100 km2, with a factor of 1.4.

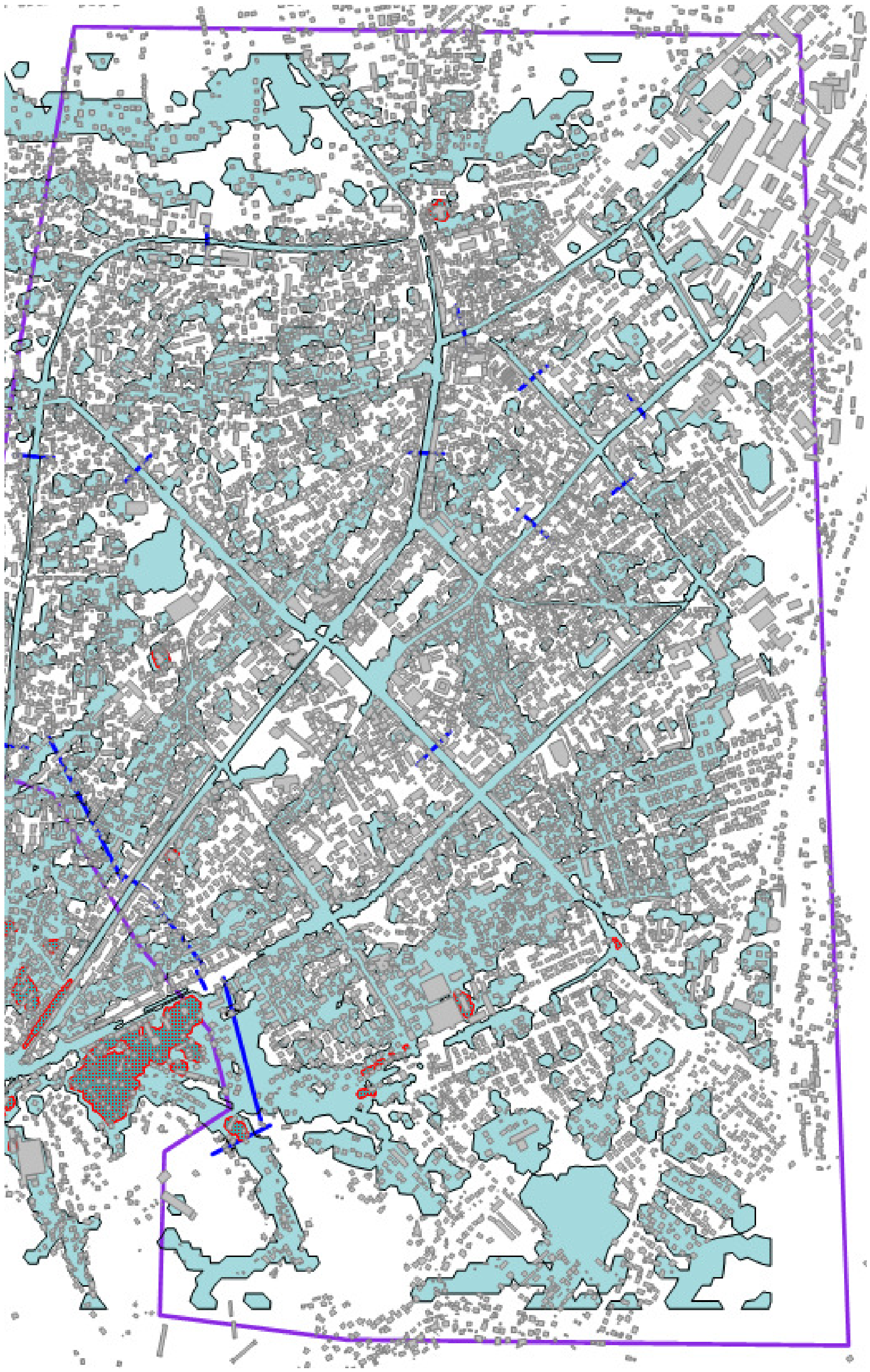

Figure 37: Computed urban flooding extend, precipitation duration 30 minutes, return period 100 years.

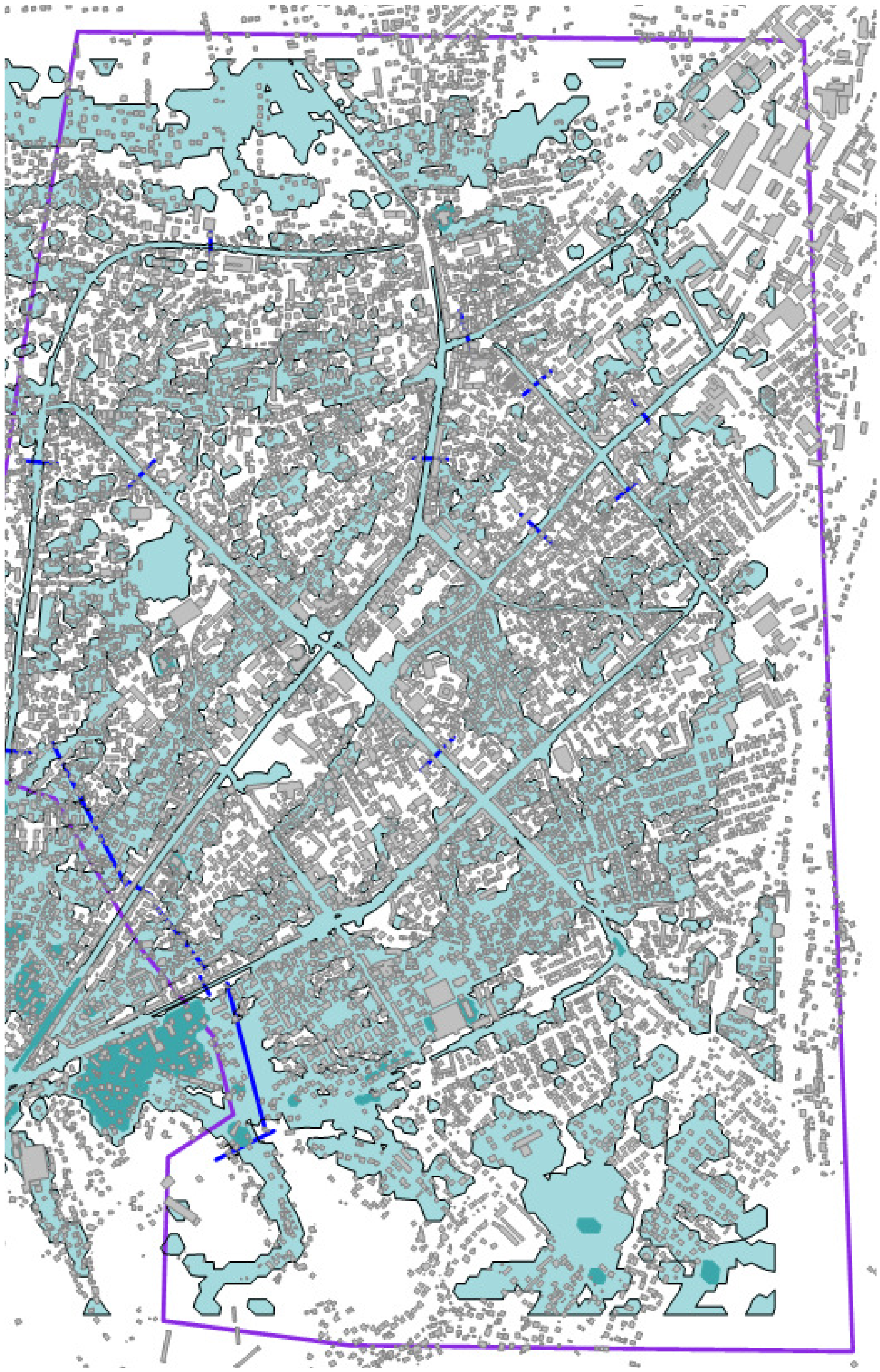

Figure 38: Urban flooding extend, precipitation duration 60 minutes, return period 100 years (modelled).

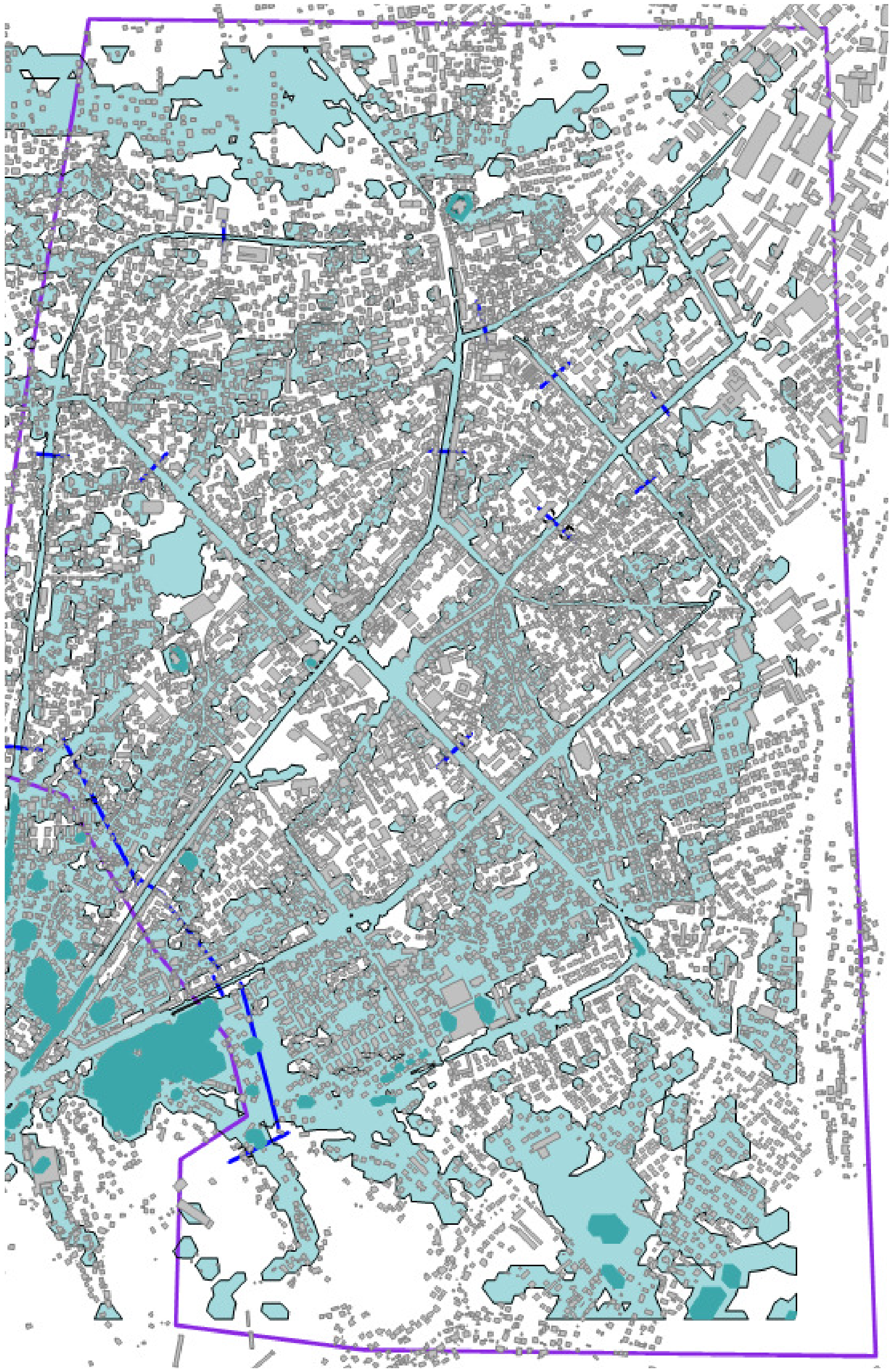

Figure 39: Urban flooding extend, precipitation duration 2 hours, return period 100 years (modelled).

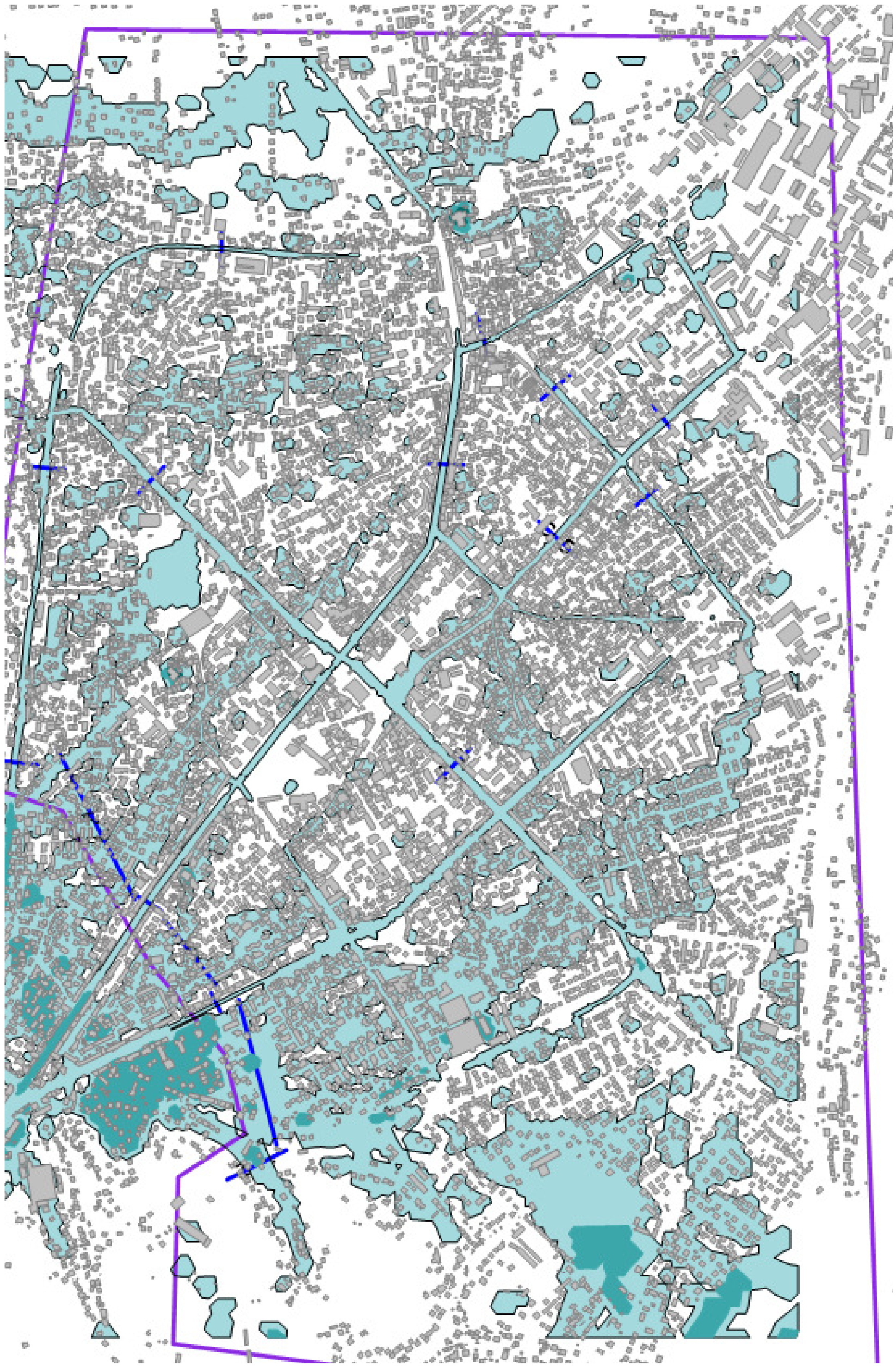

Figure 40: Urban flooding extend, precipitation duration 6 hours, return period 100 years (modelled).

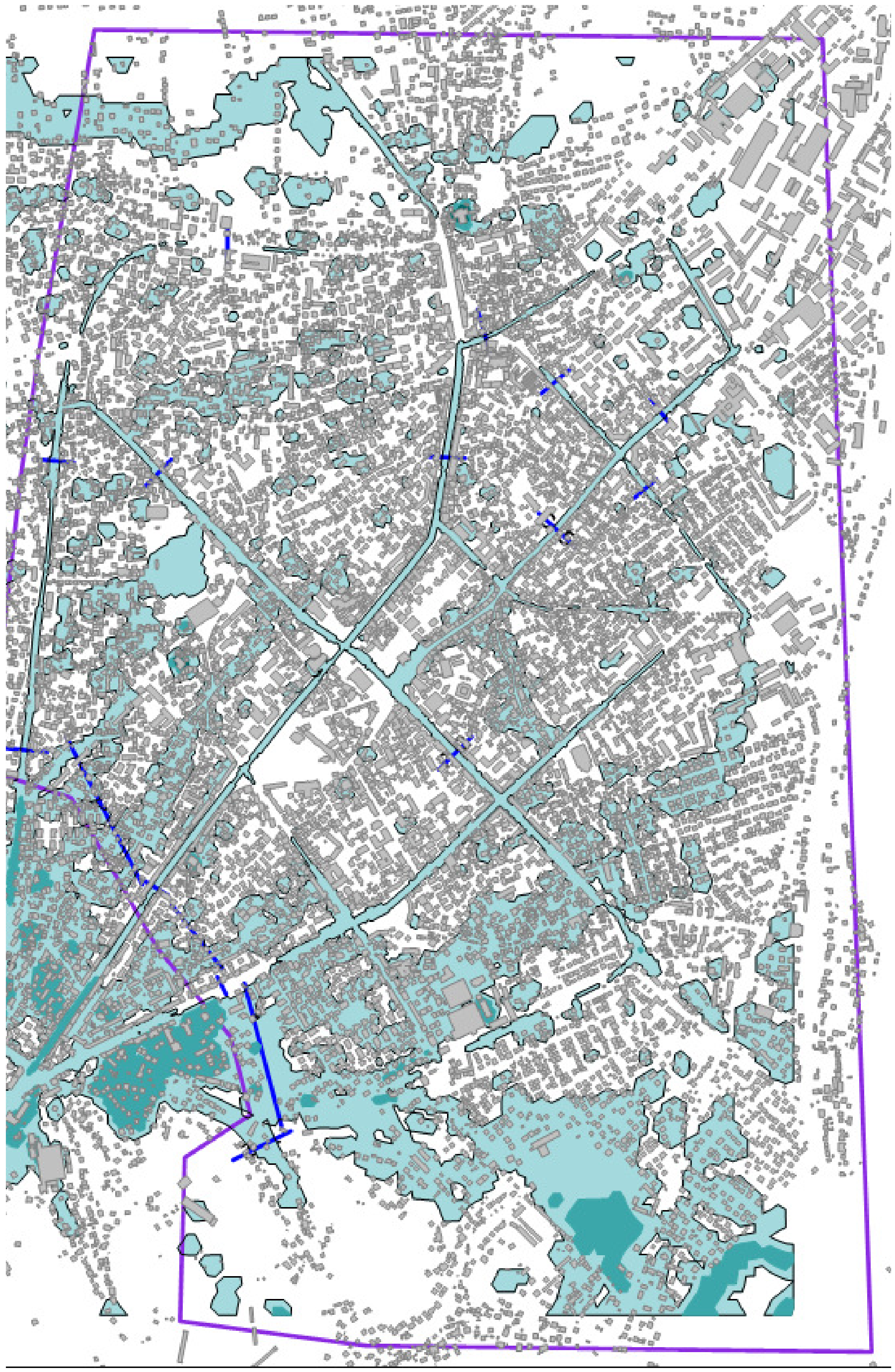

Figure 41: Urban flooding extend, precipitation duration 12 hours minutes, return period 100 years (modelled).

Figure 42: Cross sections for the analysis of cumulative discharges based upon the integrated hydrological – hydraulic model (southern part of Shkodra city).

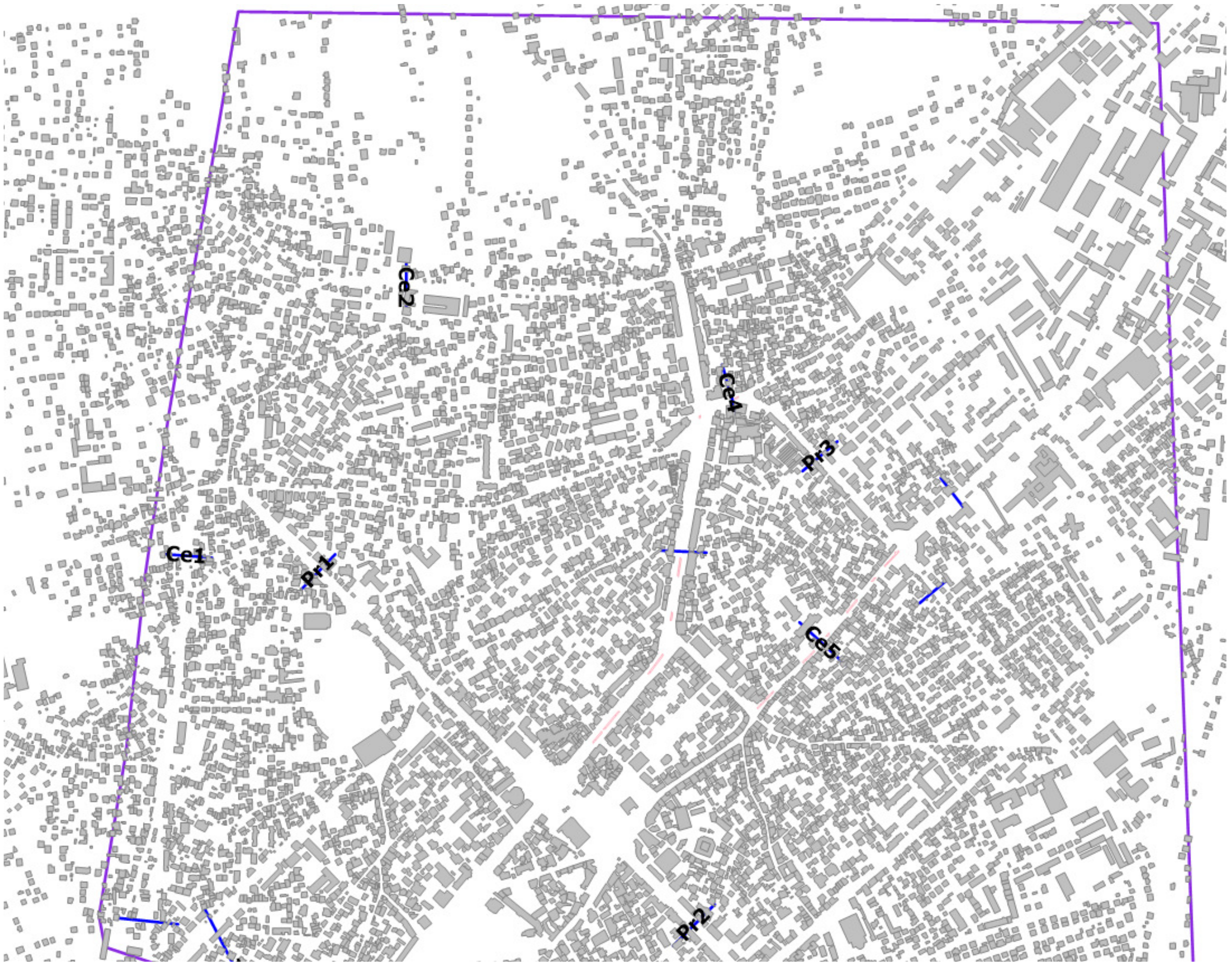

Figure 43: Cross sections for the analysis of cumulative discharges (northern part of Shkodra city).

The resulting analysis shows important findings:

1) The critical concentration period for the Shkodra city is 2 hours, as shown on the hydrogram below (Figure 44). Identified concentration period is generally matching the observed rainfall event of 23.07.2018, which held 90 minutes.

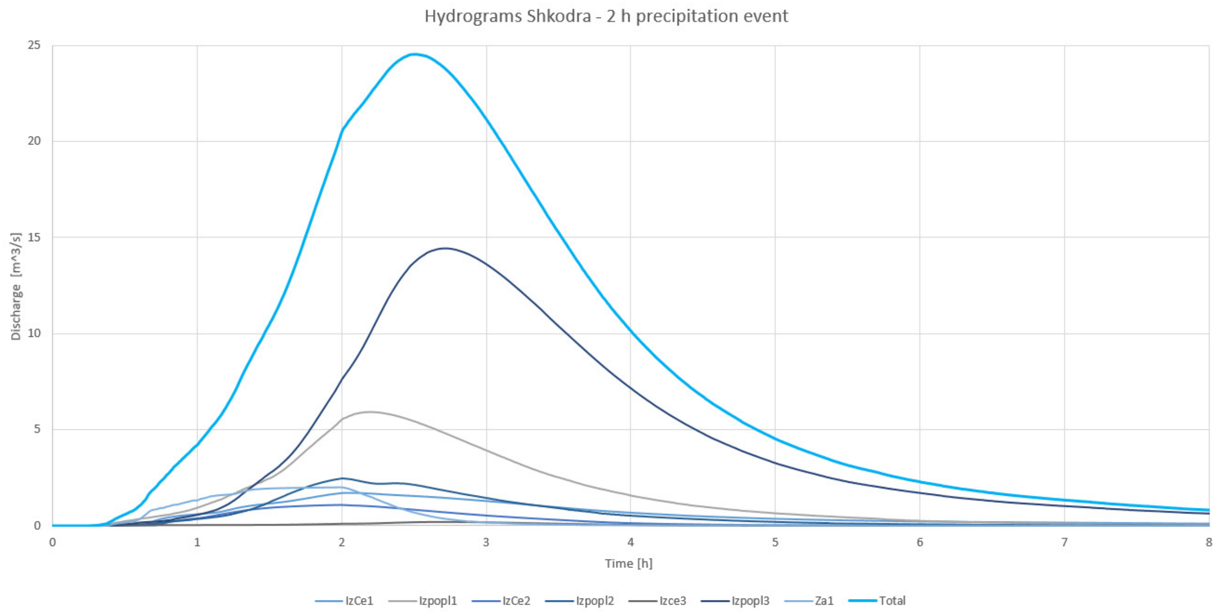

Figure 44: A 2-hour precipitation event (Qn100) for Shkodra city model.

2) The next significant result is the accumulation of rainfall in the lower parts of Shkodra city, especially next to the Rruga Dracin where the castle mountain inhibits further runoff.

In the following chapters, guidelines on improving the current situation with the identification of priority measures will be provided. Currently, the following measures (general guideline) are advised.

3.5.11.2 Proposed measures – management strategies

Proposed measures are following two main principles:

- Recognizing the characteristics of the Shkodra city topology and historical development;
- Following the sustainable drainage guidelines (SuDS).

3.5.11.2.1 Recognizing the characteristics of the Shkodra city topology and historical development

Urban drainage in Shkodra city is discharged to Lake Shkodra, impacting the recipient downstream. The submerged effluents in-pipe sedimentation cases are usually difficult to manage, as the velocity at the pipes' discharge locations is usually very low.

For stormwater management, cities usually develop a network of open canals that could also be used for other purposes. The city of Shkodra emerged and developed in the lowland area at the confluence of rivers as at important strategic location, as shown in Figure 45.

Figure 45: Fragment of an Ottoman army map, Shkodër and environs, ±1900) (S/T Collection, Leiden).

Historically the canals were always important, and some remain in operation until today, along the streets Dracin (Rruga Dracin) and Ethem Kazazi (Rruga Ethem Kazazi). Re-construction of historical canals is therefore, an important component of improved stormwater drainage.

3.5.11.2.2 Following the sustainable drainage guidelines (SuDS)

The development of sustainable urban systems is based on recognizing that the drainage systems based upon the covered (piped) urban drainage are not sustainable in several ways. In the piped systems, the water is usually removed from the environment and not available anymore for infiltration (groundwater), evaporation/transpiration, and removed from its basic ecosystem services that remain limited. On the other hand, limited conveyance capacities of piped systems and their costs (CAPEX, OPEX) make these solutions unsustainable. In the focus of observed climate changes, aging infrastructure, and intensive urban development, urban areas are pushed towards new, more sustainable urban drainage solutions.

The organized process started at the beginning of 21 century, now resulting in several guidelines, among those the SuDS approach (Sustainable Drainage Systems[54]), extending beyond the urban zones, but covering particularly the urban drainage.

To develop the improved stormwater drainage system in Shkodra, some of the sustainable solutions are proposed. Due to the low infiltration capacity and high groundwater level (vicinity of the lake), infiltration is not possible.

Applicable solutions are therefore shallow swales (grassland canals), with unique solutions for the SuDS on the floodplains (Figure 46, *Figure 47*).

[54] CIRIA C753 (2015), The SuDS Manual, Woods Ballard B, et. Al, ISBN 978-0-86017-760-0 , http://www.hrwallingford.com.cn/pdfs/news/CIRIA%20report%20C753%20The%20SuDS%20Manual-v2.pdf

Figure 46: Example of swales – providing drainage function, but also retention and vegetated corridor (CIRIA 2015).

Figure 47: Dry swale with flow control (retention function), (CIRIA 2015).

Both concepts were partially elaborated within the Shkodra Strategic Projects (Felixx 2016[55]) where historical connectivity between Kiri river and Shkodra lake was identified (Figure 48) and elaborated in the framework of water and transport functionalities.

[55] Felixx (2016) Shkodra Strategic projects June 2016, Felixx landscape architects & planners

Figure 48: Historical picture – Shkoder – view from Kiri river towards the lake.

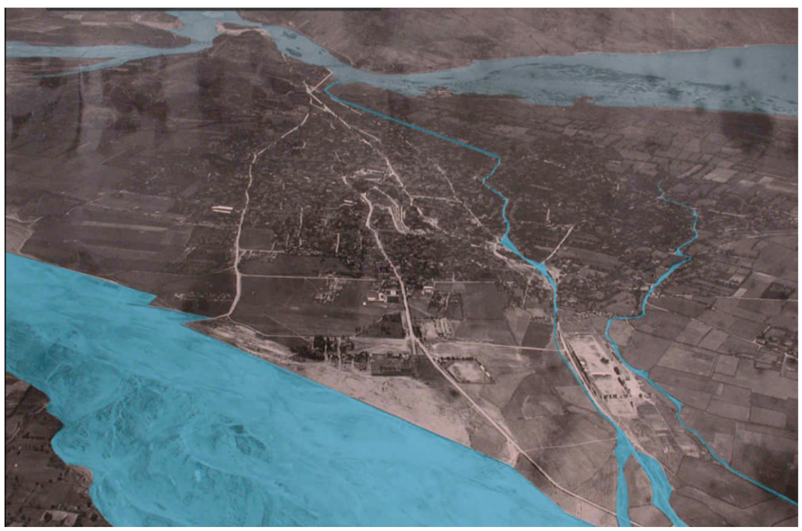

Figure 49: Proposed re-activation of surface swels (cnals) for improved urban drainage and related functions (Felixx 2016).

Figure 50: Proposed re-activation of surface swells (canals) for improved urban drainage and related functions (Felixx 2016).

Re-activation or the open canal urban drainage system for the improved stormwater drainage of the Shkoder city (Figure 49, *Figure 50*) may not be an easy solution, but it is probably the only one. Detailed analysis of potential corridors should follow, and planning and development should be engaged over the years to come.

The current situation is slightly mimicking the proposed solution, where roads are used as swells/canals. However, this situation is not acceptable from the perspective of the long-term development of the city.

3.5.11.3 Susceptibility of the WWTP site to flooding

The majority of WWTP sites are subject to thorough flooding analysis as they are usually positioned within the existing floodplains. The main reason is the fact that the sewerage systems propagate the wastewater gravitationally. As a result, the position of WWTPs is generally on the lowest level of the terrain. They are also positioned close to the recipient (river, sea), which pushes them closer to the floodplains. Floodplains are often the only remaining non urbanized areas close to the cities, available for the construction of WWTPs, which sometimes require large areas.

Potential positioning of the WWTP Shkodra was proposed already in 2006 (KICO et. Al. Water and Wastewater Project Shkodra Feasibility Study[56]), where three locations were proposed:

- Option 1A – left bank of the Drini river,
- Option 1B – left bank of the Drini river,
- Option 2 on the right bank of the Drini river.

The locations of listed options are shown on the figure below.

[56] KICO et al. (2006) Water and wastewater project Shkodra – Feasibility Study (drawing No. 002-10-00)

For this study, considering high local flood risk, the optimal locations for WWTP positioning were studied. When flooding is addressed, the studies usually analyze potential flood hazards to the designed infrastructure, on the one hand, and the changes in the flood extent and flood dynamics induced by the infrastructure. In the case of WWTP, flood effects to the WWTPs are usually low, as they can be constructed in concrete or similar flood-resistant materials and higher above the flood levels (Qn100 or higher). On the other hand, these facilities usually occupy large areas, in Shkodra WWTP from 6 ha to 16 ha, thus potentially causing significant changes in flood dynamics.

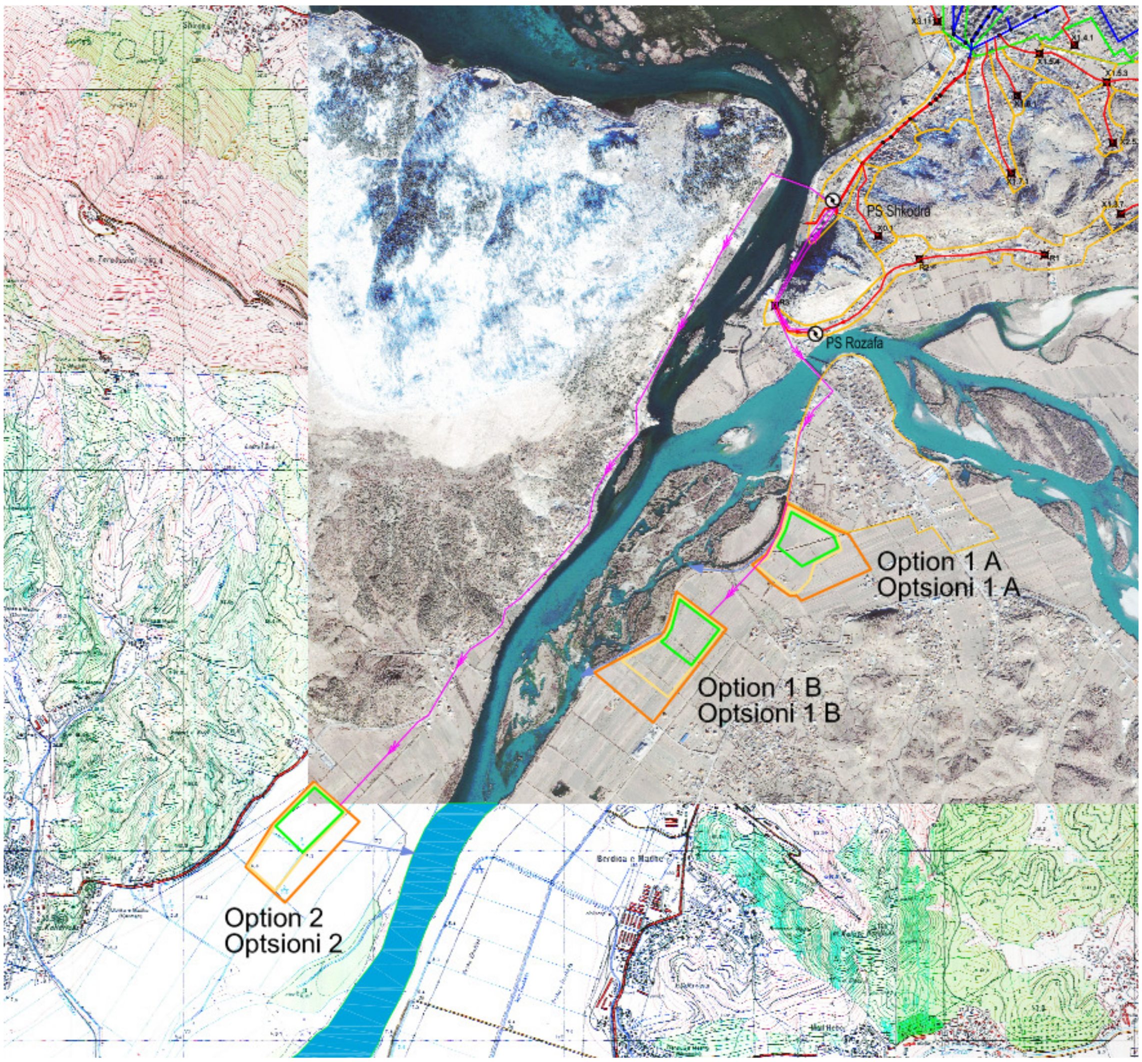

Figure 51: Water and wastewater project Shkodra, Proposed options for WWTP location (KICO 2006).

Indicative information on flood-prone zones was provided by the study from 2012: A Post-Disaster Comprehensive Flood Risk Assessment & Management Study[57], showing that all three proposed locations (Figure *51*) are in the flood-prone zones exposed to return periods of 10 years, with significant depths in the case of 100 year return period events (Figure *52*):

[57] Mott-Mc.Donald (2012) : A Post-Disaster Comprehensive Flood Risk Assessment & Management Study, Phase 2 Report:Risk Analysis of Flood Hazard & Impact March 2012

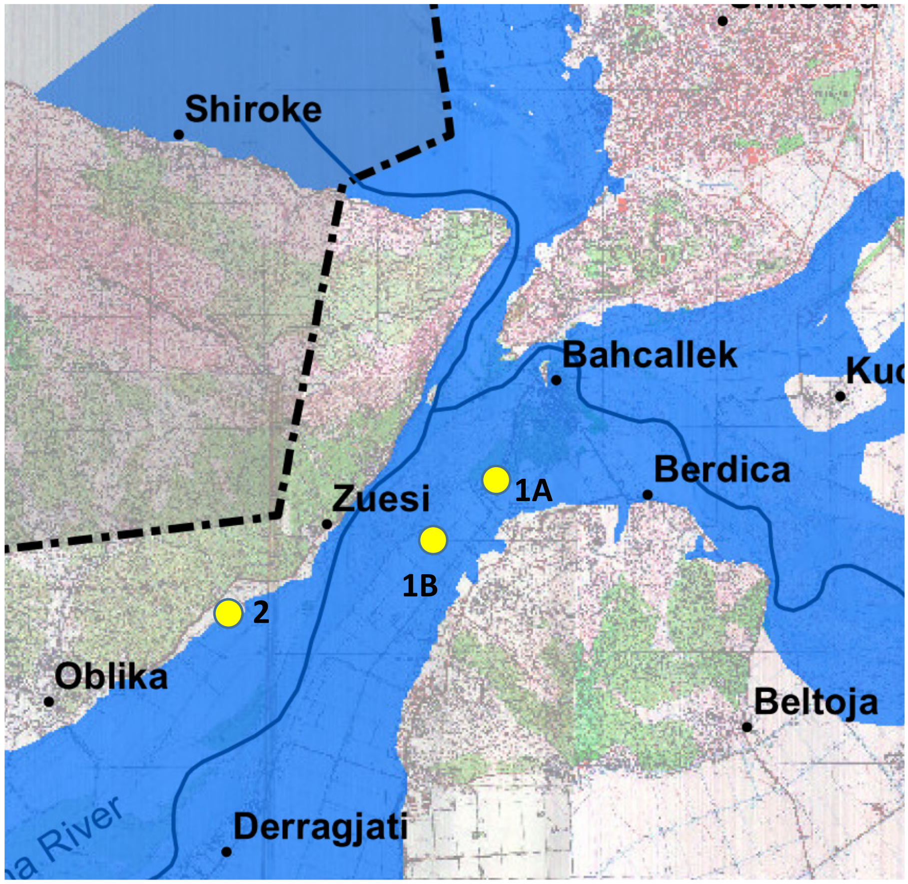

Figure 52: Modelled flood extent on the addressed area – 100-years return period event (Mott-Mc Donald 2012).

The available information from the previous study (Mott MacDonald 2012) is based upon the one-dimensional model (HEC-RAS), which has specific limitations regarding the analysis of selected measures implemented. One of the main limitations of the one-dimensional model is generally uniform water level across the analyzed cross-section. This is normally sufficient information when defining the flood extent, but on the other hand, it is of limited use when analyzing specific intervention measures, such as flood risk reduction measures or positioning of new infrastructure in the flood-prone zone.

For this purpose, the consultant has developed a new, two-dimensional model, which enables more efficient modeling of the flood phenomena and detailed analysis of the WWTP's proposed locations (Option 1A, 1B, and 2).

3.5.11.4 Description of the developed hydraulic model topology and hydrological data

o model advanced software for the two-dimensional hydraulic and hydrological analysis was used: RiverFlow2D[58]. RiverFlow2D is the most advanced two-dimensional combined hydraulic and hydrologic flexible-mesh model, offering a high-performance finite-volume engine for fast, accurate, and volume conservative computations in all rivers and estuary projects. It can tackle the most demanding flood modeling situations, including dam-break and levee-break simulations over initially dry terrain.

[58] HYDRONIA - http://www.hydronia.com/riverflow2d

The topology was developed using rescaled LIDAR DTM data from the 2015-2017 LIDAR DTM scanning campaign[59]. As the LIDAR DTM is not covering the wetted areas (rivers, lakes) due to limited reflection of these areas, the subsurface topology of the rivers and Lake Shkodra, together with the specific geometry of bridges were obtained from the Mott MacDonald (2012) one-dimensional model. Both topographies were integrated into the triangular finite element mesh with 1.330.000 finite element cells.

The model topology is demonstrated from different views on the following figures (Figure 53, Figure 54, Figure 55, Figure 56):

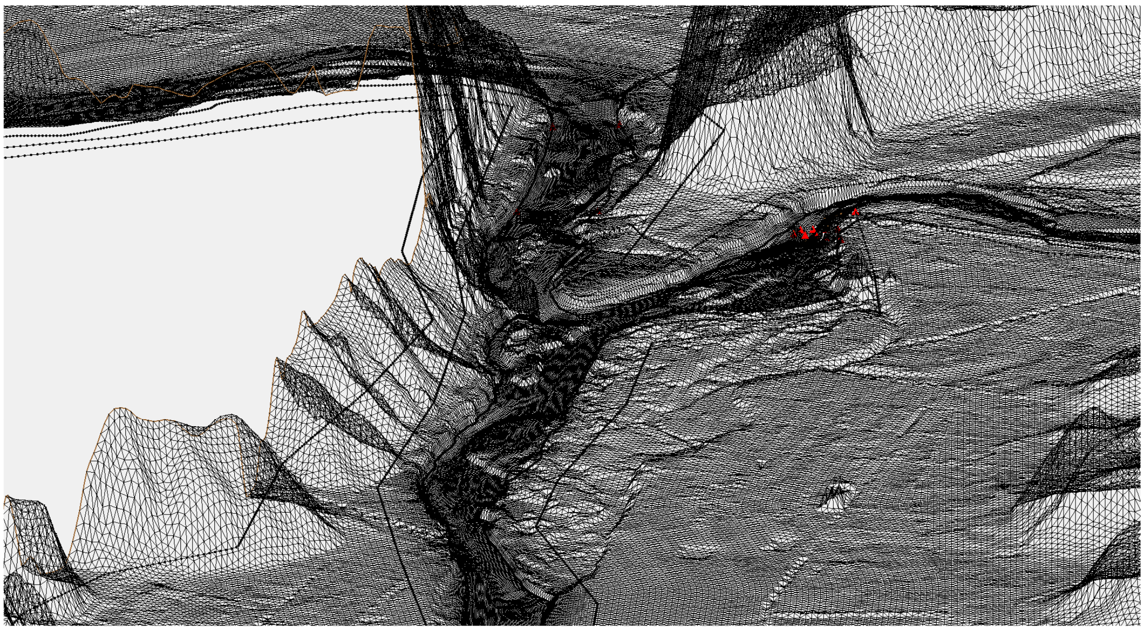

Figure 53: Finite element model mesh for flood analysis – confluence of Drin and Buna view from the south.

[59] LIDAR DATA Aerosistemi srl & HansaLuftBild gmbH
https://geoportal.asig.gov.al/geonetwork/srv/eng/catalog.search?auto=true#/metadata/3d39a80d-8a5a-4e10-a413-7159ac170dfc

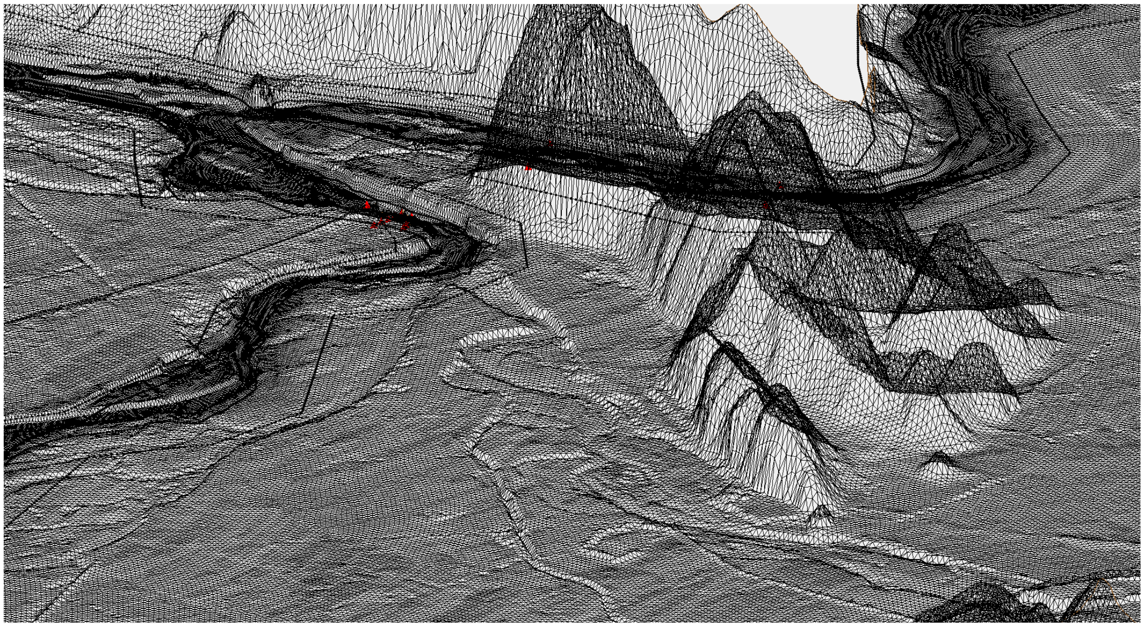

Figure 54: Finite element model mesh for flood analysis – confluence of Drin and Buna view from the east.

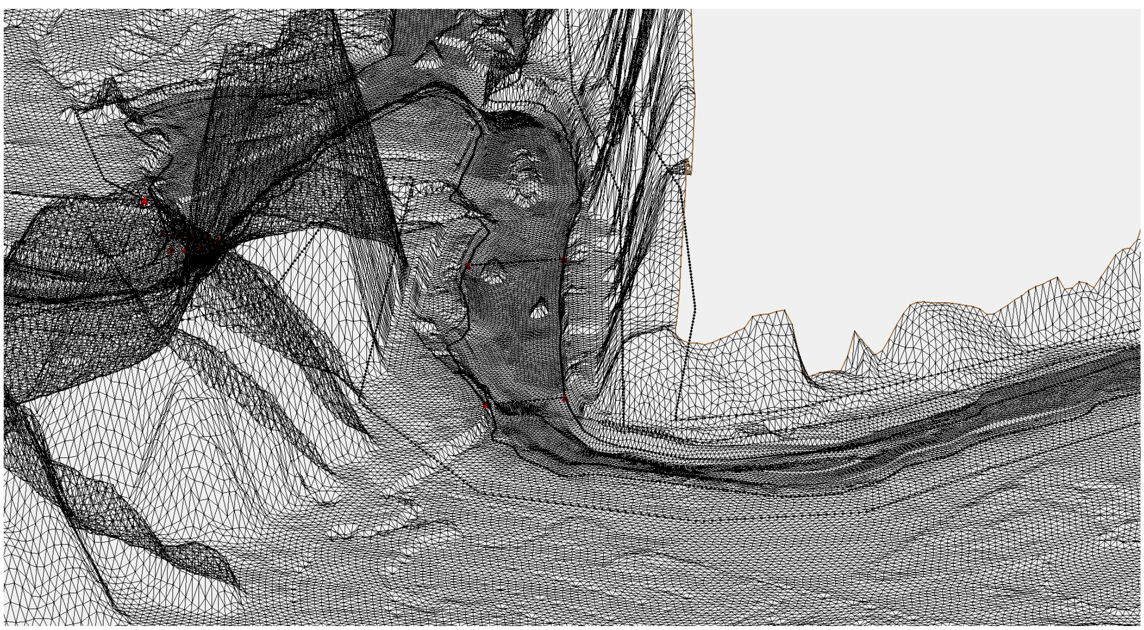

Figure 55: Finite element model mesh for flood analysis – confluence of Drin and Buna view from the north.

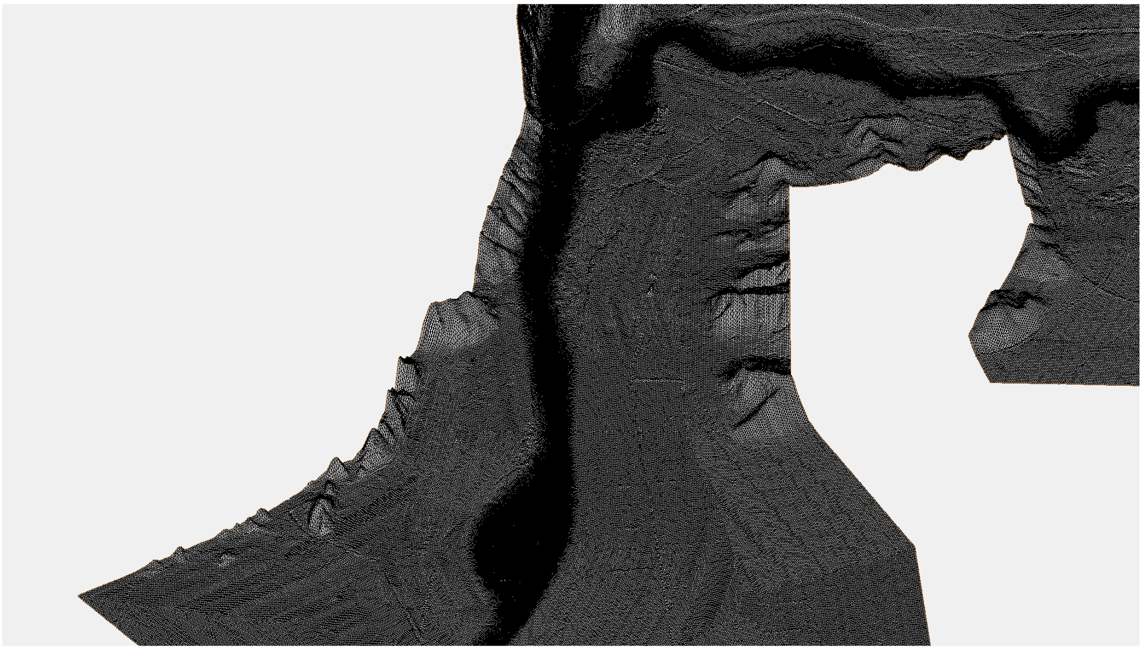

Figure 56: Finite element model mesh for flood analysis – confluence of Drin and Buna view from the south.

Hydrological conditions were also obtained from the Mott MacDonald (2012) study, which is focused on the return period analysis for both rivers and analysis of the specific flood event (2010). The analysis shows that the flood event of 2010 was close to the 100-year return period. For the analysis of WTTP positioning 100-year return, the period was modeled resulting in 3.231 m3/s as peak outflow from Vau Dejes as upstream border condition (the data in the study regarding the Qn100 differs slightly, the highest documented discharge was used in the analysis) (Table *39*):

Table 39: Peak flows for return period

Return period (years)	Peak flow (m3/s)
2	874
5	1467
10	1894
20	204
50	2834
100	**3361**
200	3627
1000	4544

As analyzed in the study, the border condition for the Buna/Shkodra lake is more complex as it is defined as a combination of level and discharge. Complementary hydrographs are applied with the maximum discharge from Shkodra lake/Buna being 1687 m3/s. The extreme discharges between the two of them occurred in 2010 with a time difference of 5 days. Downstream border condition is defined with the standard depth defined by the slope of 0,1%.

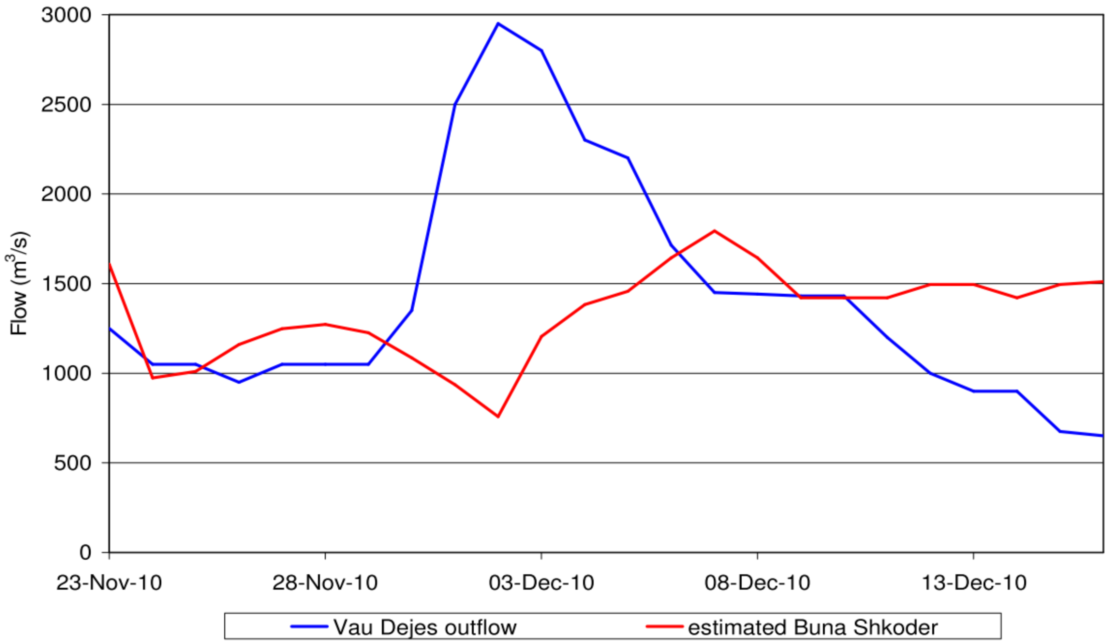

Figure 57: Drin and Buna flows in the December 2010 Flood event (Mott-Mc Donald 2012), time lag between the extreme discharges of both could be observed (5 days).

As discussed in the 2012 study, other rivers in the analyzed area (Kiri, Gjadri) have smaller catchment (smaller than 500 km2) areas and have low coincidence with Drin and Buna discharges (Figure *57*). Therefore, they also have a very low impact on overall discharges during the analyzed extreme events (Qn100). Their contribution could be estimated to approximately 3% of the total, max Drin and Buna discharge, below the uncertainty threshold of hydrological analysis.

Regarding the key calibration parameter – Manning-Strickler roughness coefficient applied, the consultant was following the one used in the Mott McDonald study. Values of ng = 0.03 for the in-bank stream areas and ng = 0.05 for other areas (floodplains) were used.

3.5.11.5 Results of hydraulic modeling

The modeling tool (approximately 75 minutes for 25 hours of modeling peak discharge) on CUDA 1070Ti GPU was carried out. In each modeling cycle, four scenarios were calculated:

- Qn100 discharge on the Drin river and complementary lower discharge on the Buna river,
- Qn100 discharge on the Buna river and complementary lower discharge on the Drin river.

The envelope of flood extent and levels was integrated from both. The modeling result is shown in Figure 58.

Figure 58: Result of the full 2D hydraulic modeling for the Drin and Buna Qn100 event (envelope).

Validation of the hydraulic modeling was performed with a comparison of the results of the hydraulic model results for the same return period event calculated in the 2012 Mott McDonald study.

Validation of the measured flood event and both models (HEC-RAS 2012 and RIVERFLOW2D 2019) shows that they are all well-calibrated. With the measured max water level at 10.00 masl during the 2010 event and 9.87 masl modeled by the HEC-RAS model, the water levels we computed with the 2D model were between 9.7 masl and 9.85 masl.

The stormwater model for Shkodra city is shown in the video (see Annex 6).

4 Action plan

General management and administration problems in Shkodra city are addressed in Annex 7. Action plan for the improvements of the wastewater collection system and stormwater management in the city of Shkodra summarizes general recommendations and not detail ones due to lack of data.

5 Annexes

5.1 Annex 1: SBR for Shkodra city

5.2 Annex 2: Sludge drying reed beds for Shkodra city

5.3 Annex 3: Constructed wetlands

5.4 Annex 4: Centralized WWTP or small WWTPs for Lake Shkodra

5.5 Annex 5: Concept solutions for WWTP Jubice (590 PE)

5.6 Annex 6: Stormwater model for Shkodra city (video)

5.7 Annex 7: Action plan