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

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

Annex 4: Cenralized WWTP or small WWTPs

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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.

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1 General

The objective of this annex is to assess the optimal case of wastewater infrastructure for three agglomerations in the vicinity of the Shkodra city. Different options are presented in the document, whether it is preferable and more sustainable (using technical and financial criteria) to have a centralized WWTP or to have small autonomous WWTP constructed for each of the agglomerations.

Three agglomerations were selected for the analysis based on their location and impact on the Shkodra Lake.

The selected agglomerations are:
• Village by the lake (Kalldrun)
• Settlement distanced from the lake (Koplik I Sipërm)
• The village very remote from the lake (Drisht)

In all pilot cases, the optimal solution for collecting and treating wastewater has been searched. A nature-based solution for treatment by constructed wetland has been studied for an autonomous variant of wastewater treatment or active sludge WWTP for centralized solution. Simplified cost estimation of 1 m of sewerage was assessed to 250 EUR to facilitate the decision. The cost of constructing 1 m of a pressure pipe is estimated at 150 EUR. Most of the sewage lines were traced along the road, but the sewerage system's construction cost does not include a reconstruction of the road.

Solutions are analyzed through investment costs for sewage and WWTP and operation/maintenance costs for the treatment plant. The investment in the sewage system is based on consultant estimation, no specific data like terrain specifics, rivers, etc., which can significantly increase investment cost were defined. Consequently, the operation/maintenance costs of the sewage system were not taken into account. Investment costs include the entire construction of the system, but the cost does not include the land purchase and elaboration of project documentation. Investment costs do not include VAT.

Generally, long sewerage systems connecting villages or cities to one central WWTP is more expensive compared to building a smaller WWTP for separate villages.

Note: When selecting a small municipal wastewater treatment plant, another type of WWTP can be selected (depending on space, funding requirements, and availability).

2 Village Kalldrun

Kalldrun (also known as Kaldrun) is a settlement in the former Qendër municipality, Shkodër County, northern Albania. At the 2015 local government reform, it became part of the municipality Malësi e Madhe.

The referenced area is situated in the northwest of Albania, northwest from the Shkodra city. The location is shown in Figure 1.

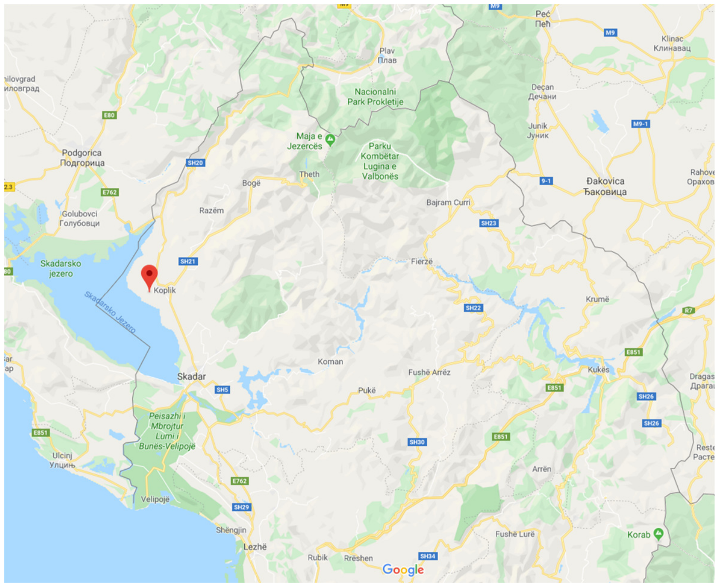

Figure 1: Location of the village Kalldrun in Albania

Design parameters:

- Population (2010): 554
- Population horizon (2045): 600 PE
- Area of influence: 1
- Distance from the lake Shkodra: 1 km

Figure 2: Location of the village Kalldrun[1]

2.1 OPTION 1 - Autonomous small WWTP

An autonomous small sewerage network and small wastewater treatment plant for village Kalldrun is predicted in this option. The solution includes the construction of 4.350 m of sewer and one wastewater treatment plant for 600 PE The recommended level of wastewater treatment is secondary. The chosen type of biological treatment plant is a constructed wetland (C.W.) with the vertical and horizontal subsurface flow.

[1] https://www.google.com/maps

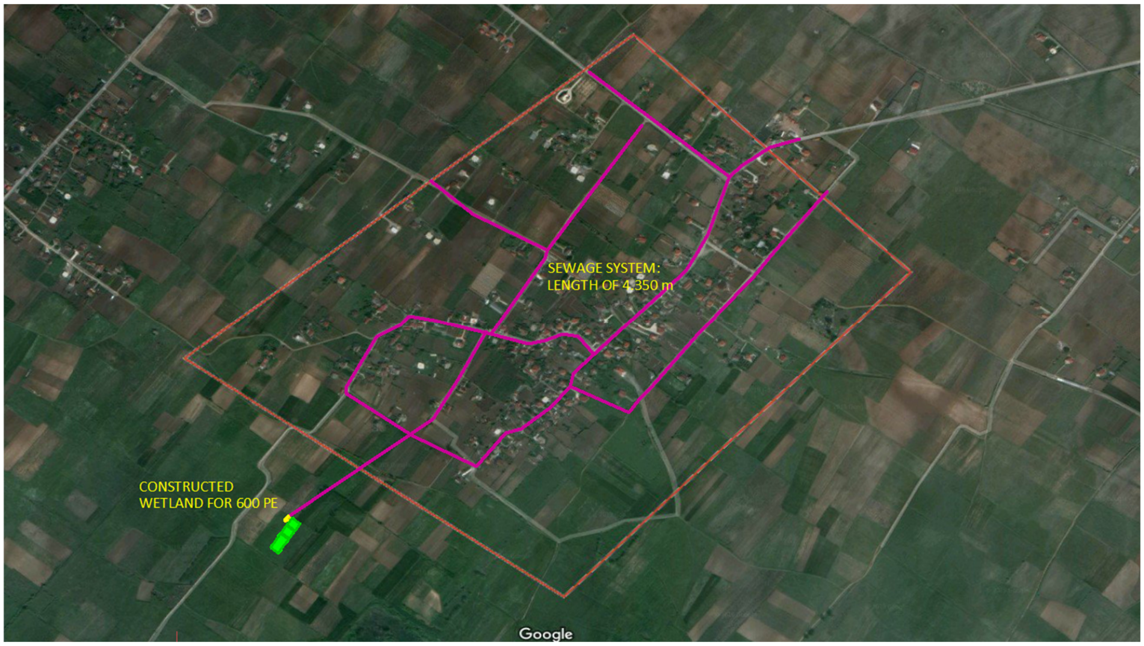

Figure 3: Scheme of the sewer system with autonomous small WWTP in the village of Kalldrun

2.1.1 *Basic dimensioning*

Hydraulic parameters:

- Estimated capacity: 600 PE
- Daily quantity of wastewaters: V = 72 m3/d
- Maximum hourly flow: Qmax = 2,5 l/s

Pollution loads:

- BOD5: 36 kg/d
- COD: 72 kg/d
- SS : 42 kg/d
- TN: 1,1 kg/d
- TP: 6,6 kg/d

CW dimensions consider the amount of time necessary for the elimination of parameters (COD, BOD5, and SS) from wastewater. Usually, over three days are required for the treatment process, under the condition that the CW is adequately maintained, and that primary treatment is executed.

Primary treatment is taking place in the sedimentation tank. Due to the correct deposition of particles, sufficient time in the sedimentation tank must be ensured to achieve a 70% suspended matter reduction. In the sedimentation tank, decomposition of organic matter takes place, ensuring a parameter decrease of COD and BOD5 by 30%.

Wastewater treatment is occurring in the following parts of a device in order of appearance:

- Primary treatment – sedimentation tank (option is also an Imhoff tank);
- Filtration beds (FB – 1, FB - 2);
- Purification bed (PB).

The dimensions of single beds are demonstrated in the table below.

Table 1: Dimension of beds

Beds	Width [m]	Length [m]	Depth* [m]	Area [m2]	Volume [m3]	Effective volume [m3]
FB - 1	17,5	20	1	350	350	105
FB - 2	17,5	20	1	350	350	105
PB	20	35	0,5	700	350	105
TOTAL				**1.400**	**1.050**	**315**

*Net depth of the substrate.

Water tightness of the beds is ensured by non-permeable foil resistant to mechanical loads, UV light, air, and root growth. The thickness and type of foil are determined by the leading designer in the main project. To protect the foil from external influences, geotextile is put above and beneath the foil. The beds are filled with the substrate of different fractions (from 0.2 – 32 mm) and different heights. Beds are usually planted with common reed (Phragmites australis) or other plants that grow well in wetlands. The density of plants should be at least 7 per m^2.

Filtration bed

Filtration bed (FB) is the first in the CW and, therefore, the most loaded. Its function is the retention (filtration) of suspended matters and others that have escaped the sedimentation tank. FB represents a sedimentation tank of nutritious and toxic matters, thus protecting the rest of the CW from being clogged. The water flow is vertical and runs underground.

Purification bed

In the purification bed (PB), an intensive degradation of waste matters is taking place. Plant activities assisted by diffusion ensure satisfactory oxygen levels, thus securing an effective nitrification process and a decrease of ammonium nitrogen. This bed's tasks are retention, accumulation, and later plant uptake of nutrients into plant and microbial biomass. The reduction of all human or animal bacteria occurs, including the reduction of pathogenic bacteria. The water flow is horizontal and runs gravitationally underground.

Recipient

Treated water from the constructed wetland should be infiltrated into the ground and not discharged directly into the Shkodra lake to protect the lake from the pollution source.

2.1.2 *Investment costs*

Investment costs for CW for treatment of wastewaters from village Kalldrun are presented in Table 2.

Table 2: Investment costs for Option 1 – autonomous small WWTP

Option 1 - autonomous small WWTP		**Costs [€]**
Sewage system	4.350 m	1.087.500,00
WWTP - Constructed wetland	600 PE	150.000,00
	TOTAL	**1.237.500,00**

2.1.3 *Operation and maintenance costs*

Operation and maintenance costs for CW for treatment of wastewaters from village Kalldrun are presented in Table 3.

Table 3: Breakdown of operation and maintenance costs for Option 1 - autonomous small WWTP

Type of cost	**Cost of operation and maintenance [EUR/year]**

Cost of sludge and waste deposition	1.250,00
Staff costs	1.400,00
Electricity	120,00
TOTAL:	**2.770,00**

Maintenance activities mostly include regular monitoring of a constructed wetland, occasional pumping of sludge from the sedimentation tank, cleaning of parts of the device with water, autumn plant cutting and landscaping.

2.2 OPTION 2 - Centralized WWTP in Koplik city

The urban district of Koplik has a sewer system, which does not cover the whole district. The remaining households continue depositing their wastewater in septic tanks. The collected untreated wastewater is discharged into a basin 1.500 m out of town and in 1.200 m distance from Lake Shkodra. The natural buffer and purification functions of the soil and groundwater passage are used before the wastewater reaches the lake (figure below).

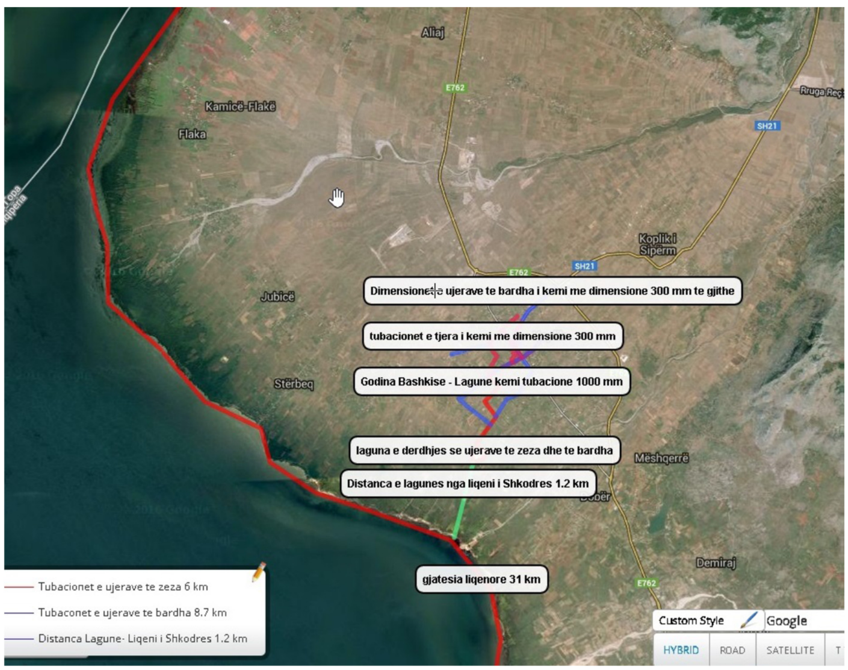

Figure 4: Existing sewerage system in Koplik city

In this option, a new wastewater treatment plant is envisaged for the Koplik city, to which the village Kalldrun is connected through the sewerage system. Firstly, the sewage is to be collected in the village Kalldrun (around 4.350 m length) and then transported by a pressure sewer system, which is estimated to be around 2.400 m, to the existing sewer system in Koplik city. A new wastewater treatment plant should be positioned at the end of the network.

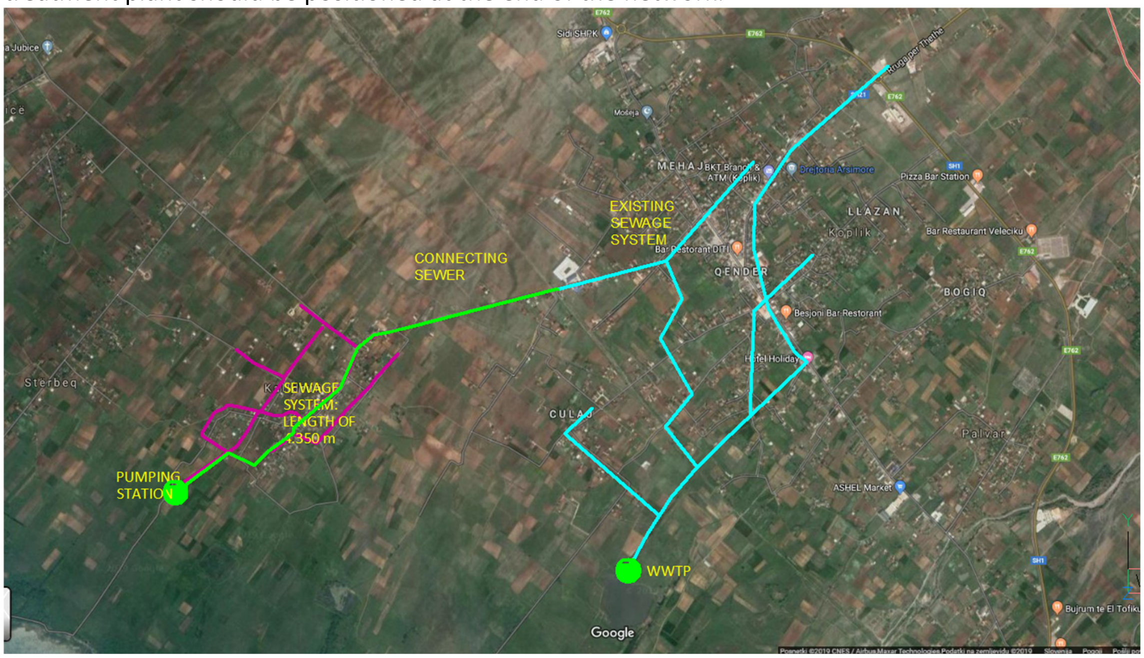

Figure 5: Scheme of the sewer system with WWTP in the village of Koplik

2.2.1 Investment costs

Investment costs to connect village Kalldrun to WWTP in Koplik city are presented in Table 4.

Table 4: Investment costs for Option 2 – centralized WWTP in Koplik city

Option 2 - centralized WWTP in Koplik city		**Costs [€]**
Sewage system	4.350 m	1.087.500,00
At least one pumping station	1 pcs	20.000,00
Connectiong sewage system (pressure pipe)	2.400	300.000,00
WWTP upgrade*	600 PE	160.000,00
	TOTAL	**1.567.500,00**

* Predicted WWTP capacity in Koplik city is estimated to around 4.000 PE The difference between costs of WWTP for Koplik city (4.000 PE) and with upgraded WWTP for village Kalldrun (4.600 PE) is 160.000 EUR.

2.2.2 Operation and maintenance costs

Operation and maintenance costs due to bigger capacity of WWTP for Koplik city are presentd in Table 5.

Table 5: Breakdown of operation and maintenance costs for Option 2 - centralized WWTP

Type of cost	**Cost of operation and maintenance [EUR/year]**
Additional costs due to higher capacity of WWTP in Koplik city	5.100,00
TOTAL:	**5.100,00**

2.3 OPTION 3 - Centralized WWTP in Shkodra city

In this option, the village is to be connected through the sewerage system to the centralized WWTP in Shkodra city. First, the sewage water is to be collected in the village Kalldrun (length around 4.350 m) and then is to be transported by a pressure sewer system, which length is estimated to around 2.400 m, to the existing sewer system in Koplik city. The existing sewer network in Koplik city ends up with the pumping station, from where waste waster is further transported, via connecting sewerage canal to the centralized wastewater treatment plant in Shkodra city. The estimated length of the connecting sewer system is more than 16.100 m. The situation is presented in Figure 6.

Figure 6: Scheme of the sewerage system connected to the centralized WWTP

2.3.1 Investment costs

Investment costs to connect village Kalldrun to centralised WWTP in Shkodra city are presented in Table 6.

Table 6: Investment costs for Option 3– centralized WWTP

Option 3 - centralized WWTP		Costs [€]
Connecting sewage system (pressure pipe)	3.800	570.000,00
Connecting sewage system	16.100 m	4.025.000,00
Min. 2 pumping stations	2 pcs	40.000,00
Sewage system in the village Kalldrun	4.350 m	1.087.500,00
WWTP upgrade*	600 PE	60.000,00
	TOTAL	**5.782.500,00**

*The difference between costs of predicted WWTP for Shkodra (115.000 PE) and with upgraded WWTP for village Kalldrun (115.600 PE).

2.3.2 Operation and maintenance costs

Operation and maintenance costs due to bigger capacity of WWTP for Shkodra city is presented in Table 7.

Table 7: Breakdown of operation and maintenance costs for Option 3 - centralized WWTP

Type of cost	Cost of operation and maintenance [EUR/year]
Additional costs due to higher capacity of WWTP	2.400,00
TOTAL:	**2.400,00**

2.4 COMPARISON OF COSTS OF PRESENTED OPTIONS

2.4.1 TECHNICAL ASPECTS

Considering the technical aspects of the presented options, the following comparison is made using criteria of the complexity of operation and suitability of technology. In the table below, technical aspects of variant solutions are compared.

Table 8: Technical aspects of single variant solutions for village Kalldrun

	Option 1 Autonomous WWTP (decentralised)	Option 2 and 3 Centralised WWTP
Advantages	- Nature-based solution – easy to operate - Less extensive project documentation (simpler process to obtain building permit) - Smaller investment costs - Small (natural) treatment systems use less energy and less energy for pumpingInvolvement of local communities - Can be constructed by local company - Reuse of sludge easier to manage	- Conventional (intensive) treatment systems, - Minimal requirement for space; - Sludge stabilisation is taking place in the same reactor (aeration tank) - 24/7 supervision
Deficiencies	- Question of managing small systems (required training of the team) - In case of constructed wetland bigger land requirements	- Higher investment,operation and maintenance costs - Bigger energy consumption - High level of mechanisation - Involvement of local communities is lost - Substantial pumping required
Rank	**1**	**2**

2.4.2 FINANCIAL ASPECTS

Financial aspects of variant solutions are compared through investment costs for sewage and wastewater treatment facility investment and operation/maintenance costs. The investment in the sewage system is consultant estimation. There is no data on terrain specifics, rivers, etc., which can significantly increase investment cost. Therefore, the operation/maintenance cost of the sewage system was not considered in the financial aspect.

Financial evaluation of all three options for wastewater treatment from the village Koplik is presented in Table 9.

Table 9: Financial aspects of single variant solutions for village Kalldrun

	Option 1	**Option 2**	**Option 3**
INVESTMENT COSTS (EUR)	1.237.500,00	1.567.500,00	**5**.782.500,00
COST OF OPERATION AND MAINTENANCE (EUR/year)	2.770,00	5.100,00	2.400,00
INVESTMENT AND O&M COSTS – RANKING THE VARIANTS	**1**	**2**	**3**

From the table above, it is evident that the Constructed wetland (Option 1) is financially most reasonable and has minimal energy (drive) and maintenance (yearly) costs. An additional option is to install sludge drying beds beside the CW to reduce the operation and maintenance costs.

Using technical and financial criteria, Option 1 is selected – small autonomous WWTP is the optimal solution for wastewater treatment for Kalldrun.

3 Village Koplik i Sipërm

Koplik i Sipërm is a settlement in the former Qendër municipality, Shkodër County, northern Albania. At the 2015 local government reform, it became part of the municipality Malësi e Madhe. It has a population of 1,259.

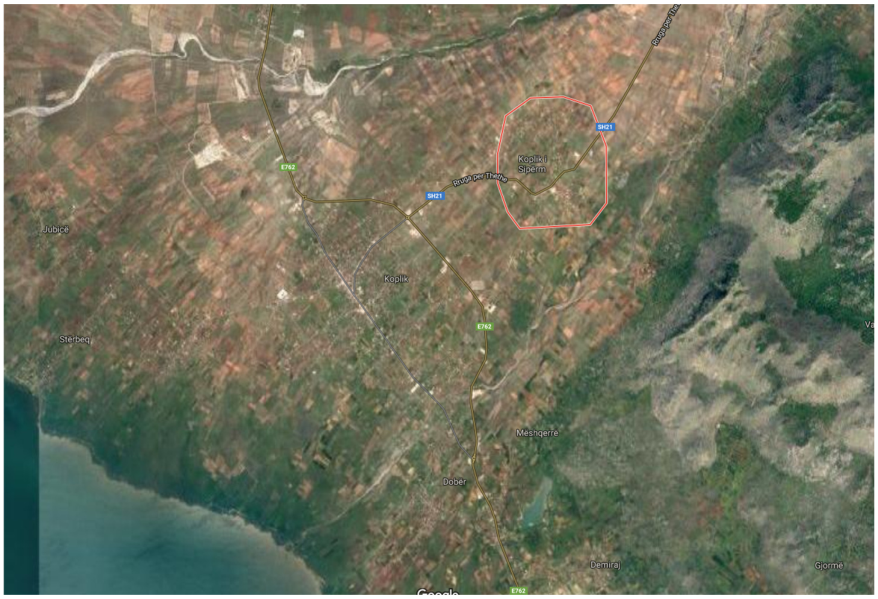

Figure 7: Location of the village Koplik i Sipërm [2]

Design parameters:

- Population (2010): 1259 PE
- Population horizont (2045): 1360 PE
- Area of influence: 1
- Distance from the lake Shkodra: 1 km

3.1 OPTION 1 - Autonomous small WWTP

n this option, an autonomous small sewerage network and small wastewater treatment plant for village Koplik i Sipërm is predicted. Construction of 6.600 m of sewer and one wastewater treatment plant for 1.360 PE is predicted. The collection of wastewater and CW's proposed location for the treatment of wastewaters from Village Koplik i Sipërm is illustrated in Figure 8. The chosen type of biological treatment plant is a constructed wetland with the vertical and horizontal subsurface flow.

[2] https://www.google.com/maps

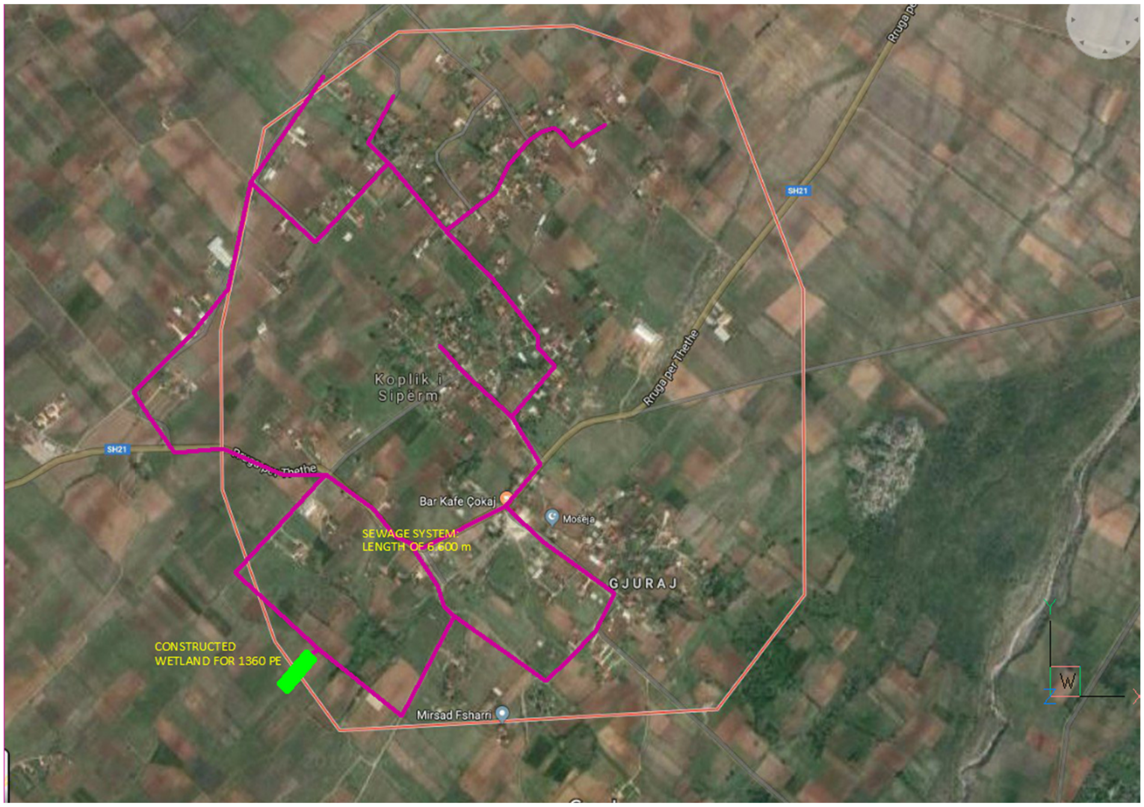

Figure 8: Scheme of the sewer system with autonomous small WWTP in the village of Koplik i Sipërm

3.1.1 Basic dimensioning

<u>Hydraulic parameters:</u>

- Estimated capacity: 1360 PE
- Daily quantity of waste waters: V = 163,2 m3/d
- Maximum hourly flow: Qmax = 5,67 l/s

<u>Pollution loads:</u>

- BOD5: 81,6 kg/d
- COD: 163,2 kg/d
- SS : 95,2 kg/d
- TN: 15,0 kg/d
- TP: 2,4 kg/d

C CW dimensions consider the amount of time necessary for the elimination of parameters (COD, BOD5, and SS). Usually, over three days are needed for the sewage water to be treated, under the condition that the CW is adequately maintained and that primary treatment is executed.

Primary treatment is taking place in the sedimentation tank. Due to the correct deposition of particles, sufficient time in the sedimentation tank must be ensured to achieve a 70% suspended matter reduction. In the sedimentation tank, decomposition of organic matter takes place, ensuring a parameter decrease of COD and BOD5 by 30%.

Waste water treatment is occurring in the following parts of a device in order of appearance:

- Primary treatment – sedimentation tank or Imhoff tank;

- Filtration beds (FB – 1, FB - 2);
- Purification bed (PB)
- Polishing bed (PsB).

The dimensions of single beds are demonstrated in the table below.

Table 10: Dimension of beds

Beds	Width [m]	Length [m]	Depth* [m]	Area [m2]	Volume [m3]	Effective volume [m3]
FB - 1	20	30	1	600	600	180
FB - 2	20	30	1	600	600	180
PB	25	50	0,5	1.250	625	188
PsB	20	30	0,4	600	240	72
TOTAL				**3.050**	**2.065**	**620**

*Net depth of the substrate.

Water tightness of the beds is ensured by non-permeable foil resistant to mechanical loads, UV light, air, and root growth. The thickness and type of foil are determined by the leading designer in the main project. To protect the foil from external influences, geotextile is put above and beneath the foil. The beds are filled with the substrate of different fractions (from 0.2 – 32 mm) and different heights. Beds are usually planted with common reed (Phragmites australis) or other plants that grow well in wetlands. The density of plants should be at least 7 per m^2.

Filtration bed
Filtration bed (FB) is the first in the CW and, therefore, the most loaded. Its function is the retention (filtration) of suspended matters which have escaped the sedimentation tank. FB represents a sedimentation tank of nutritious and toxic matters, thus protecting the rest of the CW from being clogged. The water flow is vertical and runs underground.

Purification bed
In purification beds (PB) an intensive degradation of waste matters is taking place. Plant activities assisted by diffusion ensure satisfactory oxygen levels, thus securing an effective nitrification process and a decrease of ammonium nitrogen. The tasks of this bed are retention, accumulation, and later plant uptake of nutrients into plant and microbial biomass. The reduction of all human or animal bacteria occurs, including the reduction of pathogenic bacteria. The water flow is horizontal and runs gravitationally underground.

Polishing bed
The polishing bed (PB) function is to bring the final stage of wastewater treatment to an end. Apart from further biological degradation of solute matters, this bed improves other parameters and particularly reduces the rest of the microorganisms in the wastewater. The water flow is horizontal and runs gravitationally underground.

Recipient
Treated water from the constructed wetland can be infiltrated into the ground or discharged into the nearest watercourse.

3.1.2 Investment costs

Investment costs for CW for treatment of wastewaters from village Koplik i Sipërmare are presented in Table 11.

Table 11: Investment costs for Option 1 – autonomous small WWTP

Option 1 - autonomous small WWTP		**Costs [€]**
Sewage system	6.600 m	1.650.000,00
Constructed wetland	1.360 PE	450.000,00
	TOTAL	**2.100.000,00**

3.1.3 Operation and maintenance costs

Operation and maintenance costs for CW for treatment of wastewaters from village Koplik i Sipërmare are presented in Table 12.

Table 12: Breakdown of operation and maintenance costs for Option 1 - autonomous small WWTP

Type of cost	**Cost of operation and maintenance [EUR/year]**
Cost of sludge and waste deposition	2.800,00
Staff costs	1.500,00
Electricity	150,00
TOTAL:	**4.450,00**

Maintenance activities mostly enclose regular monitoring of the operation of a constructed wetland, occasional pumping of sludge from the sedimentation tank, cleaning of parts of the device with water, autumn plant cutting, and landscaping.

3.2 OPTION 2

In this option, the Koplik city is to have a new wastewater treatment plant, to which the village Koplik i Sipërm is connected through the sewerage system to the existing sewerage system. First, the sewage is collected in the village Koplik i Sipërm (length around 6.500 m) and then is transported by connecting sewer system, which length is estimated to around 950 m, to the existing sewer system in Koplik city. The network should end up with a new wastewater treatment plant. Collection pipes and WWTP locations are presented on Figure 9.

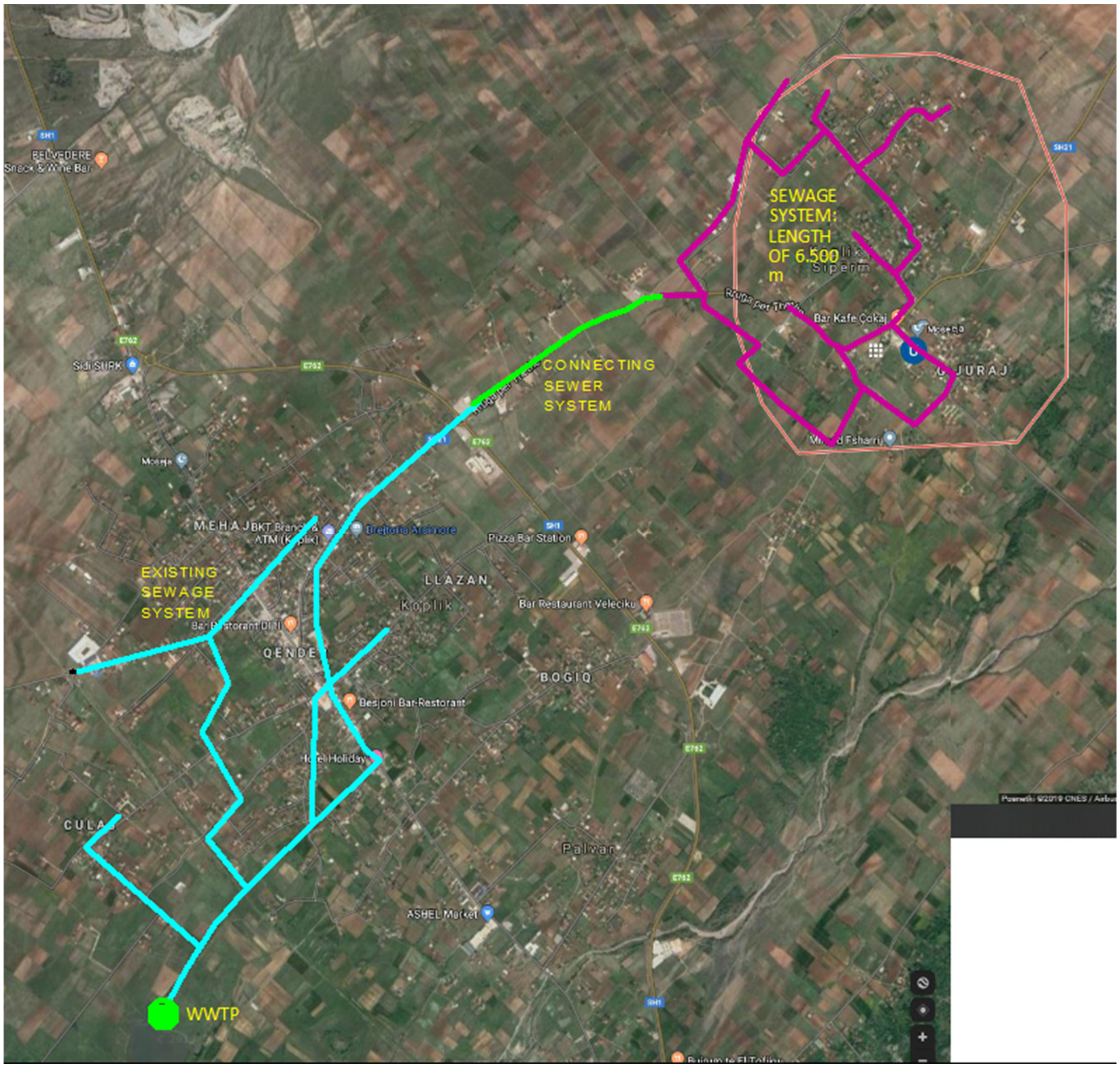

Figure 9: Scheme of the sewer system with WWTP in the village of Koplik

3.2.1 Investment costs - Centralized WWTP in Koplik city

Investment costs to connect village Koplik i Sipërmare to WWTP in Koplik city are presented in Table 13.

Table 13: Investment costs for Option 2 – centralized WWTP in Koplik city

Option 2 - centralized WWTP in Koplik city		**Costs [€]**
Sewage system in Koplik	6.500 m	1.625.000,00
Connecting sewage system	950 m	237.500,00
WWTP upgrade*	1.360 PE	360.000,00
	TOTAL	**2.222.500,00**

* Predicted WWTP in Koplik city is estimated to around 4.000 PE The difference between costs of predicted WWTP for Koplik city (4.000 PE) and with upgraded WWTP for village Koplik i Sipërm (5.360 PE) is 360.000 EUR.

3.2.2 Operation and maintenance costs

Operation and maintenance costs due to bigger capacity of WWTP for Koplik city are presented in Table 14.

Table 14: Breakdown of operation and maintenance costs for Option 2 - centralized WWTP

Type of cost	Cost of operation and maintenance [EUR/year]
Additional costs due to higher capacity of WWTP	11.300,00
TOTAL:	**11.300,00**

3.3 OPTION 3 - Centralized WWTP in Shkodra city

In this option, the village is connected through the sewerage system to the centralized WWTP in Shkodra city. First, the sewage is to be collected in the village Koplik i Sipërm (length around 6.500 m) and then transported by connecting sewer system, which length is estimated to around 17.660 m, to the existing sewer system in Shkodra city. The layout of sewage collector from village Koplik i Sipërm to the Shkodra city is illustrated in Figure 10.

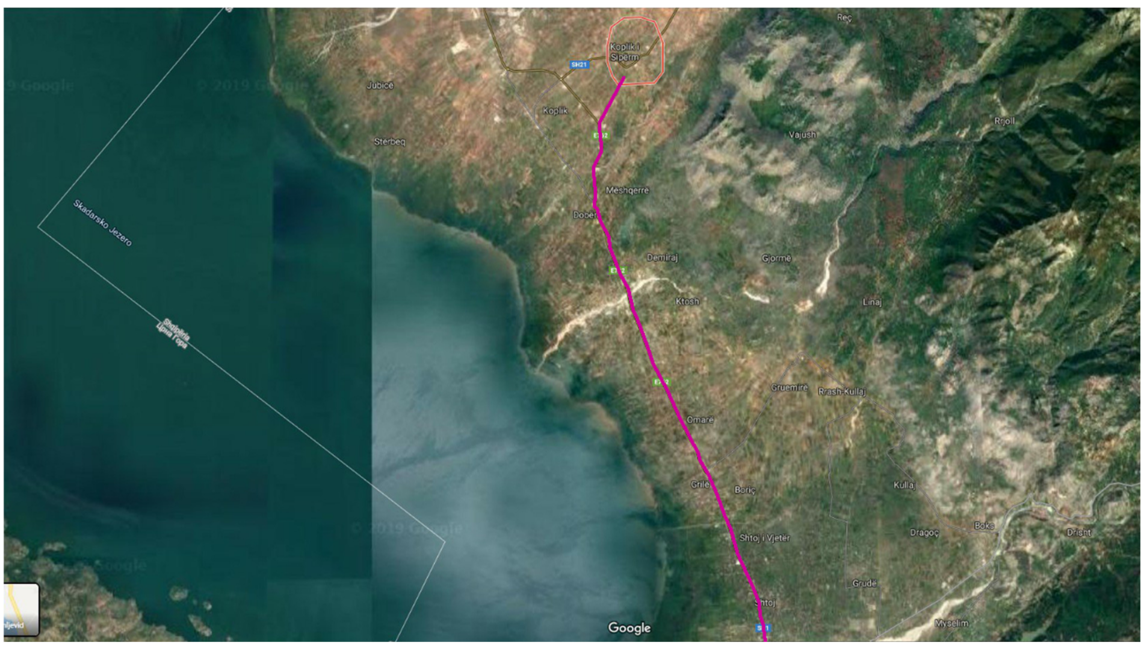

Figure 10: Scheme of the sewerage system connected to the centralized WWTP

3.3.1 Investment costs

Investment costs to connect village Koplik i Sipërm to centralised WWTP in Shkodra city are presented in Table 15.

Table 15: Investment costs for Option 2 – centralized WWTP in Shkodra city

Option 3 - centralized WWTP		Costs [€]
Connecting sewage system	17.660 m	4.415.000,00
At least 2 pumping stations	2 pcs	40.000,00
Sewage system in the village	6.600 m	1.650.000,00
WWTP upgrade*	1360 PE	130.000,00
	TOTAL	**6.235.000,00**

*The difference between costs of predicted WWTP for Shkodra (115.000 PE) and with upgraded WWTP for village Kalldrun (116.360 PE) is 130.000 EUR.

3.3.2 Operation and maintenance costs

Operation and maintenance costs due to bigger capacity of WWTP for Shkodra city is presented below.

Table 16: Breakdown of operation and maintenance costs for Option 3 - centralized WWTP

Type of cost	Cost of operation and maintenance [EUR/year]
Additional costs due to higher capacity of WWTP	5.200,00
TOTAL:	**5.200,00**

3.4 COMPARISON OF COSTS OF PRESENTED OPTIONS:

3.4.1 TECHNICAL ASPECTS

Considering technical aspects of the presented options, the following comparison is made using criteria of the operation's complexity, the suitability of technology, simplicity of spare parts management, and required space for implementation. In the table below, technical aspects of variant solutions are compared.

Table 17: Technical aspects of single variant solutions for village Koplik i Sipërm

	Option 1 Autonomous WWTP (decentralised)	Option 2 and 3 Centralised WWTP
Advantages	- Nature-based solution – easy to operate - Less extensive project documentation (simpler process to obtain building permit) - Smaller investment costs - Involvement of local communities - Can be constructed by local company	- Conventional (intensive) treatment systems, - Minimal requirement for space; - Sludge stabilisation is taking place in the same reactor (aeration tank) - 24/7 supervision

	Option 1 Autonomous WWTP (decentralised)	Option 2 and 3 Centralised WWTP
Deficiencies	- Question of managing small systems (required training) - In case of constructed wetland bigger land requirments	- Higher investment,operation and maintenance costs - Bigger energy consumption - High level of mechanisation - Involvement of local communities is lost
Rank	**1**	**2**

3.4.2 FINANCIAL ASPECTS

Financial aspects of variant solutions are considered through investment costs for sewage and wastewater treatment facilities and their operation/maintenance costs. The investment in the sewage system is a consultant estimation. There is no data on terrain specifics, rivers, etc., which can significantly increase investment costs. Therefore, the operation/maintenance cost of the sewage system was not considered in the financial aspect.

Financial evaluation of all three options on how to solve the problem of wastewaters from the village Koplik i Sipërm is presented in Table 18.

Table 18: Economic aspects of single variant solutions for village Koplik i Sipërm

	Option 1	Option 2	Option 3
INVESTMENT COSTS (EUR)	2.100.000,00	2.222.500,00	6.235.000,00
COST OF OPERATION AND MAINTENANCE (EUR/year)	4.450,00	11.300,00	5.200,00
INVESTMENT AND O&M COSTS – RANKING THE VARIANTS	**1**	**2**	**3**

From the table above, it is evident that the Constructed wetland (Option 1) is financially more reasonable and has minimal energy (drive) and maintenance (yearly) costs. An additional option is to install sludge drying beds beside the CW to reduce the operation and maintenance costs.

Using technical and financial criteria, Option 1 is selected – small autonomous WWTP is the optimal solution for wastewater treatment for the community of Koplik i Sipërm.

4 Village Drisht

Drisht is a former bishopric and Latin titular see with an Ancient and notable medieval history (Latin Drivastum, Italian Drivasto) in Albania, 6 km from Mes Bridge (Albanian: Ura e Mesit). It is located in the former municipality Postribë in the Shkodër County. At the 2015 local government reform it became part of the Shkodër municipality. The ruined 13th century Drisht Castle is on a hilltop 800m above sea level. The ruins of the castle itself contain the remains of 11 houses. Above the modern village of Drisht, further archeological remains of late-Roman and medieval Drivastum lay. The location of the village Drisht is presented in Figure 11.

Figure 11: Location of the village Drisht[3]

Design parameters:

- Population (2003): 1.700 PE
- Population horizont (2045): 1.100 PE
- Area of influence: 1
- Distance from the lake Shkodra 1 km

4.1 OPTION 1 - Autonomous small WWTP

An autonomous small sewerage network and small wastewater treatment plant for village Drisht is predicted in this option. Construction of 1.600 m of sewer and one wastewater treatment plant for 1.100 PE is predicted. The recommended level of wastewater treatment is secondary. The chosen type of biological treatment plant is constructed wetland with the vertical and horizontal subsurface flow. Below is presented village Drisht situated next to the Drin river.

[3] https://www.google.com/maps

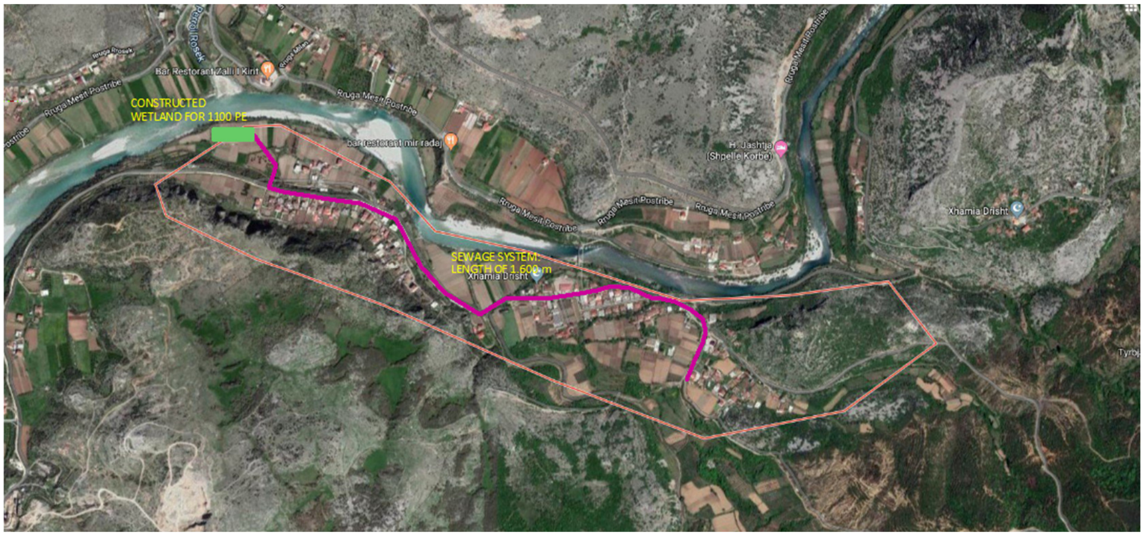

Figure 12: Scheme of the sewer system with autonomous small WWTP in the village of Drisht

4.1.1 Basic dimensioning

<u>Hydraulic parameters:</u>

- Estimated capacity: 1.100 PE
- Daily quantity of waste waters: V = 132 m3/d
- Maximum hourly flow: Qmax = 4,58 l/s

<u>Pollution loads:</u>

- BOD5: 66,0 kg/d
- COD: 132,0 kg/d
- SS : 77,0 kg/d
- TN: 12,1 kg/d
- TP: 1,98 kg/d

CW dimensions consider the amount of time necessary for the elimination of parameters (COD, BOD5, and SS). Usually, more than three days are required, under the condition that the CW is adequately maintained and that primary treatment is executed.

Primary treatment is taking place in the sedimentation tank. Due to the correct deposition of particles, sufficient time in the sedimentation tank must be ensured to achieve a 70% suspended matter reduction. In the sedimentation tank, decomposition of organic matter takes place, ensuring a parameter decrease of COD and BOD5 by 30%.

Wastewater treatment occurs in the following parts of a device in order of appearance:
Primary treatment – sedimentation tank;
Filtration beds (FB);
Purification bed (PB);
Polishing bed (PsB).

The dimensions of single beds are demonstrated in the table below.

Table 19: Dimension of beds

Beds	Width	Length	Depth*	Area	Volume	Effective volume

	[m]	[m]	[m]	[m2]	[m3]	[m3]
FB	30	20	1,00	600	600	180
PB	30	40	0,70	1200	840	252
PsB	30	25	0,50	750	375	113
TOTAL				**2.550**	**1.815**	**545**

*Net depth of the substrate.

Water tightness of the beds is ensured by non-permeable foil resistant to mechanical loads, UV light, air, and root growth. The thickness and type of foil are determined by the leading designer in the main project. To protect the foil from external influences, geotextile is put above and beneath the foil. The beds are filled with the substrate of different fractions (from 0.2 – 32 mm) and different heights. Beds are usually planted with common reed (Phragmites australis) or other plants that grow well in wetlands. The density of plants should be at least 7 per m2.

Filtration bed

Filtration bed (FB) is the first in the CW and, therefore, the most loaded. Its function is the retention (filtration) of suspended matters which have escaped the sedimentation tank. FB represents a sedimentation tank of nutritious and toxic matters, thus protecting the rest of the CW from being clogged. The water flow is vertical and runs underground.

Purification bed

In purification beds (PB) an intensive degradation of waste matters is taking place. Plant activities assisted by diffusion ensure satisfactory oxygen levels, thus securing an effective nitrification process and a decrease of ammonium nitrogen. The tasks of this bed are retention, accumulation, and later plant uptake of nutrients into plant and microbial biomass. The reduction of all human or animal bacteria occurs, including the reduction of pathogenic bacteria. The water flow is horizontal and runs gravitationally underground.

Polishing bed

The polishing bed (PB) function is to bring the final stage of wastewater treatment to an end. Apart from further biological degradation of solute matters, this bed improves other parameters and particularly reduces the rest of the microorganisms in the wastewater. The water flow is horizontal and runs gravitationally underground.

Recipient

Treated water from the constructed wetland for the village Drisht is discharged into the Drin river.

4.1.2 Investment costs

Investment costs for CW for treatment of wastewaters from village Drisht are presented inTable 20.

Table 20: Investment costs for Option 1 – autonomous small WWTP

Option 1 - autonomous small WWTP		**Costs [€]**
Sewage system	1.600 m	400.000,00
At least 1 pumping station	1 pcs	20.000,00
Constructed wetland	1.100 PE	400.000,00
	TOTAL	**820.000,00**

4.1.3 Operation and maintenance costs

Operation and maintenance costs for CW for treatment of wastewaters from village Drisht are presented in Table 21.

Table 21: Breakdown of operation and maintenance costs for Option 1 - autonomous small WWTP

Type of cost	Cost of operation and maintenance [EUR/year]
Cost of sludge and waste deposition	2.800,00
Staff costs	1.500,00
Electricity	150,00
TOTAL:	**4.450,00**

Maintenance activities mostly enclose regular monitoring of the operation of a constructed wetland, occasional pumping of sludge from the sedimentation tank, cleaning of parts of the device with water, plant cutting, and landscaping.

4.2 OPTION 3 - Centralized WWTP in Shkodra city

In this option, the village is connected through the sewerage system to the centralized WWTP in Shkodra city. First, the sewage is collected in the village Drisht (length around 1.600 m) and then is transported by connecting sewer system, which length is estimated to around 8.000 m, to the existing sewer system in Shkodra city. The recommended level of wastewater treatment is tertiary. The length of sewage collector from village Drisht to the Shkodra city is illustrated in Figure 13.

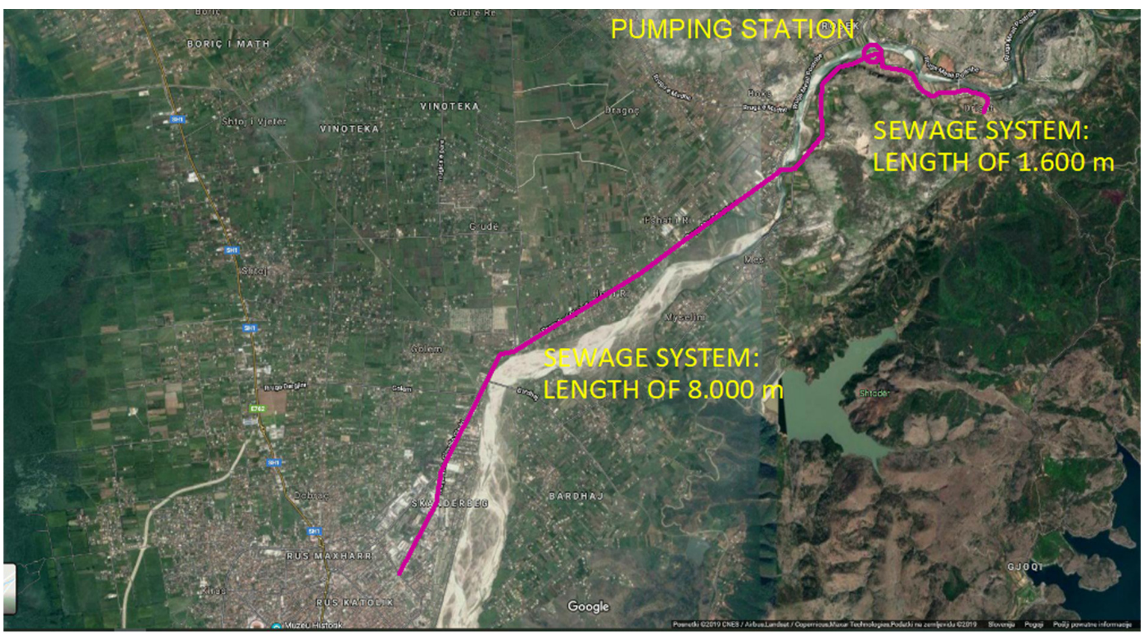

Figure 13: Scheme of the sewerage system connected to the centralized WWTP

4.2.1 Investment costs

Investment costs to connect village Drisht to centralised WWTP in Shkodra city are presented in Table 22.

Table 22: Investment costs for Option 2 – centralized WWTP in Shkodra city

Option 3 - centralized WWTP	Costs [€]

Connecting sewage system	8.000 m	2.000.000,00
At least 3 pumping stations	3 pcs	60.000,00
Sewage system in the village	1.600 m	400.000,00
WWTP upgrade*	1.100 PE	100.000,00
	TOTAL	**5.636.000,00**

*The difference between costs of predicted WWTP for Shkodra (115.000 PE) and with upgraded WWTP for village Kalldrun (116.100 PE).

4.2.2 Operation and maintenance costs

Operation and maintenance costs due to bigger capacity of WWTP for Shkodra city is presented in below.

Table 23: Breakdown of operation and maintenance costs for Option 2 - centralized WWTP

Type of cost	Cost of operation and maintenance [EUR/year]
Additional costs due to higher capacity of WWTP	4.400,00
TOTAL:	**4.400.00**

4.3 COMPARISON OF COSTS OF PRESENTED OPTIONS:

4.3.1 TECHNICAL ASPECTS

Comparison of technical options consider the following criteria of ease of operation, the suitability of technology, ease of spare parts management, and required space for implementation. In the table below, technical aspects of variant solutions are compared.

Table 24: Technical aspects of single variant solutions for village Drisht

	Option 1 **Autonomous WWTP**	**Option 2 and 3** **Centralised WWTP**
Advantages	- Nature-based solution – easy to operate - Less extensive project documentation (simpler process to obtain building permit) - Smaller investment costs - Involvement of local communities - Can be constructed by local company	- Conventional (intensive) treatment systems, - Minimal requirement for space; - Sludge stabilisation is taking place in the same reactor (aeration tank) - 24/7 supervision
Deficiencies	- Question of managing small systems (required training) - In case of constructed wetland bigger land requirments	- Higher investment,operation and maintenance costs - Bigger energy consumption - High level of mechanisation - Involvement of local communities is lost
Rank	**1**	**2**

4.3.2 FINANCIAL ASPECTS

Financial aspects of variant solutions are considered through investment costs for sewage and wastewater treatment plant and operation/maintenance costs for the treatment plant. The investment in the sewage system is only consultant estimation. There is no data on terrain specifics, rivers, etc., which can significantly increase investment cost. Therefore, the operation/maintenance cost of the sewage system was not taken into account in the financial aspect.

Financial evaluation of all three options on how to solve the problem of wastewaters from the village Drisht is presented in Table 25.

Table 25: Financial aspects of single variant solutions for village Drisht

	Option 1	**Option 2**
INVESTMENT COSTS (EUR)	820.000,00	5.636.000,00
COST OF OPERATION AND MAINTENANCE (EUR/year)	4.450,00	4.400,00
INVESTMENT AND O&M COSTS – RANKING THE VARIANTS	**1**	**3**

From the table above, it is evident that the Constructed wetland (Option 1) is financially more reasonable and has minimal energy (drive) and maintenance (yearly) costs. An additional option is to install sludge drying beds beside the CW to reduce the operation and maintenance costs.

Using technical and financial criteria, Option 1 is selected – small autonomous WWTP is the optimal solution for wastewater treatment for the community of Drisht.

5 Influence areas of Shkodra Lake

The areas of influence to Shkodra Lake were evaluated based on an orthophoto. The first area of influence (1) is directly adjacent to the Shkodra Lake and its tributaries and covers settlements and agricultural areas directly among the watercourse. The second area of influence (2) extends deeper into the catchment area's hinterland and comprises mainly meadows and dispersed settlements along tributaries. The third area of influence (3) mainly consists of settlements in hilly areas not adjacent to watercourses.

Table 26: List of settlements in the catchment area of the lake Shkodra in Shkoder Municipality

Administrative Unit	**Village**	**Population number Regional Council (Qarkt) of Shkodra (2003)**	**Civil Registry**	**Census (2011)**	**Distance from the lake**	**Area of influence estimation**
Administrative Unit of Postribë	Boks	1854	11730	7069	7,5	3
	Domen	1020			/	/
	Dragoç	1739			7	3
	Drisht	1700			/	/
	Kullaj	1385			6,5	2
	Mes	823			/	/
	Myselim	813			/	/
	Prekal	678			21	2
	Shakotë	333			11	2
	Ura e Shtrenjtë	963			14,5	2
	Vilëz	474			/	/
Administrative Unit of Rrethinat	Bardhaj	901	23923	21199	/	/
	Bleran	2023			/	/
	Dobraç	2455			3	1
	Golem	1365			3	1
	Grudë e Re	3376			5	1
	Guci e Re	757			5	1
	Hot i Ri	1604			/	/
	Shtoj i Ri	1343			3	1
	Shtoj i Vjetër	1644			3	1
	Zues	778			/	/

Table 27: List of settlements in the catchment area of the lake Shkodra in Malësi e Madhe Municipality

Administrative Unit	**Village**	**Population number Regional Council (Qarkt) of Shkodra (2003)**	**Civil Registry and**	**Census (Office of Statistics)**	**Distance from the lake**	**Area of influence estimation**
Administrative Unit of Gruemirë	Boriç i Madh	1585	13089	8890	2	1
	Boriç i Vogël	611			2	1
	Demiraj	1416			3,5	1
	Gjormë	408			6,5	2
	Grilë	886			1	1
	Grudë	978			5	1
	Gruemirë	881			5	2
	Kerraj				3	1
	Ktosh	861			4	1
	Kurtë	362			9,5	2
	Linaj	1064			6,5	3
	Mëshqerrë	542			5	2
	Omaraj	530			2	1
	Rrash-Kullaj	789			5,5	2
	Vajush	662			7,5	3
	Vorfë	609			7,5	?
	Aliaj	1,033 (2010)			4	2
Administrative Unit of Kastrat	Bratosh	530 (2010)	11994	6883	6	3
	Goraj	693 (2010)			5,5	3
	Gradec	738 (2010)			7,5	2
	Hot	1473 (2010)			4	2
	Ivanaj	789 (2010)			3,5	3
	Jeran	661 (2010)			4,5	2
	Kastrat	682 (2010)			5,5	3
	Pjetroshan	1216 (2010)			5	1
	Premal				4,5	2
	Rrapshë	813 (2010)			8	3
	Vukpalaj	768 (2010)			2,5	2
	Brojë	744			15,5	2
Administrative Unit of Kelmend	Kozhnjë	232	6239	3056	34	2
	Lëpushë	512			/	/
	Nikç	547			39	2
	Selcë	1239			39,5	

Administrative Unit	Village	Population number Regional Council (Qarkt) of Shkodra (2003)	Civil Registry and	Census (Office of Statistics)	Distance from the lake	Area of influence estimation
	Tamarë	504			18	2
	Vermosh	1457			/	/
	Vukël	1359			26	2
	Bogiq	670 (2010)			3	1
Administrative Unit of Qendër	Dobër	552	5950	4740	2	1
	Jubicë	479			2	1
	Kalldrun	498			2	1
	Kamicë-Flakë	849			2	1
	Koplik i Sipërm	1259			6	2
	Lohe e Poshtme	554			11	3
	Stërbeq	542			1,5	1
	Bogë	522			30	2
Administrative Unit of Shkrel	Bzhetë	448	5940	3520	18	2
	Bzhetë-Makaj	509			22	2
	Dedaj	570			16	2
	Droç-Rrepisht	391			15	2
	Kokë-Papaj	375			13	2
	Lohe e Sipërme	305			13	2
	Qafë-Gradë	804			13	3
	Reç	1000			10	2
	Vrith	638			9	3
	Vuç-Kurtaj	210			8,5	3
	Zagorë	1064			9	3

In the Shkodra Lake catchment area, in the administrative units of Rrethinat and Malësi e Madhe Municipalities, the river network is widely diversified. Watercourses originate in a hilly area, in the so-called Albanian Alps Zone. The karst area begins at the lake's mouth and covers the area to the Adriatic coast and extends south. The eastern shore of Lake Shkodra is composed of river sediments forming a creek. Young riparian soils with a rough texture and a high degree of infiltration develop on creeks. Due to the influence of groundwater and the connection with lake water, the impact on Shkodra Lake's quality from the settlements and agriculture in the catchment area is large[4,5].

6 Proposed phases of WW infrastructure

As wastewater issues in all settlements cannot be solved simultaneously, the following phases of WW infrastructure works are proposed (priority list).

1. Implementation of measures in the first impact zone of the Shkodra Lake (direct effect on the Lake)

- Where sewerage network exists, upgrading the system with the wastewater treatment with a tertiary level of treatment is recommended, particularly in the case where a direct discharge into the Lake or the nearest stream occurs;
- Construction of a sewerage network with a wastewater treatment plant with a tertiary level of treatment, where a direct discharge into the Lake or the nearest stream flowing into the Lake occurs.

2. Implementation of measures in the second impact zone of the Shkodra Lake (indirect effect on the Lake)

- Where sewerage network exists, upgrading the system with the wastewater treatment with a tertiary level of treatment is recommended, particularly in the case where a direct discharge into the Lake or the nearest stream occurs;
- Construction of a sewerage network with a wastewater treatment plant with a tertiary level of treatment, where a direct discharge into the Lake or the nearest stream flowing into the Lake occurs.
- Other: Construction of a sewerage network with the treatment plant with at least the second stage of treatment (secondary level)

3. Implementation of measures in the third impact zone of the Shkodra Lake

- Other: Construction of a sewerage network with the treatment plant with at least a second stage of treatment (secondary level), settlements are to be solved with small autonomous WWTP.

7 Conclusions

Many cities in developing countries are facing surface water and groundwater pollution problems. This deterioration of water resources needs to be controlled through effective and feasible concepts of urban water management.[6] The development of the wastewater master plan must consider the capacity and resources for implementation, particularly in technical, financial, and administrative capacities. The elaborated document envisages domestic wastewaters' collection and treatment based on financial costs and technical point of view. The objective is the minimization of financial cost while ensuring that environmental objectives are met. The analysis consists of a sewage and wastewater treatment component, analyzed separately to determine total costs.

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[4] https://www.researchgate.net/figure/Simplified-geological-map-of-Albania-modified-from-Meco-and-Aliaj-19-Geological_fig1_261646296

[5] https://www.researchgate.net/figure/Overview-of-the-geology-of-Albania-according-to-Meco-Aliaj-2000-The-various-zones_fig1_230015786

[6] https://www.researchgate.net/publication/263237324_The_3-Step_Strategic_Approach_to_Sustainable_Wastewater_Management

The robust scenario-based analysis allows strategic prioritization. The analysis is based on the location of villages Kalldrun, Koplik i Sipërm and Drisht compared for each option (Option 1 - Autonomous small WWTP for the village; Option 2 - Connection of village to the centralized WWTP in Koplik city; Option 3 - Connection of village to the centralized WWTP in Shkodra city). The conclusions of addressing wastewater issues around Lake Shkodra are briefly presented below:

- Input data used (population) stems not from the statistical survey from 2011 as the census did not include villages around Shkodra lake, only Administrative units instead., The data used is from 2003, and the accuracy of the data is questionable.

- The greater the distance from the village to centralized WWTP, the greater the costs. The study proved that it is not reasonable to connect all analyzed villages (Kalldrun, Koplik i Sipërm and Drisht) to the central WWTP in Shkodra city.

- The study showed that addressing the WWTP's micro-location is a comprehensive process, and local public authorities (Municipality) should actively participate in decision-making processes. There is also a need to carry on detailed assessments considering a variety of aspects (in particular non-technical aspects such as environmental, financial, social, and institutional ones)[7]. A detailed feasibility study should follow to elaborate details of planned implementation.

- Clear thresholds have to be set when evaluating option solutions (e.g., construction of small WWTP is feasible if initial investment costs in sewer network and WWTP causes more than triple the costs of equipping the location with small WWTP for groups of objects or entire village[8]). Below, the ranking with that transferred threshold from Slovenia is presented. However, any thresholds must be agreed in collaboration with local authorities and not just transferred from abroad. The alignment of planning and management can be expected.

Table 28: Comparison of investment costs for option solutions for three different solutions

	Village Kalldrun	Village Koplik i Sipërm	Village Drisht
Option 2/Option 1	1.567.500,00/1.237.500,00 =1,26 Option 2 is more reasonable.	2.222.500,00/2.100.000,00 = 1,06 Option 2 is more reasonable.	-
Option 3/Option 1	5.782.500,00/1.237.500,00 = 4,67 Option 1 is more reasonable.	6.235.000,00/2.100.000,00 = 2,97 Option 1 is more reasonable.	5.636.000,00/820.000,00 =6.87 Option 1 is more reasonable.

The analysis shows that it is more reasonable to connect villages to the central WWTP in Koplik city than connecting them to the Shkodra city. Construction of (individual) small WWTP is feasible and the cheapest option, but critical contextual issues may impede implementation and later operation and maintenance such as:

- Lack of political commitment and awareness to solve wastewater issue;

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

[8] https://www.gov.si/assets/ministrstva/MOP/Javne-objave/Javne-obravnave/OP-odvajanja-in-ciscenja-komunalne-odpadne-vode/OP_besedilo_julij19_final.pdf

- Absence of stakeholder cooperation to support the wastewater solution and its objectives and actions;
- Poor information and communication to facilitate project implementation and efficient operation.

Small communities are too often left alone to deal with wastewater issues on a local level. Reasons for failure in operating the decentralized systems are a frequent change of operators, poorly trained staff, lack of O&M, and lack of funds.[9]

- Annual O&M costs decrease with WWTPs' size (smaller WWTP – smaller costs). However, O&M costs per PE are impacted by the population density (Table 29) and have to be further analyzed (including affordability analysis) before making any final decision. O&M of the sewage network is not taken into account.

Table 29: Comparison of O&M costs for option solutions for three different solutions

	Village Kalldrun	Village Koplik i Sipërm	Village Drisht
Option 1 (EUR/PE)	= 1.900/600 = 3,17	= 4.300/1.360 = 3,16	= 3.450/1.100 = 3,14
*Option 2 (EUR/PE)	= 5.100/600 = 8,5	= 11.300/1.360 = 8,3	-
*Option 3 (EUR/PE)	= 2.400/600 = 4	= 5.200/1.360 =3,82	= 4.400/1.100 =4

*Costs derived from additional loading on central WWTP.

- Elaboration of a strategic plan to address capacity-related needs and prioritizes wastewater facilities for the entire Shkodra region. A decision on connecting villages to the central WWTP affects design factors and overall financial viability. Thus, a strategic approach to wastewater planning must receive priority attention.

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