P170526

Report on adaptation and flood mitigation measures

Assessment of Suitable Flood Mitigation Measures (based on Dukniskhevi River Extreme Flood Analysis) in Tbilisi, Georgia

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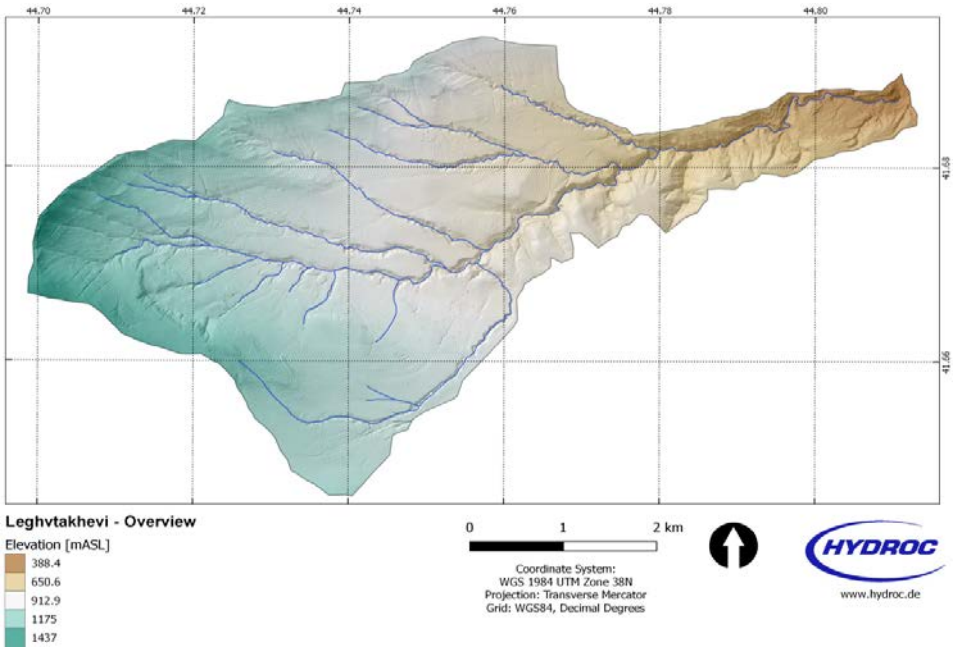

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Table of Contents

Table of Contents iii
List of Figures iv
List of Tables v
List of Abbreviations v
1. Introduction 1
2. Flood Risk Management 2
2.1 General 2
2.2 Flood Risk Management in Tbilisi 7
3 Flood Mitigation Methods 8
3.1 General 8
3.2 Reduce the magnitude and/or frequency of flooding 8
3.3 Reduce the community's exposure to flooding 9
3.3.1 Structural Measures 9
3.3.2 Non-structural measures 13
3.4 Increase the community's resilience to flooding 16
3.5 Residual Flooding 17
4 Application to the Leghvtakhevi River 18
4.1 Current Conditions 18
4.2 Flood Problems 19
4.3 Flood Mitigation Option Approach 21
4.4 Long list of Flood Mitigation Options and Discussion with Stakeholders 21
4.5 Short List of Proposed Flood Mitigation Options 22
4.4.1. Point 1 - Downstream Culverts to Kura River 23
4.4.2. Points 2 and 3 - Upstream Storage 25
4.4.3. Point 4 – Culvert Upgrade 27
4.4.4. Point 7 – Culvert Upgrade 29
4.4.5. Point 8 – Culvert Upgrade 31
4.4.6. Point 11– Culvert Upgrade 32
4.6 Option Analysis 33
4.7 Recommendations 35
4.7.1 Opening of Second Downstream Culvert 35
4.7.2 Upstream Storage 35
4.7.3 Road Crossings 35
5. Flood Early Warning System 36
5.1 Flood Forecasting 36

5.1.1 Meteorological and Hydrological Considerations 37
5.1.2 Nature of Risks and Impacts (Flood Risk) 38
5.1.3 Institutional and Legal Aspects 38
5.1.4 Requirements for a Flood Forecasting System 38
5.1.5 Elements of Flood Forecasting and Early Warning System 39

5.2 Key Activities Required for the Design and Implementation of a Flood Early Warning System 39
5.3 Recommendations for the Leghvtakhevi River 40

5.3.1 Risk Knowledge 40
5.3.2 Monitoring and Warning 41
5.3.3 Communication and Dissemination 43
5.3.4 Response 43

6. Overall Recommendations 44
7. References 46
Appendix A – Ecological Considerations 47

A.1 Approach 47
A.2 Data Collection and Analysis 47
A.3 Ecological Assessment 48

A.3.1 Mitigation 50

A.5 Institutional Visits 54
A.6 Ecological and WFD Status of the Leghvtakhevi River basin 54
A.7 WFD Recommendations 59

List of Figures

Figure 1 Components of flood risk -1 3
Figure 2 Components of flood risk -2 3
Figure 3 Building resilience measures - flooding (Source: QRA 2012) 6
Figure 4 Principle of flood control storage 9
Figure 5 Basic levee construction 10
Figure 6 River "benches" 12
Figure 7 Meander cut-off 12
Figure 8 Land use planning related to flood probabilities 14
Figure 9 River Reaches 18
Figure 11 Results for second culvert opening in Point 1. 24
Figure 12 Location of Possible Dam 25
Figure 13 Dam 26
Figure 14 Flows through the dam location 26
Figure 15 Culvert Upgrade - Point 4 27

Figure 16 Culvert Upgrade - Point 7 29
Figure 17 Culvert Upgrade - Point 8 31
Figure 18 Culvert Upgrade - Point 11 32
Figure 19 EWS components 36
Figure 20 Recommended Flood Forecasting Early Warning System 41

List of Tables

Table 1 Scale of Likelihood (Source: AIDR 2015) 3
Table 2 Consequences for people (Source: AIDR 2015) 4
Table 3 Economic consequences (Source: AIDR 2015) 4
Table 4 Consequences for public administration (Source: AIDR 2015) 5
Table 5 Typical risk matrix (Source: AIDR 2015) 5
Table 6 Examples of appropriate levels of flood risk management 5
Table 7 Agencies responsible for flood risk management in Tbilisi 7

List of Abbreviations

CTC-N	Climate Technology Centre and Network
DEM	Digital Elevation Model
ED	Environment and Development
EMA	Emergency Management Agency
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System
GPM	Global Precipitation Measurement
HEC	Hydrologic Engineering Center
MPE	Multisensor Precipitation Estimate
NEA	National Environment Agency
RMS	Root Mean Square Error
SCS	Soil Conservation Service
TRMM	Tropical Rainfall Measuring Mission
UNFCCC	United Nations Framework Convention on Climate Change
WFD	Water Framework Directive

1. Introduction

The main objective of this consultancy is to improve the flood risk management in the Leghvtakhevi River basin in Tbilisi (Georgia). This will be accomplished through the implementation of a modelling framework, the inclusion of climate change impacts, the definition of flood maps and the designation of flood mitigation and adaptation measures. capacity building and technological transfer activities.

This consultancy started in August 2017 and has finished in August 2018 (duration of 12 months). The contract between UNIDO and HYDROC was signed on the 14th of August 2017.

Ecological considerations are discussed in Appendix A.

The technical assistance is managed by the CTC-N, the National Designated Entity is the Ministry of Environment and Natural Resources Protection of Georgia, while key stakeholders are the National Environmental Agency Request (request applicant), the Tbilisi Municipality and the Emergency Management Agency under the Ministry of Internal affairs.
This report will describe the methodology that will be followed during the implementation of this technical assistance.

2. Flood Risk Management

2.1 General

Floods result principally from periods of heavy rainfall, sometimes exacerbated by snowmelt, and in coastal areas by high tides and storm surges. In Georgia the primary cause is heavy rain, which may be exacerbated by snowmelt during late spring in some areas.

Depending on both the type of rainfall event and the catchment size, floods may be either "flash floods" of short duration, and with little warning, due to intense rainfall from thunderstorms, or longer duration "riverine floods" due to longer period heavy rainfalls over larger catchments.

Current best practice for flood management is to treat flooding in a risk management context, in which the flood itself is a natural hazard and risk results from the exposure of the community to the hazard and its ability to deal with the occurrence of the hazard. The consequences of a flood depend on both its magnitude, how exposed the community is to the flood, and how vulnerable the community is in terms of people, property, infrastructure and environmental impacts. This relationship is shown in Figure 1. In a simpler format Figure 2 directly expresses the risk as the combination of likelihood (or chance) of an event of a given size occurring and the consequences of that occurrence.

Breaking this concept down further into these two key elements, a convenient concept of the likelihood scale is given in Table 1 in which ranges of probability are expressed in terms of everyday language from "almost certain" to "extremely rare".

Different tables of consequence are required for various type of impact. By way of example, the AIDR (2015) tables for consequences for people, the economy, and public administration are given in Tables 2 to 4. Other tables for environmental and ecological consequences can also be developed but need to more specifically relate to local conditions.

Likelihood and consequences are then related in a risk matrix, a typical example of which is shown in Table 5. Note that the risk levels in this matrix are not fixed and depend on the outcome of a thorough risk analysis.

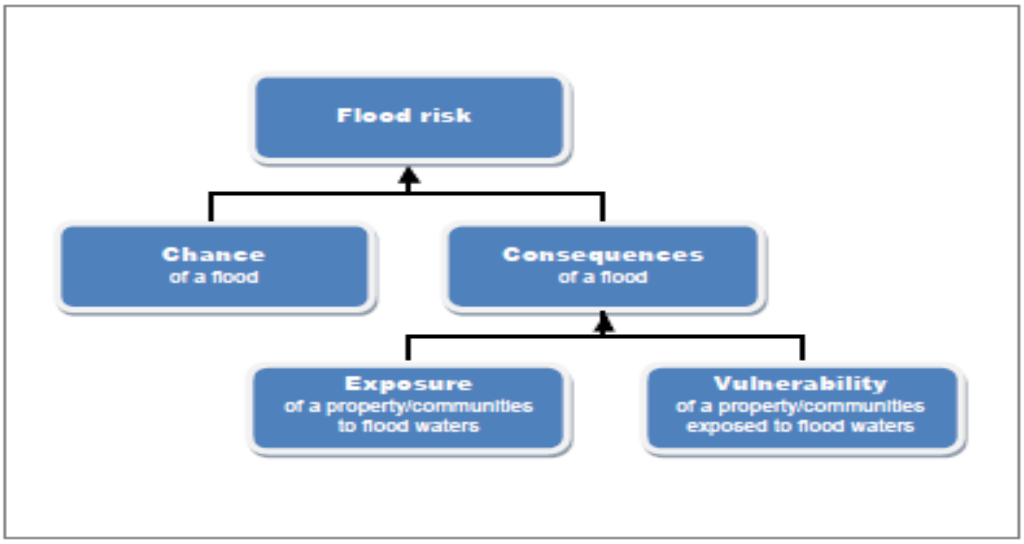


Figure 1 Components of flood risk -1

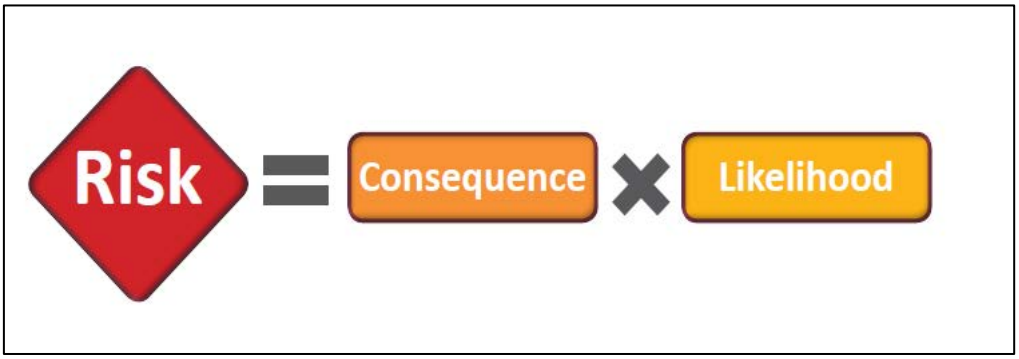


Figure 2 Components of flood risk -2

Table 1 Scale of Likelihood (Source: AIDR 2015)

Likelihood	Annual exceedance probability (AEP)	Average recurrence interval (ARI) (indicative)	Frequency (indicative)
Almost certain	63% per year or more	Less than 1 year	Once or more per year
Likely	10% to <63% per year	1 to <10 years	Once per 10 years
Unlikely	1% to <10% per year	10 to <100 years	Once per 100 years
Rare	0.1% to <1% per year	100 to <1000 years	Once per 1000 years
Very rare	0.01% to <0.1% per year	1000 to <10,000 years	Once per 10,000 years
Extremely rare	Less than 0.01% per year	10,000 years or more	Once per 100,000 years

NOTE: it is useful to consider the likelihood levels based on the likely number of events in a typical lifetime

Table 2 Consequences for people (Source: AIDR 2015)

Level	Criteria	
	Death	**Injury or illness**
Catastrophic	Deaths directly from emergency greater than 1 in 10,000 people for population of interest	Critical injuries with long-term or permanent incapacitation greater than 1 in 10,000 people for population of interest
Major	Deaths directly from emergency greater than 1 in 100,000 people for population of interest	Critical injuries with long-term or permanent incapacitation greater than 1 in 100,000 people for population of interest or Serious injuries greater than 1 in 10,000 people for population of interest
Moderate	Deaths directly from emergency greater than 1 in 1,000,000 people for population of interest	Critical injuries with long-term or permanent incapacitation greater than 1 in 1,000,000 people for population of interest or Serious injuries greater than 1 in 100,000 people for population of interest
Minor	Deaths directly from emergency greater than 1 in 10,000,000 people for population of interest	Critical injuries with long-term or permanent incapacitation greater than 1 in 10,000,000 people for population of interest or Serious injuries greater than 1 in 1,000,000 people for population of interest
Insignificant	Deaths directly from emergency less than 1 in 10,000,000 people for population of interest	Critical injuries less than 1 in 10,000,000 people for population of interest or Serious injuries less than 1 in 1,000,000 people for population of interest or Minor injuries to any number of people

Table 3 Economic consequences (Source: AIDR 2015)

Level	Criteria	
	Loss in economic activity and/or asset value	**Impact on important industry**
Catastrophic	Decline of economic activity and/or Loss of asset value greater than 4% of gross product produced by the area of interest	Failure of a significant industry or sector in area of interest as a direct result of emergency event
Major	Decline of economic activity and/or Loss of asset value greater than 0.4% of gross product produced by area of interest	Significant structural adjustment required by identified industry to respond and recover from emergency event
Moderate	Decline of economic activity and/or Loss of asset value greater than 0.04% of gross product produced by area of interest	Significant industry or business sector is significantly impacted by the emergency event, resulting in medium-term (i.e. more than one year) profit reductions directly attributable to the event
Minor	Decline of economic activity and/or Loss of asset value greater than 0.004% of gross product produced by area of interest	Significant industry or business sector is impacted by the emergency event, resulting in short-term (i.e. less than one year) profit reductions directly attributable to the event
Insignificant	Decline of economic activity and/or Loss of asset value less than 0.004% of gross product produced by area of interest	Inconsequential business sector disruption due to emergency event

Table 4 Consequences for public administration (Source: AIDR 2015)

Level	Criteria
Catastrophic	Governing bodies are unable to deliver their core functions
Major	Governing bodies encounter severe reduction in the delivery of core functions Governing bodies are required to divert a significant amount of available resources to deliver core functions or seek external assistance to deliver the majority of their core functions
Moderate	Governing bodies encounter significant reduction in the delivery of core functions Governing bodies are required to divert some available resources to deliver core functions or seek external assistance to deliver some of their core functions
Minor	Governing bodies encounter limited reduction in delivery of core functions
Insignificant	Governing bodies' delivery of core functions is unaffected or within normal parameters

Table 5 Typical risk matrix (Source: AIDR 2015)

	Consequence level				
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Very low	Low	Medium	High	High
Very rare	Very low	Very low	Low	Medium	High
Extremely rare	Very low	Very low	Low	Medium	High

It can be seen from Table 5 that the highest risks are associated with relatively high likelihood events which have major or catastrophic consequences, and these are the highest priorities for risk management.

In the flooding context, different levels of risk management are generally applied to different causes of flooding to take account of their relative likelihoods and consequences. Some examples are given in Table 6.

Table 6 Examples of appropriate levels of flood risk management

Type of event	Likelihood	Consequence level	Design level
Urban stormwater flooding	Almost certain	Minor	2 to 10 year ARP (10-50% AEP)
Major road flooding	Likely	Moderate	50 year ARP (2% AEP)
Significant property damage	Unlikely	Moderate to Major	100 year ARP (1% AEP)
Failure of major dam	Rare/very rare	Catastrophic	>10,000yr ARP (<.01% AEP

ARP = average return period AEP annual exceedance probability

The terminology of **annual exceedance probability** (AEP) is introduced here as a better means of expressing probability (or likelihood) than **return period** as it shows the chance of an event of a given size occurring every year. Whilst **average return period** (ARP) conveys the same information, the "average" is often lost and many people believe if that if a 100 year return period event has just occurred there won't be another similar event for the next 100 years. This is patently wrong, the correct interpretation being a 1 in 100 chance **each and every year**.

The aim of flood risk management is to reduce the vulnerability of the community to flooding by a combination of reducing their exposure and reducing the consequences of a flood event.

Resilience is the inverse of vulnerability, so reducing vulnerability is equivalent to increasing resilience. The latter terminology is preferred as it sends a more positive message.

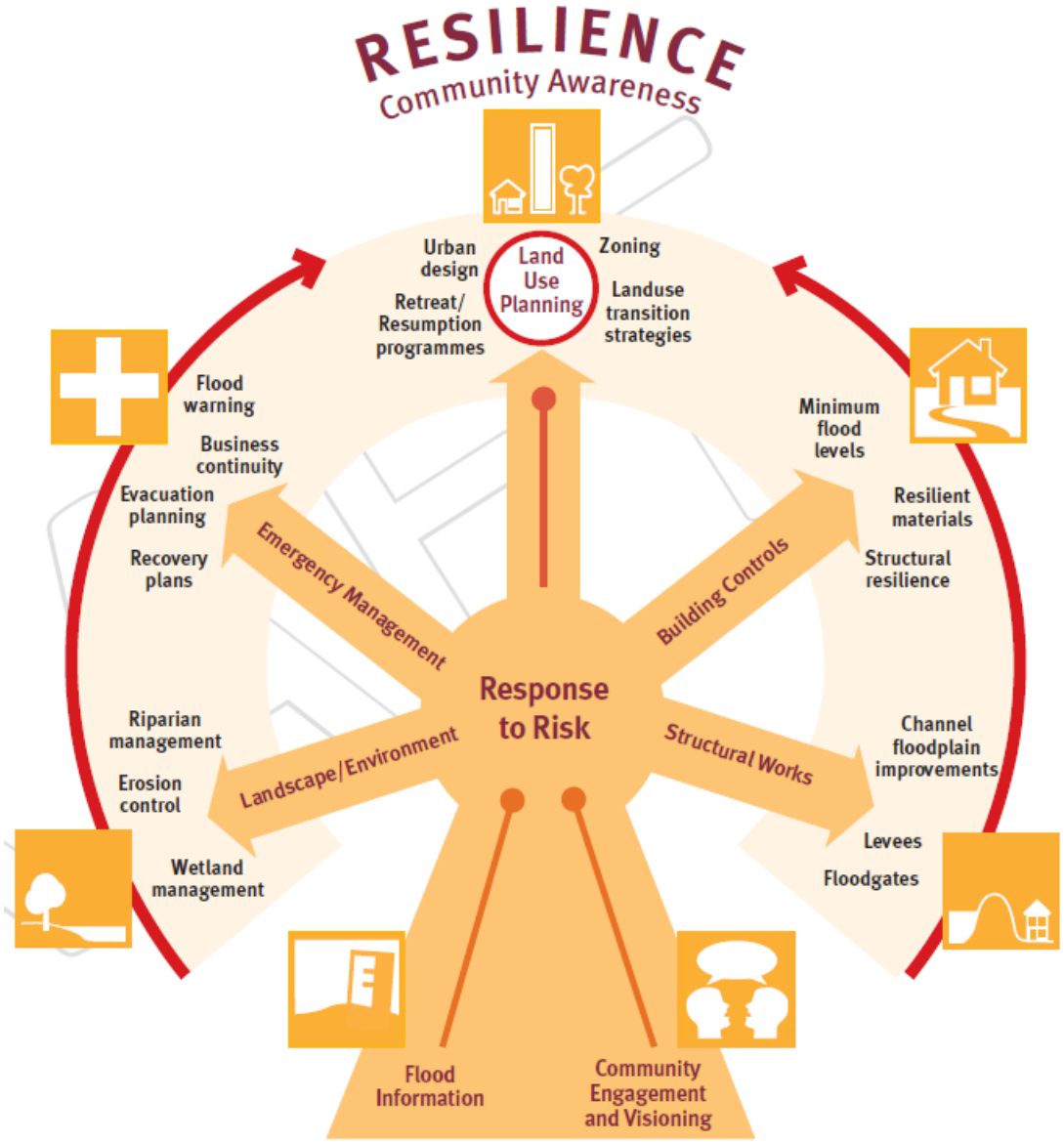


Figure 3 Building resilience measures - flooding (Source: QRA 2012)

The material presented above, whilst drawing heavily on Australian publications is in accordance with the European Union's *Water Framework Directive* (WFD).

2.2 Flood Risk Management in Tbilisi

Successful application of flood risk management principles as outlined above requires active cooperation between the various agencies involved. It is preferable for there to be formal recognition of the respective roles and organisational responsibility. This can be on an informal basis initially, although a formal basis is preferable in the long term.

From our recent discussions with the relevant agencies in Tbilisi, our understanding of current roles and responsibilities is as shown in Table 7.

Table 7 Agencies responsible for flood risk management in Tbilisi

Agency	**Responsibility for flood plain management**
National Environment Agency	Lead agency, responsible for: - Hydro-meteorological data collection - Flood forecasting and warning
Tbilisi City Hall	Responsible for infrastructure and development control within Tbilisi
Emergency Management Department	Responsible for response and recovery in disaster events
Other agencies likely to be involved in response and recovery phases	
Police and Ambulance Services	Maintaining public order during/after a disaster
Hospital Services	Treatment to persons injured in flood event
Military	Providing additional resources in major disasters
Animal welfare agencies	Housing and welfare of misplaced and injured pets and other animals
Non-Government Organisations (NGOs)	Assistance with food and shelter of displaced persons

It does not appear that there is any formal structure of cooperation between these agencies at present in Tbilisi and that such cooperation exists on an ad-hoc basis. From our discussions, delineation of some functions, such as the issue of flood warnings to the public was unclear even amongst agency staff.

Therefore, as a first step, we recommend the formation of a *Flood Risk Management Committee* with representatives from the above agencies to:

- Define current roles and responsibilities;
- Develop an appropriate structure for integrated flood risk management in Tbilisi;
- Implement structure, monitor and periodically review its performance.

3 Flood Mitigation Methods

This section provides an overview of both structural and non-structural flood mitigation methods.

3.1 General

As discussed above, flood risk is the combination of the following factors:

- The occurrence of a flood (hazard);
- The exposure of a community to the flood (people, buildings, farmland, infrastructure and so on);
- The ability of the community to respond to the flood exposure (resilience).

Hence, in order to reduce the flood risk, one or more of the following must be adopted:

- Reduce the magnitude and/or frequency of flooding;
- Reduce the community's exposure to flooding; and/or
- Increase the community's ability to cope with the flood and its aftermath.

3.2 Reduce the magnitude and/or frequency of flooding

As the flood hazard derives from natural phenomena (mostly rainfall), there is nothing which can be done to reduce these underlying causes.

Where there has been extensive deforestation resulting in increased runoff, it is possible to reverse this impact to some degree by re-afforestation. However, this takes many years before it becomes effective. Whilst the use of native tree species endemic to the area is to be preferred, an argument can be made for the use of faster growing species. No decision on species used should be made without a thorough investigation of the ecological consequences.

However, the typical situation, particularly in urban environments, is that land use changes from forest and farmland to urban development result in increased runoff volume from a given rainfall event as a significant portion of the land area is paved for roads and buildings. Furthermore, the built landform is responding faster in shedding water and the runoff reaches peak levels more quickly. These two factors taken together typically result in peak flow rates in heavily developed catchments being typically 3 or 4 times that from the undeveloped catchment.

In addition to the above, current climate change science indicates that, as a result of increasing temperatures, whilst annual rainfalls may be declining, the intensity of storm rainfalls is typically increasing, further exacerbating the flooding situation.

The magnitude of flood peaks can be reduced by the construction of flood control storage, i.e. by temporarily storing the floodwater and releasing it at a lower rate over a longer period of time. This is illustrated in Figure 4.

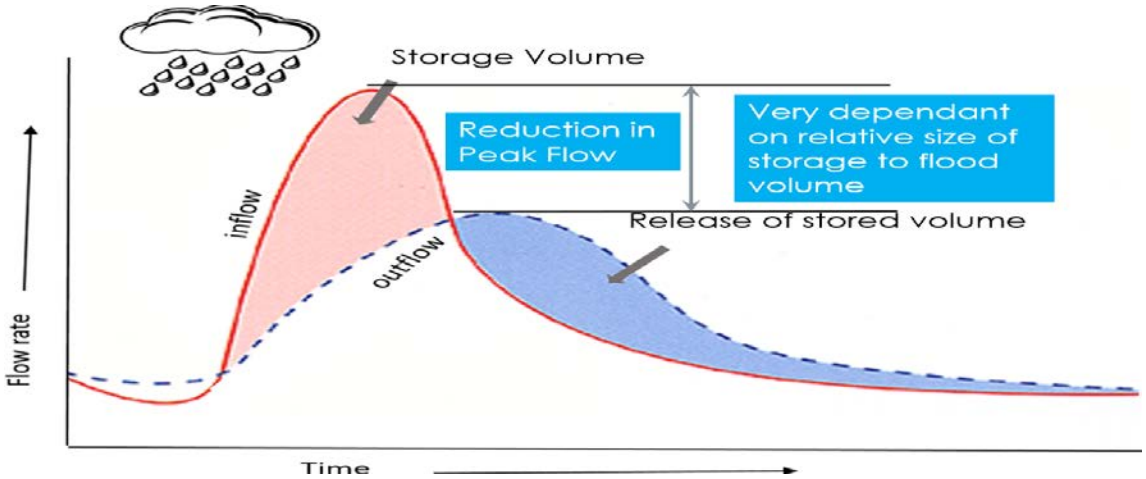


Figure 4 Principle of flood control storage (Source: QRA 2012)

3.3 Reduce the community's exposure to flooding

There are a number of ways in which the community' exposure to flooding can be reduced. These comprise both structural and non-structural measures:

- Structural measures include;
  - Flood control dams (also called detention basins – these can be wet or dry);
  - Levees (dykes);
  - Enlargement of channels and culverts;
  - Channel straightening (not recommended);
  - Diversion (bypass) channels.
- Non-structural measures include;
  - Land use planning/development controls;
    - Development restrictions based on Defined Flood Event (DFE);
    - No increase in runoff from new developments (on-site storage); and
    - Floor level controls.
  - House raising;
  - Flood proofing existing buildings
  - Building in flood resilient materials;
  - Removal of buildings from worst areas.

3.3.1 Structural Measures

a) Flood Control Dams (Detention Basins)

As outlined above, flood control dams (also known as detention basins) reduce the peak flow downstream by temporarily storing some or all of the upstream flow volume and releasing it at a slower rate over a longer period of time. This can be achieved on a catchment scale or on a development or sub-division scale. These dams are most effective if they are dry except during flood periods, that is, low flows are allowed to pass through the structure unheeded.

When higher flows occur, above the capacity of the low flow pipework the water level rises. Spillways are added to ensure that more extreme flood flows are passed downstream to

maintain the integrity of the structure. Hence, these structures are useful for mitigating the effects of small to medium floods, but have little or no effect in more extreme flood events. In the urban context, as noted in Table 6, the spillway is typically set at the 1% AEP (100year ARP) so that mitigation occurs up to this level.

The dry detention basin has the advantage of minimising the environment/ecological impacts downstream and also allows the storage area to be used for recreational use during non-flood times (for example as sports fields). Alternatively, small permanent water bodies can be formed in the lower levels which is useful in park conditions or to enhance the local environment, but this limits the flood storage capacity.

b) Levees (dykes)

Levees (also known as dykes) protect areas from flooding by creating a physical barrier between the watercourse and the protected area. Most commonly these are earthfill embankments but can also be concrete retaining walls or sheet piling walls where space is restricted.

The basic construction is shown in Figure 5 which shows an earthfill embankment levee creating a barrier between the floodwater and the developed area. Whilst levees are simple in concept, there are many problems associated with them relating both to a relatively high risk of failure, and also the expectations of those protected who often do not realise that, like the flood control dam, they only provide protection up to a certain flood event magnitude/probability.

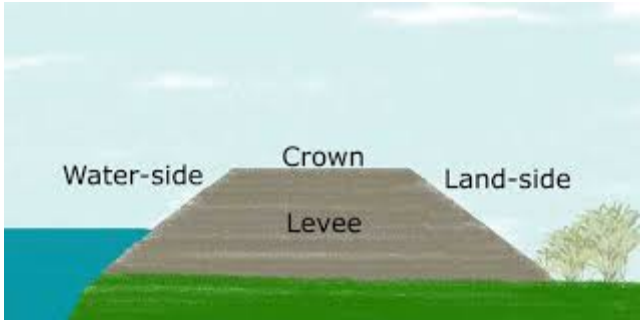


Figure 5 Basic levee construction

In flows exceeding the design flow the levee will overtop and even if it does not fail, the "protected area" will then flood. In other words, levees often result in false sense of security amongst the population protected.

Careful levee design is required to ensure that failure risk is minimised. There are a number of design issues to minimise the risk of failure. For example:

- The levee should be designed so that when it overtops it does so evenly along its length, requiring the crest slope of the levee to be the same as the flood slope in the watercourse at the design flow – this reduces the risk of flow concentrating in a few spots which can lead to erosion;
- Also, it is customary to include spillways at intervals along the levee crest at slightly lower levels than the crest. This allows for protected escapes and ensures that at the point of overtopping of the entire levee there is already some water behind the levee

covering the levee toe, which reduces the likelihood of the levee failing due to headwards erosion;

- Slope stability failure or slumping, if the levee slopes are too high;
- Rapid drawdown failure if pore water pressures, which build up during a flood event, are not dissipated quickly as the water level drops; and
- Levees can also fail during lower water levels due to piping failure, and the embankment design needs to take account of the hydraulic properties of the soil from which it is constructed to limit flow through the embankment and to allow for the safe drainage of water that does so.

Also, as the levee constrains the floodwater within the watercourse, it leads to an increase in flood levels within the length of the levee and upstream. Depending on the relative top of bank levels on both sides of the river, a levee on one side can force more floodwaters onto the opposite bank and raise flood levels there. Levees on both banks are rarely successful as they result in significant increase in flood water level upstream and increase the water volumes channelled downstream. All of these possible consequences need to be taken into account in the levee design.

Even with these limitations, levees are one of the main flood mitigation options and are widely used, but they do require careful design and appropriate community awareness of their limitations.

c) Enlargement of channels and culverts

Where the capacity of the watercourse is insufficient to contain flood flows, the banks overtop. In some locations, only those areas immediately adjacent to the river banks become inundated but, in some cases, the overtopping flow results in the initiation of flow in an overflow channel, which is often a former river course. This type of flow which breaks out of the normal watercourse is often referred to as a “flood breakout” or “flood breakaway”.

In either of these cases, levees can provide a solution. Alternatively, the channel cross-section can be increased to increase flood conveyance.

Where channel capacity has reduced over time by siltation, usually as a result of deforestation or other significant land use change upstream, dredging of the sediment to re-instate the former channel capacity is often considered. Whilst this may be successful in the short term, it is not a reliable long-term measure as further sedimentation will occur in subsequent floods negating the result of this work. Hence, dredging is not considered a sustainable solution and is to be avoided.

Where river sediments are sand and gravel, removal of these materials in a controlled manner for construction materials may be sustainable, but carries the risk of propagation of erosion both upstream and downstream. Extractive use of river sediments needs careful control and monitoring.

If channel enlargement is considered, it is preferable to leave the low flow channel in its existing form, as this minimises ecological damage, but to create “benches” or “terraces” within the overall river cross-section, as shown in Figure 6 to increase the overall flow capacity. In plan, the benching should follow the river shape at its high banks and not the shape of the

low flow channel i.e. the benching should be less sinuous than the low flow channel and more representative of the path followed by flood flows.

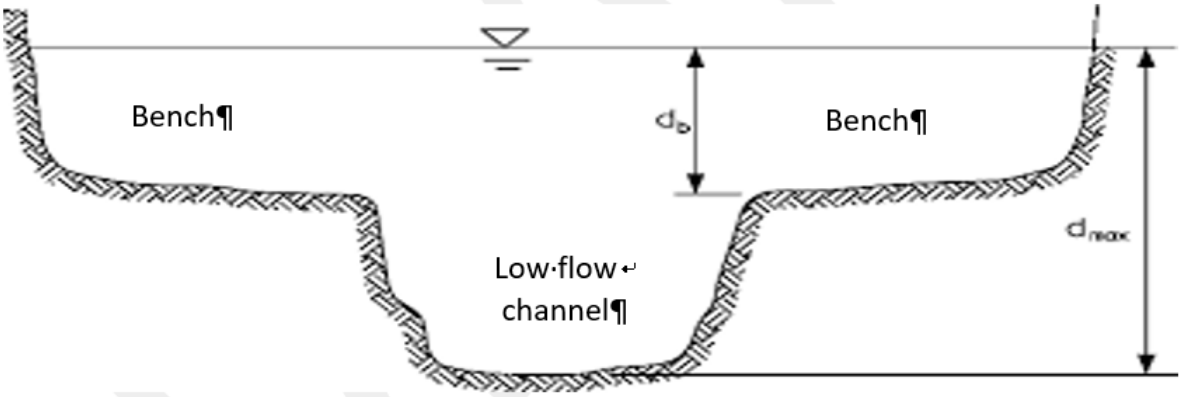


Figure 6 River "benches"

Channel enlargement, even by benching, can initiate a broader scale cycle of channel widening and deepening resulting in increased sediment load and ecological damage. Any such works should only be undertaken after a detailed investigation of the likely impacts on channel geomorphology and ecology.

Where culverts are used to convey the river flow under a road or rail embankment, flooding can result where the culvert capacity is insufficient. In this case increasing the culvert capacity to match that of the river channel upstream and downstream is a viable means of flood level reduction.

Where culverts have insufficient capacity, the water level rises on the upstream side and this may result in overtopping of the road. This may also result in scour downstream as with the culvert subject to pressure flow, a high velocity jet may form at its exit.

This same effect can result at bridges if the flow constriction is severe, but more commonly occurs with culverts.

d) Channel straightening

Channel straightening is usually achieved by cutting through the neck of one or more meanders as shown in Figure 7. The outcome is that the river course is shortened and its gradient is increased, increasing the flow velocity and channel capacity.

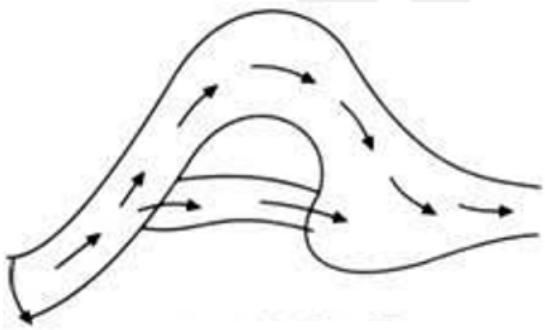


Figure 7 Meander cut-off

Whilst the development of meander cut-offs occurs naturally, its use as a means of increasing river conveyance is not recommended, unless there is careful design to prevent initiation of headwards erosion. Successful use of this technique requires control structures at each end of the cut-off to ensure that that cut-off operates only during flood and that the original river course is maintained. Failure to do so results, not only in the shortened course becoming the main course, but in the adverse effects of headwards erosion and of loss of biological diversity within the meander reach.

e) Diversion (bypass) channels

Diversion (or bypass channels) are sometimes constructed to relieve a river of high flow volumes at constricted sections of channel which have insufficient flow carrying capacity. The problems with this approach generally occur at the downstream end of the diversion where the flow is returned to the river, or sometimes to another river.

Engineering requirements are similar to those outlines above in respect of meander cut-offs.

3.3.2 Non-structural measures

Non-structural flood mitigation measures have the advantage that they do not require high capital cost but may take many years to reach their objectives and become effective.

- Non-structural measures include;
    - Land use planning/development controls;
        - Development restrictions based on Defined Flood Event (DFE);
        - No increase in runoff from new developments (on-site storage); and
        - Floor level controls.
    - House raising;
    - Flood proofing of existing buildings
    - Building in flood resilient materials;
    - Removal of buildings from worst areas.

a) Land use planning control

Land use planning controls for flood management are generally based on the definition of the *Defined Flood Event* (DFE). Whilst this is typically set to be the 100 year ARP (1% AEP) flood in urban areas, it should be selected based on socio-economic and environmental grounds to give the best trade-off between development and protection. As determination of the most appropriate level is complex, the default position is often taken.

The DFE is determined on a catchment by catchment basis with flood mapping studies used to define flood extents under both current conditions, and to include for future planned developments. Once the level of the DFE is obtained throughout the catchment, planning controls can be introduced for various types of development relative to the DFE. For example,

- New residential or commercial development is only permitted where it will not be flooded in the DFE;
- Critical infrastructure such as hospitals, emergency services facilities and fuel depots should be above a higher level (ranging from 500 year ARP (0.2% AEP) to probable maximum flood); and

- Other activities such as recreational areas and agriculture may be permitted below the DFE providing evacuation is possible in the DFE.

This is illustrated in Figure 8.

Figure 8 Land use planning related to flood probabilities (Source: WMAwater)

The most important of these is that new residential and commercial developments must be built so that they do not flood in the DFE. In addition, changes to existing developments must meet the desired new flood protection standards

In order to allow for uncertainties in the estimation of the DFE, flood level controls are also often introduced requiring minimum floor levels to be some given height above the DFE depending on the use (for example these are typically between 300mm and 500mm above DFE for residential floor levels).

Also, whilst individual future developments may not worsen flooding significantly, the cumulative effect of many such developments can have a significant effect. Many jurisdictions limit this impact by requiring that the peak runoff post-development does not exceed the pre-development value. This requires the provision of on-site flood control storage which is often provided within parks or recreational areas which form part of the development.

In older towns and cities, there are, typically, significant areas of development below the DFE level. The aim in that situation, is to require compliance with the planning controls when re-development work is undertaken. Hence it may take many years to reduce the flood risk in these areas by means of planning controls alone.

b) House Raising

Where houses built of lightweight materials are subject to flooding, most notably timber houses built on timber or concrete piers, it is possible to physically raise the houses by jacking them up and installing longer piers. This is not feasible where houses of built of brick, stone or concrete blocks on a concrete slab base.

Where houses are raised, it is important that utilities, especially the electricity supply, are also raised above DFE.

c) Flood proofing

Existing buildings can be flood-proofed to some extent but this can be costly and of limited value. The external walls (and basement walls where present) can be made watertight by the application of various paints and membranes or with plastic or rubber sheeting. However, if the building is subject to movement due to water pressure on the structure, cracking may occur, and the lifetime of such measures may be very limited.

Flood proofing of new buildings is easier and more effective, but should not be required if the type of land use planning controls outlined above are in place,

d) Building in resilient materials

Similarly, it is possible to limit flood damage to both existing and new buildings by the use of water resilient materials in both the structure and the building contents and in ensuring that electrical wiring is above the potential flood level.

In existing buildings, the bulk of flood damage occurs with over floor flood depths of up to about 150mm assuming that there has been time to remove the more expensive contents (or move them to higher levels). This is because the electrical power cables and fittings are usually located just above floor level, and non-resilient materials such as plaster board, once damaged must be replaced. Also, most kitchen and bathroom furniture is made of chip-board or other non-resilient materials and water damage can be extensive even at shallow depths.

Where over floor flooding has occurred the replacement of these non-resilient materials with water resilient materials should be considered.

e) Removal of buildings from the floodplain

As a last resort removal of buildings that were constructed in the floodplain may be required. Such decision may be made based on the constricting effect and respective loss of floodplain storage and upstream flooding such buildings may cause when constructed in high density. Further, removal may also be considered if a risk to the building occupants is significant and relocating persons to reduce the risk is the chosen strategy.

Depending on local laws, the buildings may be acquired by the relevant agency through voluntary or compulsory sale, and subsequently demolished. The area is then redeveloped for a more compatible use such a parkland.

3.4 Increase the community's resilience to flooding

Approaches under this category are all non-structural in nature and include:

- Flood Mapping;
- Education/awareness campaigns;
    - Raising community awareness of flooding issues;
    - How to understand and make use of flood warning information;
- Flood forecasting and warning;
    - Meaningful, timely, preparation of flood forecasts and the dissemination of flood warning information; and
- Disaster Management Planning and emergency services response.

a) Flood Mapping

Flood mapping is a fundamental requirement in raising community resilience as it provides both the data required by the responsible agencies for good planning and is also a very useful tool to enable the community to understand the flood risk. Use of animations of the development and recession of the flood wave has also been found to be very useful in this regard.

b) Flood forecasting and warning

Hydraulic models for flood mapping may also be used for real time flood forecasting with a combination of rainfall and upstream river level data. In small catchments where flood warning "lead" times are short, forecasts are generally based on rainfall data alone, but in larger river systems, more accurate forecasts can be developed incorporating upstream water levels.

The aim of flood forecasting is to provide information to the public in respect of the estimated severity of the imminent flood (in terms of flood height) together with the time at which flooding is expected to start (and its likely duration). This information empowers the community to act to remove themselves, their pets, vehicles and, if necessary, housing commodities, to higher ground. The longer the warning or "lead" time, the greater amount of damage can usually be avoided.

This information may be made available to the community via a range of techniques, the most recent of which is by the use of SMS messaging. Other methods include television and radio broadcasting or the use of sirens.

In addition to receiving the warning in a timely manner, it is essential that the communities are able to interpret the warning as it relates to their own circumstances (i.e. location and elevation level). The official warnings usually refer to specific locations, so some means of interpretation is required. This information can be provided by a variety of means including:

- The distribution of flood maps showing flood levels at key points and corresponding flooding elsewhere;
- By the use of street markers to mark flood levels on street furniture such as lamp posts or on individual buildings – a colour coding representing "minor", "moderate" and "major" floods may be used, alternatively the levels of historic floods may be used.

c) Education/awareness campaigns

Especially in areas where dangerous flooding is infrequent or has not occurred for many years, it is likely that a significant proportion of the community is not aware of the flood risk.

Hence, there is a need to raise community awareness by the circulation of the flood maps, making them available in public buildings such as City Hall and public libraries, and via the internet. Newspaper articles and radio interviews can also be useful in this regard.

In addition to providing the basic information regarding areas at risk of flooding, the public awareness campaigns can also provide information as to how to interpret and respond to flood warnings.

Well run awareness campaigns can significantly increase the community's resilience to flooding.

d) Disaster management planning and emergency services response

As discussed in Section 2.2 hereof, it is recommended that a *Flood Risk Management Committee* be formed to develop a flood risk strategy for Tbilisi as a whole.

Part of the work of this committee (or whatever equivalent structure is put in place) will be to develop a *Flood Disaster Management Plan* as part of the city wide *Disaster Management Plan.*

This should include a clear statement as to the responsibilities of the various agencies, the operational structure during an emergency period, and specific actions to cover the range of circumstances envisaged.

Training activities need to be undertaken with disaster scenarios so that the plan can be fine tuned before being needed in a real disaster situation. The plan should be reviewed initially after 1 or 2 years, then in 5 yearly intervals.

3.5 Residual Flooding

Residual flooding is that which when the design floods are exceeded. Unless, flood mitigation works are designed for the probable maximum flood, which is hardly ever the case, there is an, albeit low, risk that flooding in excess of the design flow will occur at some time.

Whilst works are not designed for this residual risk, consideration should be given in flood risk planning of the consequences of residual flooding, and the development of contingency plans to deal with this situation. For example, if floods in excess of design floods are expected, orderly evacuation of the affected area may be required.

4 Application to the Leghvtakhevi River

This section considers specific flood mitigation interventions in the Leghvtakhevi River. This is based on consideration of both structural and non-structural interventions which are considered to be appropriate.

The effectiveness of the structural measures which have potential are evaluated by modifying the hydraulic model. However, this is not possible with the non-structural measures.

4.1 Current Conditions

The Leghvtakhevi River is a small catchment (catchment area 24km^2) situated in the south-western part of Tbilisi. Its length is about 10km and it flows into the Kura River about 100km downstream of the Metecki Bridge on the Kura River in Tbilisi via large twin culverts.

For the purposes of this flood mitigation evaluation, the river can be divided into 4 reaches, namely:

- Reach 1 upstream of the Tbilisi – Kojori Road bridge – this reach is undergoing active residential development;
- Reach 2: downstream from Reach 1 to the Botanical Gardens;
- Reach 3: through the Botanical Gardens; and
- Reach 4: discharge culverts to Kura River.

These reaches are shown in Figure 9.

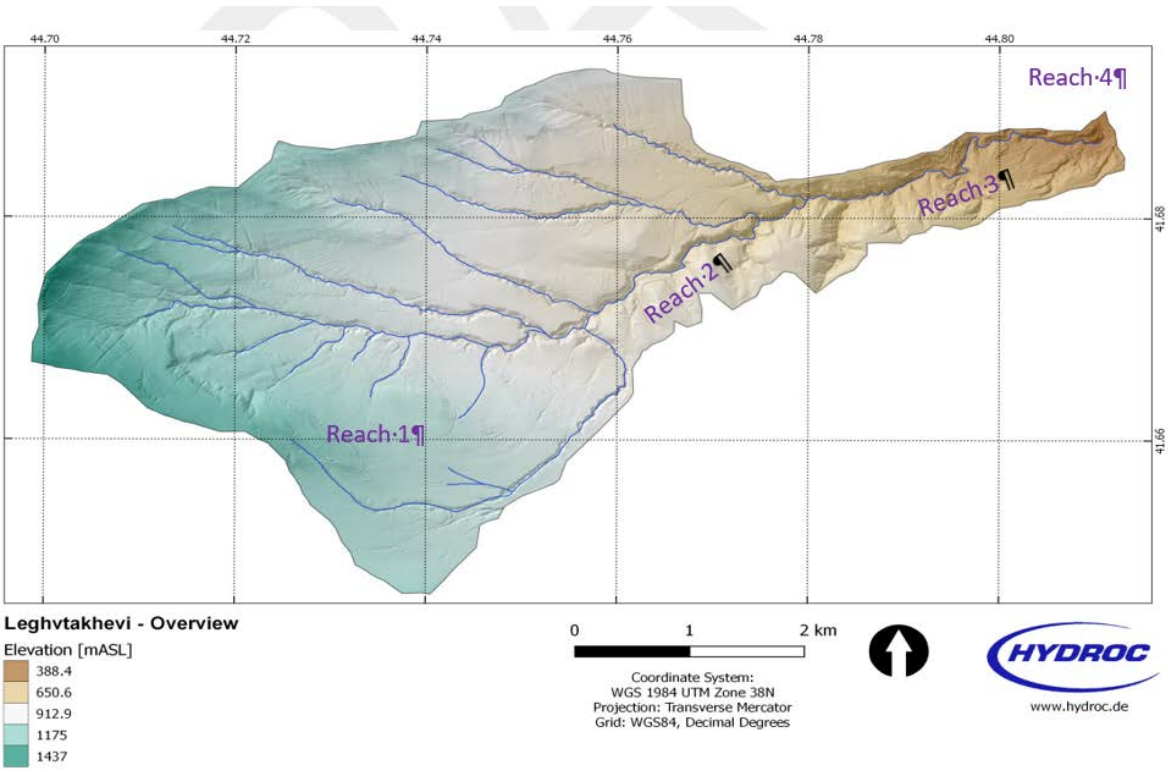


Figure 9 River Reaches

The recent and ongoing development in Reach 1 is increasing the flood runoff and will exacerbate flooding further downstream.

It is possible that a flood control storage could be constructed within Reach 2, to mitigate this effect. A number of very small dams have previously been constructed along the river in reaches 2 and 3 but most of these are dysfunctional or have failed. It is not clear if these were constructed to mitigate flood flows or to act as sediment traps. It is clear that the dams have intercepted sediment and in most the sediment is at or close to the dam crest.

4.2 Flood Problems

The hydraulic modelling for the Leghvtakhevi River has identified the 10 flood prone areas or 'hotspots" as shown in Table 8 and Figure 10.

Table 8 Identified flood hotspots

Flood Prone Area No	Reach	Issue
1	Main river	Flooding in Downstream Urban Area
2	Main river	Flooding on road and on property in house upstream Botanical Gardens
3	Main river	Flooding at large New Building
4	Main river	road flooding - insufficient culvert capacity
5	1st left bank tributary	road flooding - insufficient culvert capacity
6	2nd left bank tributary	road flooding - insufficient culvert capacity - resulting in breakout flow to the north
7	4th left bank tributary	road flooding - insufficient culvert capacity
8	1st right bank tributary	road flooding - insufficient culvert capacity
9	1st right bank tributary	road flooding - insufficient culvert capacity and flow out of catchment to adjacent river
10	1st right bank tributary	road flooding - insufficient culvert capacity - resulting in breakout flow to the north
11	1st right bank tributary	road flooding - insufficient culvert capacity - resulting in breakout flow to the south

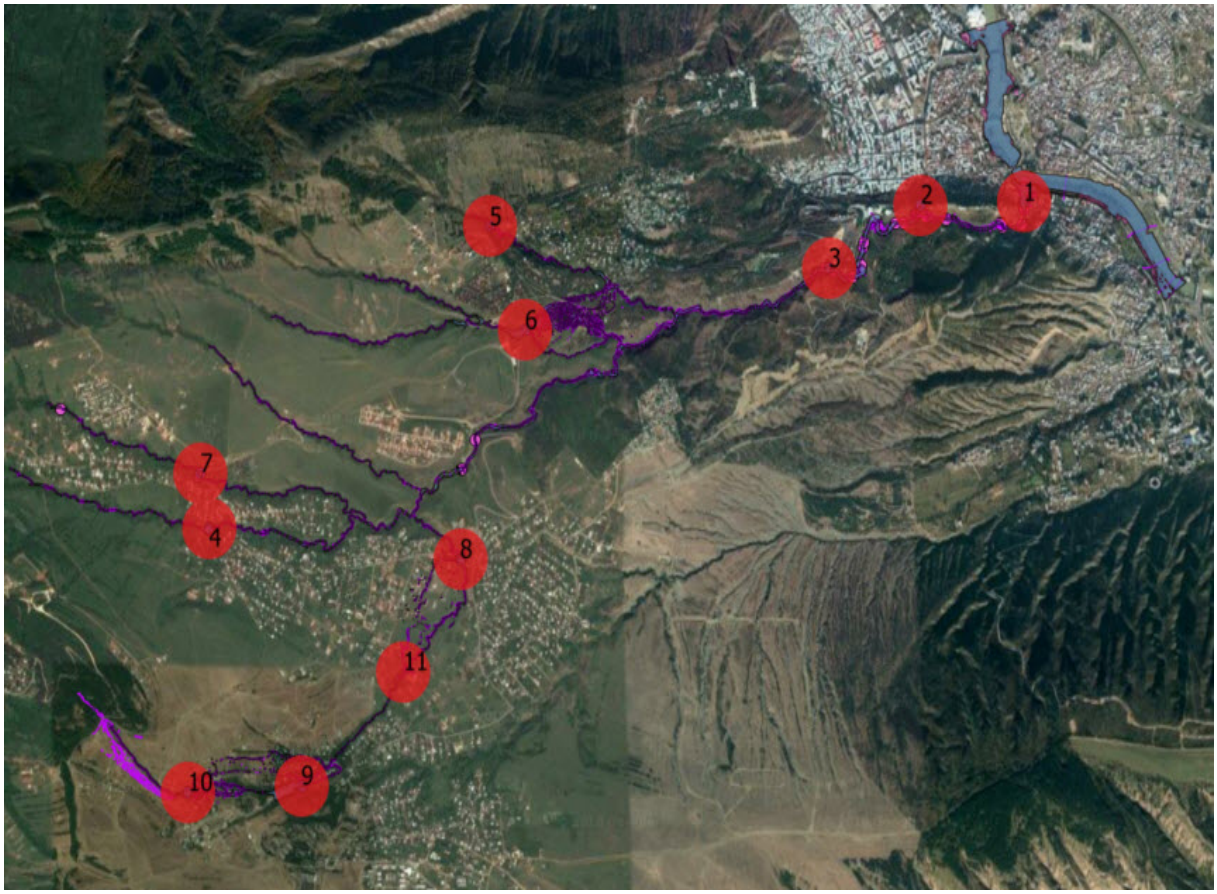


Figure 10 Identified Flood "Hotspots"

The flood impact was analysed in the Deliverable 7 of this technical assistance ('Report on Flood Mapping'). Nonetheless, the following should be noted:

- The flooding mechanism in the Leghvtakhevi catchment can be explained mainly by the lack of capacity, in either culverts or in the channel itself.
- The most significant flood impact can be found in the downstream end of the catchment, due to the lack in capacity in the last culvert close to the junction with the Kura River.
- There is minor flooding in several road crossings due to the lack of capacity in culverts. This leads in some occasions to either some properties being affected or to widespread overland flooding over fields or unpopulated areas.

4.3 Flood Mitigation Option Approach

In most flood mitigation studies, the development of a broad range of options (long list) is often followed by the selection of some of these options (short list). The main approach is as follows:

- A long list of options aimed to mitigate flooding in the catchment is developed.
- The list and approach is discussed with stakeholders.
- Some options are discarded during this process due to their unsuitability, their high cost or other reasons.
- A short list of options is created. These are the options that are studied further using hydraulic modelling tools.

The idea behind this approach is to limit the resources spent on the detailed analysis of all the possible options and to avoid analysing options that may not be suitable for different reasons

In the following sections the followed process will be described in detail.

4.4 Long list of Flood Mitigation Options and Discussion with Stakeholders

A long list of flood mitigation options was developed by HYDROC's experts (Table 9). It should be noted that the proposed options was limited due to the river characteristics and the flood impact.

Table 9 Long list of flood mitigation options

Flood Prone Area No	Flood Mitigation Option
1	Re-opening of 2nd culvert
1	Levees
2	Upstream Storage
3	Upstream Storage
4	increase culvert capacity
5	increase culvert capacity
5	Small dam upstream
6	increase culvert capacity
6	Small dam upstream
7	increase culvert capacity
7	Small dam upstream
8	increase culvert capacity
8	Small dam upstream
9	increase culvert capacity
10	increase culvert capacity
10	Levees
11	increase culvert capacity

The main approach regarding the flood mitigation structural options was thoroughly discussed with relevant stakeholders during a specific mission to Tbilisi. This included the National Environment Agency, the Emergency Management Agency and the Tbilisi City Hall. These

discussions have been outlined in progress report by the consultancy team. Nonetheless, the following can be detailed:

- The main project objectives were outlined in all the meetings.
- The initial results from the flood mapping exercise were presented and discussed.
- The basics of flood risk management and flood mitigation, prevention and preparedness were outlined.
- The main approach regarding flood mitigation from a structural point of view in the Leghvtakhevi River was explained. A combination of levees, culvert enhancements and upstream storage was proposed.
- There was no significant input from any of the noted stakeholders regarding this approach.

4.5 Short List of Proposed Flood Mitigation Options

The modelled flood levels under existing conditions and with proposed flood mitigation are outlined in the following paragraphs for the shortlisted flood mitigation options. These are based on 5 year ARP (20% AEP) allowing for climate change effects, which is equivalent to the current 100 year ARP (1% AEP) without climate change.

Points 2, 3, 5, 6, 9 and 10 did not require upgrading for 5 year plus climate change flood immunity. Proposed upgrades for the other flood "hotspots" are outlined in the following paragraphs.

It should be noted that the options presented in the following sections are the result of a detailed hydraulic modelling analysis. The culvert and dam dimensions proposed below are the final results yielded by the hydraulic model, and that these dimensions have been refined in order find the correct balance between the cost and the benefit from a flood mitigation perspective. This process can be summarised in Table 10.

Table 10 Proposed Options

Flood Prone Area	Mitigation Option	Suggested Modelling Approach	Discarded Options	Baseline Culvert Size	Final Culvert Size
1	Re-opening of 2nd culvert	Re-opening of 2nd culvert	None	No culvert	Arch Culvert
2	Upstream Storage	Dam Located upstream of hydrological station	None		2.4
3					
4	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.		Circular 1.2m	**two box 3x3m**
5	increase culvert capacity	Increase the number of culvert openings and size.	Small dam upstream	Box 1.68x1.26m	**three 2.1x1.5**

6	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.	Small dam upstream	Circular 2.4m	**three box 3x3**
7	increase culvert capacity	Increase the number of culvert openings and size.	Small dam upstream	2 circular 1.0m	**six 2.1x0.9m**
8	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.	Small dam upstream	Circular 1.2m	**three box 3x3m**
9	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.		Circular 1.0m	**three box 3x3m**
10	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.		Circular 1.0m	**three box 3x3m**
11	increase culvert capacity	Increase the number of culvert openings and size. Lowering of the cross section.		Circular 1.0m	**three box 3x3m**

As it can be observed, some options were discarded during the hydraulic modelling analysis. This was the case for most of the culvert crossings, because the increase of upstream storage was initially tested with the inclusion of a dam. However, the dam dimensions needed to mitigate flooding in the road crossings cannot be justified, it would be a very expensive way of dealing with road flooding.

In the following sections the shortlisted flood mitigation structural options are discussed.

4.4.1. Point 1 - Downstream Culverts to Kura River

There are currently two large culverts which discharge flows from the Leghvtakhevi River into the Kura River, but one of these is no longer operational, as it was described in the Deliverable 7 ('Report on Flood Mapping').

Some simulations have been undertaken in order to ascertain the merit of re-opening the second (right) culvert. There are some limitations to this because the size of this culvert is uncertain. However, the simulations were undertaking assuming that the culvert size inside was not being reduced, and therefore the outside (visible) shape and size was considered.

These tests indicated that the opening of the second culvert will limit the flooding downstream (Figure 11). While the simulations for the baseline scenario (one culvert open) predict overtopping of the road at this location, the modelling results indicates that the opening of the second culvert would reduce the water levels at this location. Under the same conditions, no overtopping is predicted, but the culverts will be surcharged.

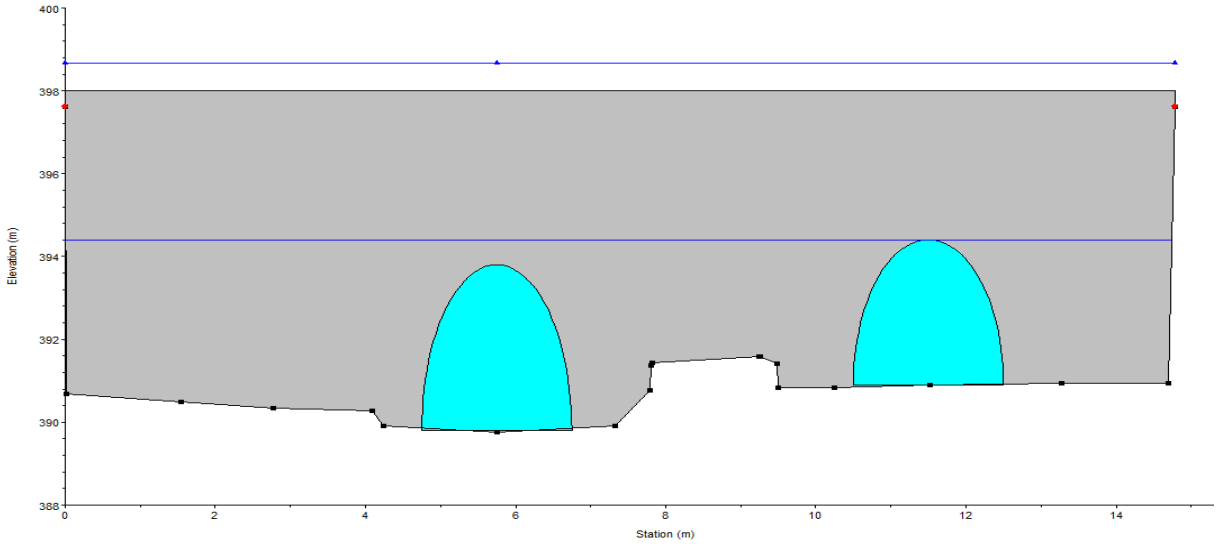


Figure 11 Results for second culvert opening in Point 1. The upper line corresponds to the 100yr event with just one culvert. The lower line corresponds to the 100yr event with the second culvert opened.

In addition it is recommended raising the height of the banks in order to further mitigate flooding immediately upstream of this culvert entrance (and therefore flooding in the urban area of Tbilisi). The highest water elevations predicted at this location are shown in Table 11.

Table 11 Water Surface Elevation immediately upstream of the culvert entrance

Return Period Event	**Water Surface Elevation (m)**
100yrCC	397.02
100yr	396.62
5yrCC	396.77
5yr	395.67

4.4.2. Points 2 and 3 - Upstream Storage

The possibility of including an upstream storage to reduce flood levels in the lower reaches (points 2 and 3) was investigated. The dam was located upstream of the bridge where the water level recorder is located near one of the failed small dams. This location is shown in Figure 12. The dam would need to be a concrete gravity dam with the spillway weir over the dam crest.

Figure 12 Location of Possible Dam

The dam crest is at 802 m, while the spillway level would be at 799 m. The width of the spillway would have to be 25 m in order to ensure that there is no overtopping for either the 5 year (with climate change) or the 100 year (baseline) events (Figure 13).

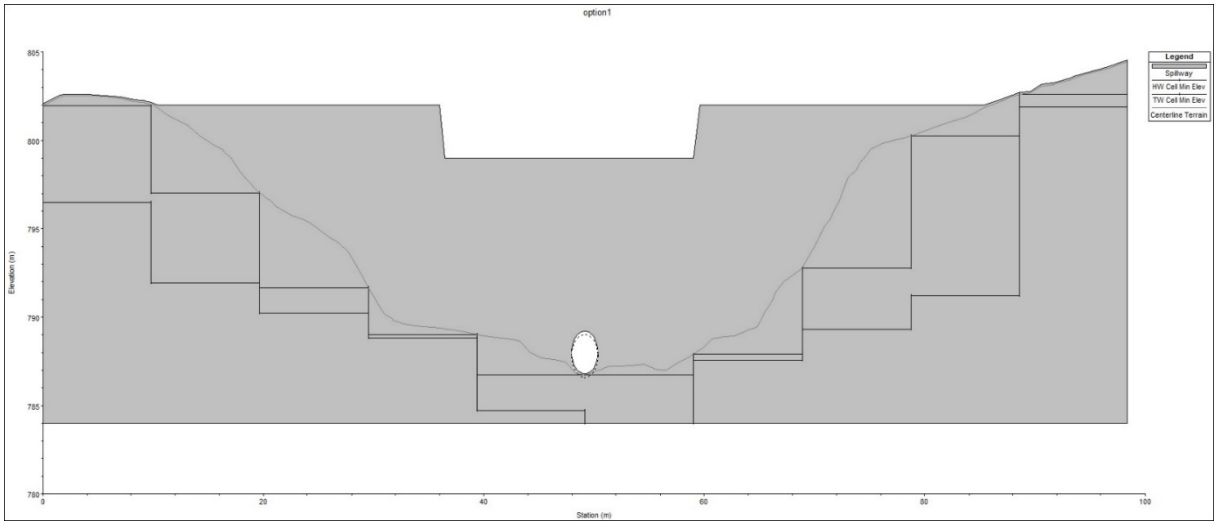


Figure 13 Dam

At the dam location, the reduction in flow passing downstream can be observed in Figure 14. There is a reduction of 50 m^3/s for the 100 year event and of 40 m^3/s for the 5 year event.

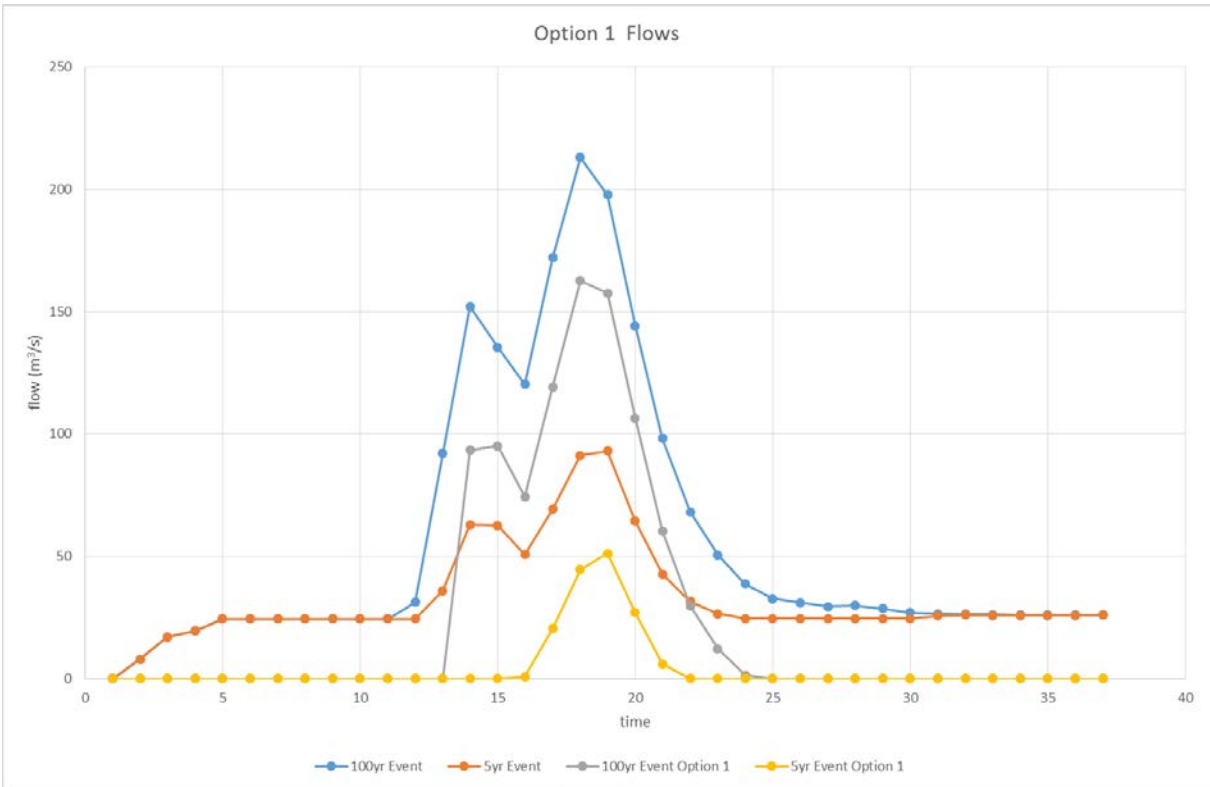


Figure 14 Flows through the dam location

However, modelling of the downstream area shows that there is negligible reduction in flooding downstream (maximum of 0.6m), so this option is not warranted.

4.4.3. Point 4 – Culvert Upgrade

The over-road flooding at this point can be eliminated for the 5 year event with climate change by increasing the culvert size as shown in Figure 15.

Existing conditions 5 yr CC
(with climate change)
Existing culvert 1 no 1.2m diameter
Flow through culvert 0.5m^3/s
Flow over road 9.5m^3/s
2 houses flooded
Road crossing flooded

With culvert upgrade 5yr CC
Existing culvert replaced by
2 no 3m x 3m box culverts
Flow through culvert 10.0m^3/s
Flow over road 0m^3/s
No flooding

Figure 15 Culvert Upgrade - Point 4

As it can be observed in Figure 15, the required change of the culvert size in order to accomplish the flood reduction for the 5 year (with Climate Change) event would be from a 1.2m diameter culvert to two 3x3m box culverts (Figure 16).

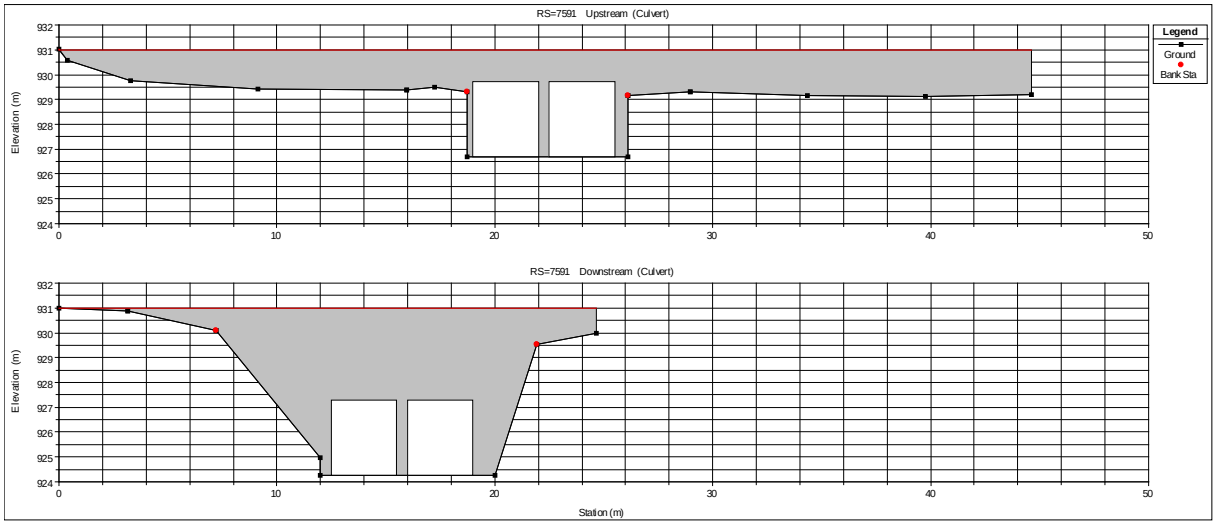


Figure 16 Culvert Upgrade – Point 4

It should be added that in order to accommodate this new culvert in the existing location, the cross section in that location would have to be modified too (Figure 17).

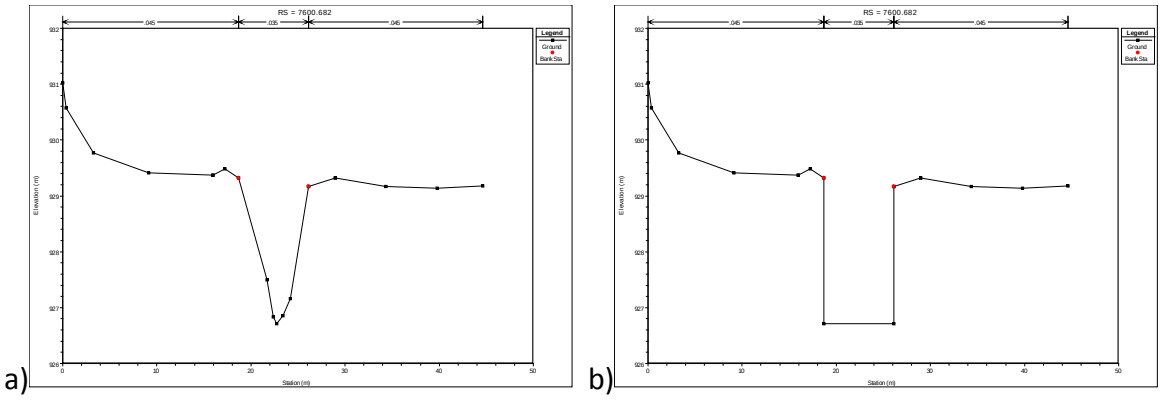


Figure 17 Cross Section Modification – Point 4. a) Existing cross section. b) Required cross section

The invert levels for the new culvert would be the same as for the old culvert, although obviously the soffit level for the new culvert would change due to the increase in culvert height.

4.4.4. Point 7 – Culvert Upgrade

The over-road flooding at this point can be eliminated for the 5 year event with climate change by increasing the culvert size as shown in Figure 18.

Existing conditions 5yr CC Existing culvert 2 no diameter 1.0m Flow through culvert 3.3m^3/s Flow over road 22.8m^3/s Road crossing flooded	With culvert upgrade 5yr CC Existing culvert replaced by 6 no 2.1m x 0.9m box culverts Flow through culvert 26.1m^3/s Flow over road 0m^3/s No flooding

Figure 18 Culvert Upgrade - Point 7

As it can be observed in Figure 18, the required change of the culvert size in order to accomplish the flood reduction for the 5 year (with Climate Change) event would be from a 1.0 metres diameter culvert to six 2.1x0.9m box culvert (Figure 19).

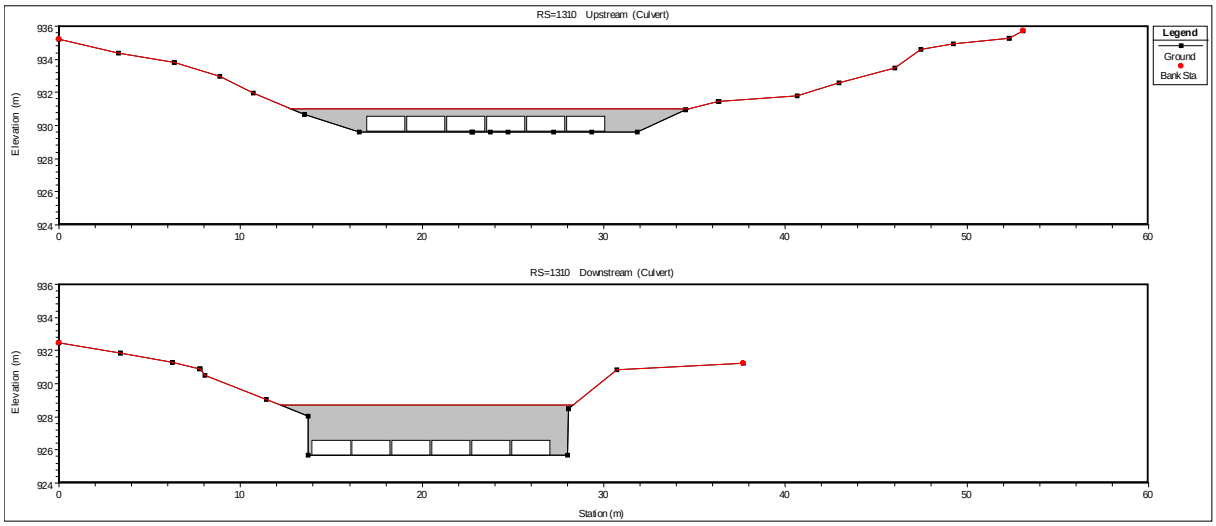


Figure 19 Culvert Upgrade – Point 4

In order to accommodate this new culvert in the existing location, the cross section in that location would have to be modified too (Figure 20).

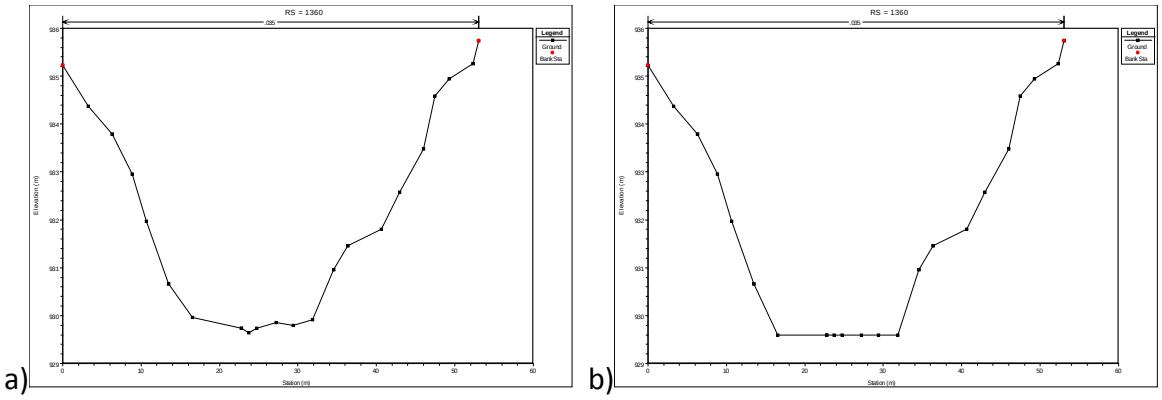
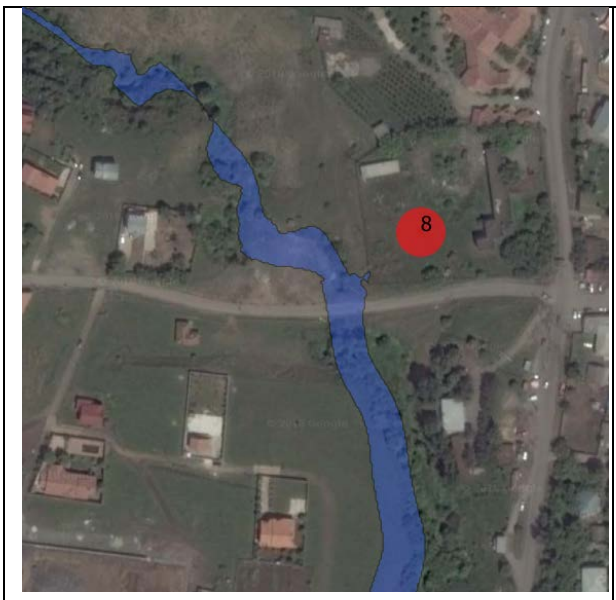


Figure 20 Cross Section Modification – Point 4. a) Existing cross section. b) Required cross section

The invert levels for the new culvert would be the same as for the old culvert, although obviously the soffit level for the new culvert would change due to the increase in culvert height.

4.4.5. Point 8 – Culvert Upgrade

The over-road flooding at this point can be eliminated for the 5 year event with climate change by increasing the culvert size as shown in Figure 21.



Existing conditions 5 yr CC
Existing culvert 1 no 1.2m diameter

Flow through culvert 2.0m^3/s
Flow over road 8.0m^3/s
Road crossing flooded

With culvert pgrade 5yr CC
Existing culvert replaced by
3 no 3.0m x 3.0m box culverts
Flow through culvert 10.0m^3/s
Flow over road 0m^3/s
No flooding

Figure 21 Culvert Upgrade - Point 8

As shown in Figure 21, the required change of the culvert size in order to accomplish the flood reduction for the 5 year (with Climate Change) event would be from a 1.2 metres diameter culvert to three 3x3m box culvert (Figure 22).

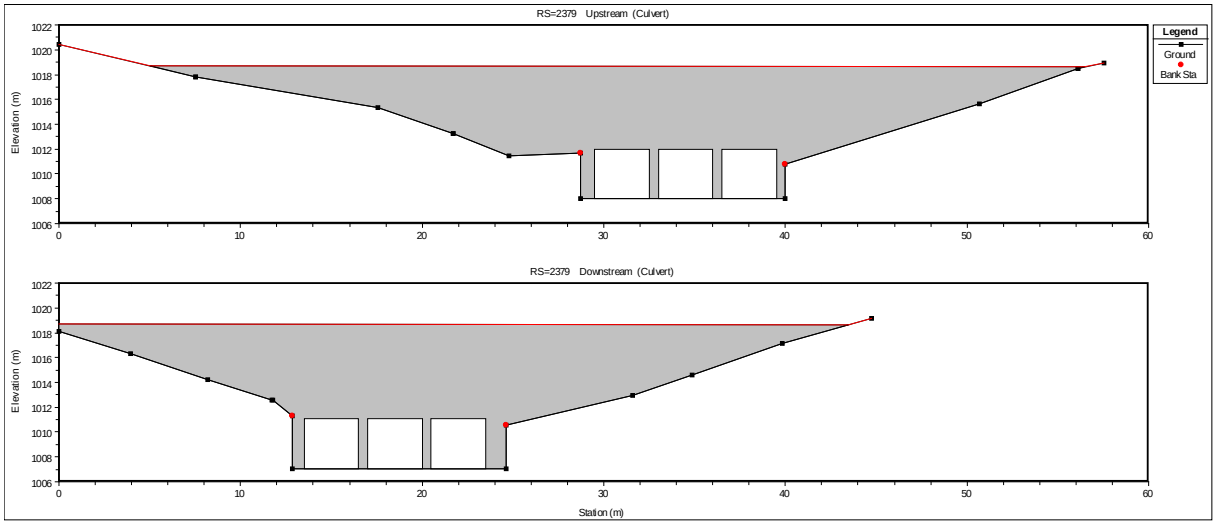


Figure 22 Culvert Upgrade – Point 4

It should be added that in order to accommodate this new culvert in the existing location, the cross section in that location would have to be modified too (Figure 23).

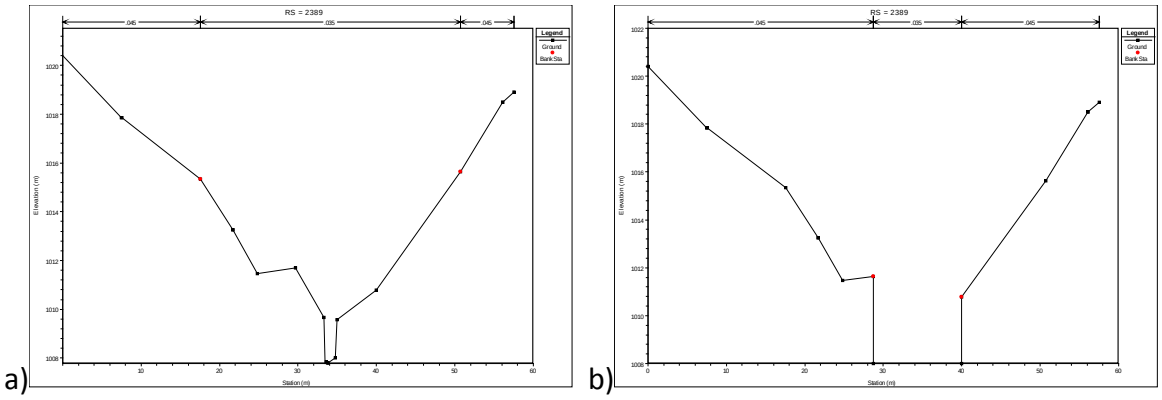


Figure 23 Cross Section Modification – Point 4. a) Existing cross section. b) Required cross section

The invert levels for the new culvert would be the same as for the old culvert, although obviously the soffit level for the new culvert would change due to the increase in culvert height.

4.4.6. Point 11– Culvert Upgrade

The over-road flooding at this point can be eliminated for the 5 year event with climate change by increasing the culvert size as shown in Figure 24.

Existing conditions 5 yr CC Existing culvert 1 no 1.2m diameter Flow through culvert 2.0m^3/s Flow over road 11.3m^3/s Road crossing flooded	With culvert upgrade 5yr CC Existing culvert replaced by 3 no 3.0m x 3.0m box culverts Flow through culvert 13.3m^3/s Flow over road 0m^3/s No flooding

Figure 24 Culvert Upgrade - Point 11

As shown in Figure 24, the required change of the culvert size in order to accomplish the flood reduction for the 5 year (with Climate Change) event would be from a 1.2m diameter culvert to three 3x3m box culvert (Figure 25).

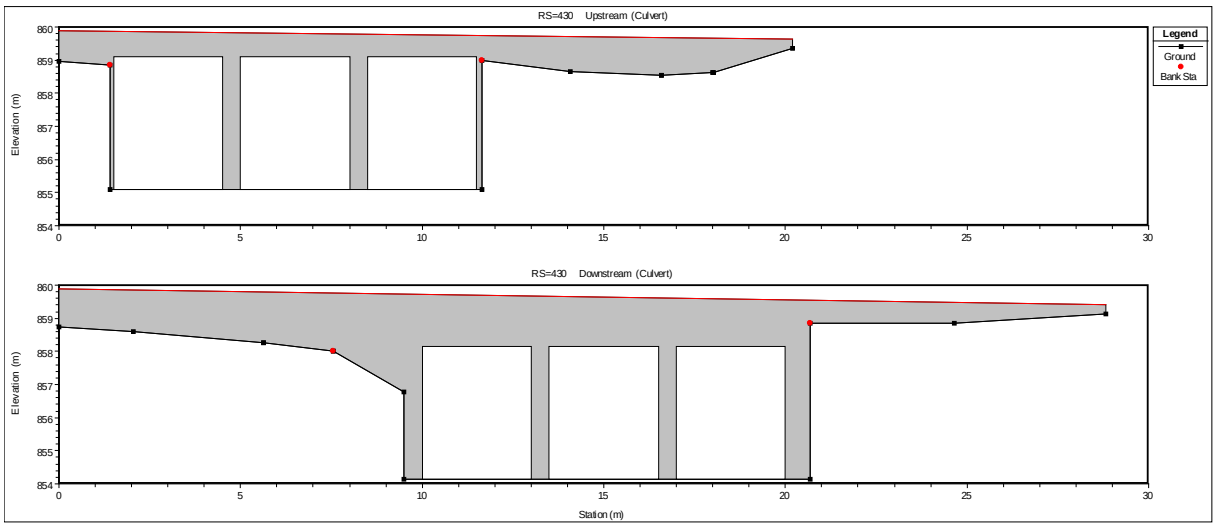


Figure 25 Culvert Upgrade – Point 4

In addition, in order to accommodate this new culvert in the existing location, the cross section in that location would have to be modified too (Figure 26).

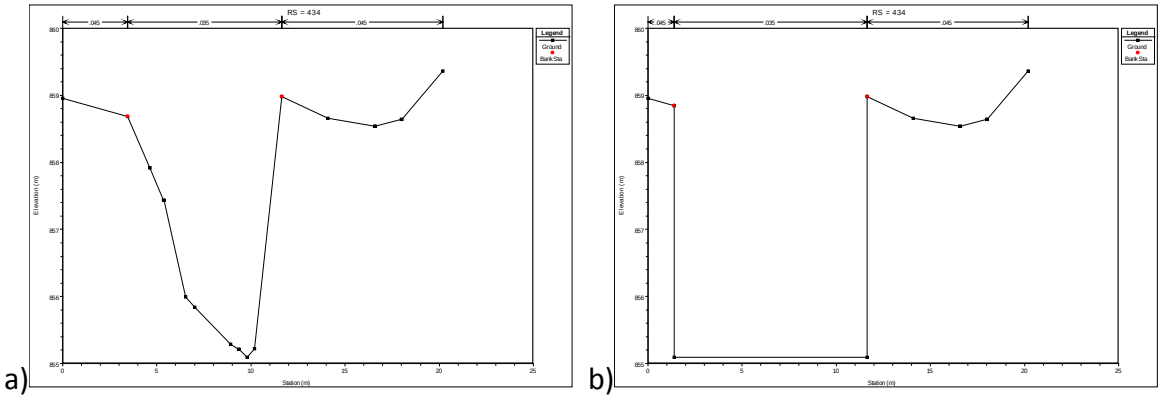


Figure 26 Cross Section Modification – Point 4. a) Existing cross section. b) Required cross section

The invert levels for the new culvert would be the same as for the old culvert, although obviously the soffit level for the new culvert would change due to the increase in culvert height.

4.6 Option Analysis

All the analysed and studied options are listed in Table 12 with an associated rating. The rating description is as follows:

- Flood benefit rating: the flood rating has been calculated depending on the impact that the flood mitigation measures have in flooding, from 1 to 5, 1 being a lesser impact

and 5 a greater impact (reduction in the number of properties predicted to be affected by flooding).

- Cost rating: the cost rating has been calculated depending on the estimated associated cost to implement the flood mitigation options. In this case a cost rating of 5 indicates a minimum cost while 1 indicates a high cost.
- Ecological impact rating: the ecological cost has been calculated considering the impact that the interventions would have on the ecological status of the river. A rating of 5 indicates no or beneficial impact while 1 indicates a significant impact on the ecological status.

Therefore, the higher the total rating, the more recommended the intervention is. In this case, any option with a total rating higher than 10 has been recommended.

Table 12 Analysed Options

Flood Area	Mitigation Option	Baseline Culvert Size	Final Culvert Size	Flood Benefit Rating	Cost Rating	Ecolo. Impact Rating	Total Rating	Recommended
1	Re-opening of 2nd culvert	No culvert	Arch Culvert	4	5	5	14	Yes
2 and 3	Upstream Storage		2.4	2	1	2	5	No
4	increase culvert capacity	Circular 1.2m	two box 3x3m	2	2	5	9	No
5	increase culvert capacity	Box 1.68x1.26m	three 2.1x1.5	4	2	5	11	Yes
6	increase culvert capacity	Circular 2.4m	three box 3x3	4	2	5	11	Yes
7	increase culvert capacity	2 circular 1.0m	six 2.1x0.9m	2	2	5	9	No
8	increase culvert capacity	Circular 1.2m	three box 3x3m	2	2	5	9	No
9	increase culvert capacity	Circular 1.0m	three box 3x3m	2	2	5	9	No
10	increase culvert capacity	Circular 1.0m	three box 3x3m	2	2	5	9	No

11	increase culvert capacity	Circular 1.0m	three box 3x3m	2	2	5	9	No

4.7 Recommendations

Based on all the information outlined above, the following is recommended from a flood mitigation structural point of view.

4.7.1 Opening of Second Downstream Culvert

It is recommended that the option of opening the second culvert in the downstream end of the Leghvtakhevi River is fully considered and implemented by the stakeholders. Three things should be noted on this respect:

- The possibility of using the second (closed) culvert for recreational purposes is being considered. This is not recommended
- The modelling of this section should be refined with the actual dimensions of this second culvert
- As previously noted, the raising of the banks in the urban section upstream of the culvert would reduce further the flood risk in the urban area.
- This option is not supposed to produce any impact from an ecological point of view.

4.7.2 Upstream Storage

This option is not recommended. The estimated high cost associated and the limited impact do not warrant the upstream storage option. In addition to the high cost, this option would be the one producing a higher impact from an ecological point of view.

4.7.3 Road Crossings

As detailed in the options above, there are several road crossing options that have been explored in detail using hydraulic modelling tools. It should be noted that in some cases the road crossing flooding is minimal, or that the road that is being flooded is not of specific significance. Also, in order to calculate the flood benefit rating, the extent of flooding and the possibility of properties being affected has been considered. Therefore, just the options at flood prone areas 5 and 6 are recommended. This is because the associated (and predicted) reduction in flooding impact for these two points is more significant than for all the other road crossings.

5. Flood Early Warning System

The basic idea behind early warning is that the earlier and more accurately potential risks associated with natural and human induced hazards can be predicted, the more likely disaster impacts can be managed and mitigated.

A flood early warning system is an integrated system of tools and plans that guide detection of- and coordinates the response to emergencies. A properly designed and implemented system can save lives and reduce property damage by increasing the time to prepare and respond to the threat of risks and time available to take protective measures prior to the occurrence of them. People-centred early warning systems have four different components (ISDR, 2006), namely:

1. Risk knowledge: risk assessment exercises provide essential information in order to set priorities for mitigation and prevention strategies and designing early warning systems.
2. Monitoring and forecasting: systems with monitoring and forecasting capabilities provide timely estimates of the potential risk faced by communities.
3. Dissemination: communication systems are needed for delivering warning messages to the potentially affected locations. Messages need to be reliable and simple to be understood by authorities and the public.
4. Response: coordination, good governance and appropriate action plans are key points in effective early warning. Likewise, public awareness and education are critical aspects of disaster mitigation.

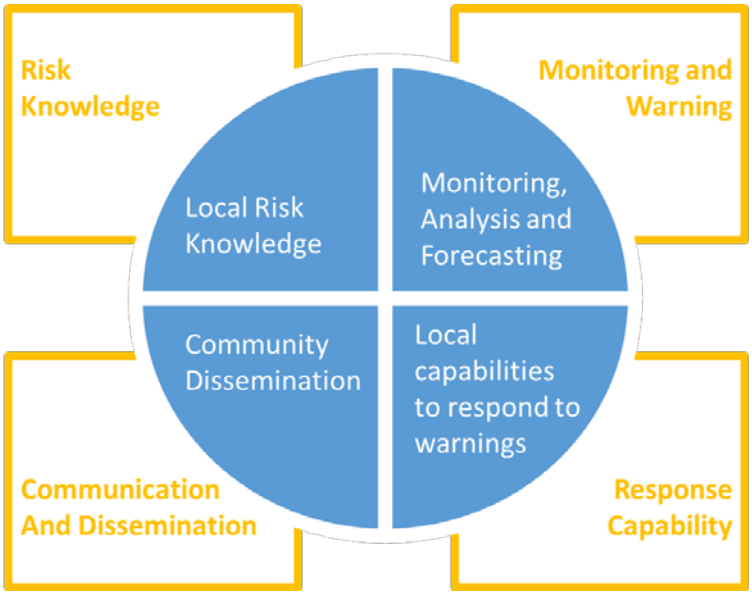


Figure 27 - EWS components

5.1 Flood Forecasting

One of the critical components of a flood early warning system is the flood monitoring and forecasting. Flood forecasting is the use of precipitation (real-time or forecasted) and hydrology data (stream flow, soil moisture, snow melting etc.) in rainfall-runoff and flow routing models to forecast flow rates and water levels for certain areas. The precise role and domain of flood forecasting will vary according to the circumstances dictated by both the

hydro-meteorological environment and the built environment. Urban areas are presenting different problems than rural areas. The nature of flooding events is also important, particularly whether floods are regular in occurrence, as in a highly predictable seasonal climate, such as monsoon or hurricane seasons, or irregular, such as violent thunderstorms. Finally, the type of event is very relevant to the flood forecasting strategy, especially considering the different lead time that riverine floods and flash-floods typically have. This is very relevant to the project area considered in this assignment.

There is, thus, no set design for a flood forecasting system, and the balance between particular components, for example meteorological and hydrological forecasts, scale and timing, have to be adapted to circumstances. Within a given area or country, a number of different flood types may be encountered and each will require a different forecasting approach. Headwater areas may require a system concentrating on flash-floods, whereas floodplain areas may need a system to be focused on the slow build-up of flooding and inundation. This will be fully addressed in the following sections regarding the project area.

The purpose of flood warning is to give advice about impending flooding so that people can act to minimise the negative impacts of the flood. Flood warnings are deemed effective if they help agencies play their roles efficiently during floods and if they persuade community members to act to reduce undesirable flood impacts. Therefore, capacity building and training activities are paramount for the successful implementation of a system.

To form an effective real-time flood forecasting system, the basic structures need to be linked in an organised manner. This basically requires:

1. Provision of specific forecasts relating to meteorological variables (especially rainfall), for which numerical weather-prediction models are necessary.
2. Establishment of a network of manual or automatic hydrometric stations, linked to a central control by some form of telemetry.
3. Flood forecasting model software (including both hydrology and hydraulic modelling), linked to the observing network and operating in real time.

It should be clarified that flood warnings are distinct from forecasts since they are issued when an event is imminent or already occurring. Flood warnings must be issued to a range of users and for various purposes such as:

A. Readying operational teams and emergency personnel.
B. Warning the public of the timing and location of the event.
C. Warning of the likely impacts on roads, dwellings and flood defence structures, among others.
D. Giving individuals and organisations time to prepare.
E. In extreme cases, to enable preparation for undertaking evacuation and emergency procedures.

5.1.1 Meteorological and Hydrological Considerations

There are several meteorological and hydrological aspects to consider when designing and implementing a flood forecasting early warning system. The ability to forecast critical events in time, location and quantity with a sufficient degree of certainty is essential for effective

flood forecasting and warning. Meteorological knowledge associated with flood warning falls into two broad areas, namely the climatology behind flooding and the operational meteorology involved. Understanding the types of weather systems from which flooding can originate contributes significantly to making decisions about the type of observational and forecast systems required. Similarly, understanding the seasonality of flooding is also operationally important since this understanding will affect staff assignments and the organisation of alert and background working patterns.

5.1.2 Nature of Risks and Impacts (Flood Risk)

Flood-risk management consists of systematic actions in a cycle of preparedness, response and recovery and should form a part of Integrated Water Resources Management (IWRM). Risk management calls for identifying, assessing and minimising risk, or eliminating unacceptable risks through appropriate policies and practices.

The magnitude of flood events and impacts is variable, and thus flood forecasting and warning has to operate over a range of event magnitudes. Defensive and remedial measures are designed to operate up to a particular level of flood severity having a particular level of probability. These measures reflect economic decisions balancing costs against losses. As an example, design considerations may cover 100 year return period for urban areas with key infrastructure, 50 year for lesser populated centres and transport facilities and 20 year for rural areas and minor protection structures. The level of protection varies from place to place.

5.1.3 Institutional and Legal Aspects

A flood forecasting and warning system needs to include clearly defined roles and responsibilities for the concerned institutions. Operating authorities may have permissive powers but not a statutory duty to carry out or maintain flood defence works in the public interest. However, such responsibilities may be incorporated in the legislative acts and regulations under which various government departments operate. Regarding legislation, it is therefore important that the interfaces between the duties and obligations of affected departments are carefully considered before statutory instruments are introduced.

5.1.4 Requirements for a Flood Forecasting System

Establishing a viable flood forecasting and warning system requires a combination of data, forecast tools, and trained forecasters. A flood forecast system must provide sufficient lead time for communities to respond. Increasing this lead time enhances the potential for limiting damages and loss of life. Forecasts must be sufficiently accurate to promote community confidence so that they will respond when warned. If forecasts are inaccurate, the credibility of the programme will be questioned and there will be no response.

Implementing an end-to-end flood forecast, warning and response system has many components, and these components must be linked in order to operate successfully. Their interaction may be represented as a multi-linked chain, with each link present and functioning if there are to be benefits.

The essential components of a flood forecasting, warning and response system consist of a data source, communications, forecasts, decision support, notification (often referred to as dissemination), coordination, and actions (or responses). A flood forecast and warning

programme should be designed to mitigate floods and is an asset to overall water management.

All of the components of the system must therefore be functional. If any component is dysfunctional it becomes a weak link in the chain, undermining effective warning and response.

5.1.5 Elements of Flood Forecasting and Early Warning System

An important element in developing flood warning systems is ensuring its robustness so that it can cope with the range of potential events. Flooding is a phenomenon subject to a wide variability of scale and severity. Flood warning systems must, therefore, be designed to forecast rare and severe events as well as less serious and more common ones. However, the uncertainties inherent in forecasting are likely to be magnified during extreme events and such scientific and technological limitations must be taken into account.

To design a suitable flood forecasting service, it is necessary to understand:

A. The hydro-morphological characteristics of the basin topography, geology and soils, and the degree of structural development.
B. The main physical processes occurring during hydro meteorological events.
C. The type of service that is required and that can be achieved technically and economically

5.2 Key Activities Required for the Design and Implementation of a Flood Early Warning System

The design and the implementation of a Flood Early Warning System should consider all the different aspects described above. In order to address these, the following tasks and activities are usually envisaged.

Task 1 – Inception Phase

- Review of available documentation from past and ongoing studies
- Data collection and analysis
- Analysis of potential overlaps/duplication with other relevant projects
- Structured consultations with key stakeholders
- Field visits to selected communities, districts, gauges
- Develop work plan, risk matrix and programme for main phase

Task 2 – Monitoring – river and rainfall monitoring and data acquisition

- Assessment of gauges to be improved or provided
- Identification of equipment required
- Preparation of tender documentation and proposals for procurement
- Tender review and contract award
- Deployment

Task 3 – Data interpretation and procedures for issue of flood warnings

- Assessment of requirements
- Recommendations for implementation

- Guideline documents and procedures
- Training and capacity building
- Tender documentation and proposals for procurement
- Tender review and contract award
- Implementation

Task 4 – Dissemination of warnings to districts and communities

- Assessment of overall requirements
- Identification of equipment required
- Tender documentation and proposals for procurement
- Tender review and contract award
- Implementation

Task 5 – Establishment of Community-based flood warning schemes

- Development of programme
- Community engagement
- Training and capacity building
- Guidance documents and procedures

Task 6 – Establishment of flood warning scheme

- Design and implementation
- Guidance documents and procedures
- Community engagement
- Training and capacity building
- Tender documentation and advice on procedures for procurement
- Tender review and contract award

Task 7 – Development of Flood Forecasting Capability

- Design and implementation
- Guidance documents and procedures
- Training and capacity building
- Tender documentation and advice on procedures for procurement
- Tender review and contract award
- Implementation

5.3 Recommendations for the Leghvtakhevi River

There are several recommendations regarding the implementation of a flood forecasting early warning system for the Leghvtakhevi River. These recommendations are going to be structured following the four components of the typical people-centred EWS.

5.3.1 Risk Knowledge

The risk knowledge component has been the main one addressed within the framework of this technical assistance. The flood risk of the whole Leghvtakhevi River has been analysed thoroughly using the latest technology available. One of the most important output from this risk assessment exercise is the flood mapping, identifying the areas at risk in the catchment. The risk knowledge component should provide information about these areas at risk and the areas to be addressed through the other components.

It should be noted that in addition to the definition of the flood prone area, there are some other things to consider within this component.

- Mechanisms should be implemented in order to disseminate this information further. Within this technical assistance the flood modelling results and mapping have been disseminated to relevant stakeholders (both at national and local level). However, this information should be further disseminated to the local population in order to raise flood risk awareness.
- Mechanisms should be implemented in order to ensure that this exercise is repeated periodically. This is of special importance because of the significant changes being undertaken in this catchment. New development and alterations to the river bed are being carried out and will be carried out in the next months/years. This will change the response time of the catchment, and therefore it is important that the risk knowledge exercise is re-visited periodically with updated information.

5.3.2 Monitoring and Warning

The monitoring and warning is at the core of any EWS system. One of the first tasks within the implementation of a monitoring and warning component is the definition of the service to be implemented, which is directly related to the lead time in the catchment. The lead time of the Leghvtakhevi River has been thoroughly analysed in the Deliverable 7 of this technical assistance (Report on Flood Mapping), identifying a lead time of less than one hour. This indicates that the Leghvtakhevi River is a flash-flood river, and therefore this should be taken into consideration in the implementation of the system. The following approach is recommended (Figure 28).

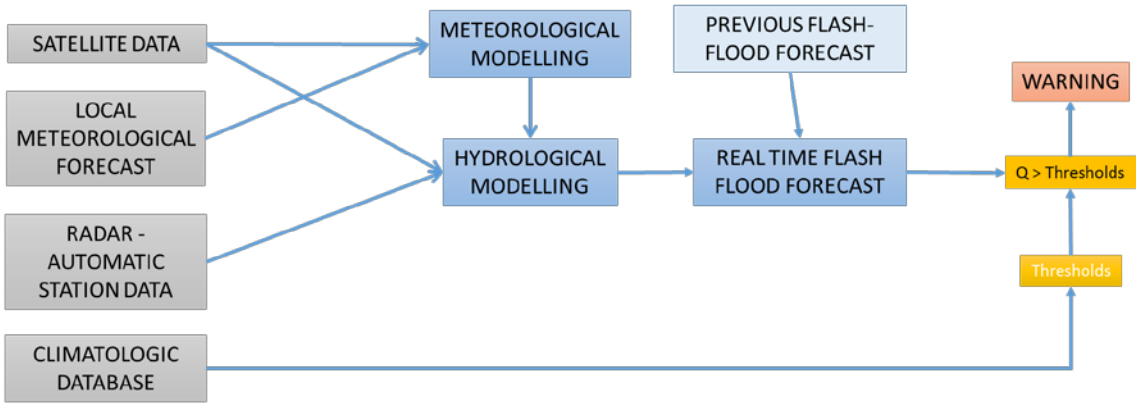


Figure 28 Recommended Flood Forecasting Early Warning System

The short lead time characterising this catchment limits the possibilities of flood forecasting. The use of meteorological forecasting is highly recommended in order to increase the lead time available. This should be combined with more information such as satellite data, meteorological monitoring (weather radar and weather automatic stations) and hydrological forecasting. The use of hydrological monitoring is also recommended.

- Meteorological forecasting: meteorological forecasting is highly recommended to be able to predict the occurrence of an event with several hours in advance. Providing that at this stage the local meteorological models in NEA are run every 24 hours, events

will be predicted 48 and 24 hours in advance. The meteorological model outputs will be coupled with hydrological models in order to determine the possibility of an event occurring in the next 24 or 48 hours. It should be noted that because this will be based on forecasting information, there is a degree of uncertainty associated to these warnings.

  - It should be added that the meteorological models implemented in Georgia (in NEA) should be improved in order to provide more reliable and local predictions, especially regarding the grid spacing of the meteorological models.

- Meteorological Monitoring: meteorological monitoring in the catchment should be improved. The following is recommended:
  - Weather Radar: the use of weather radar data would improve the accuracy of the system. Also, the lead time would be improved. The weather radar data should be coupled to the hydrological model in order to forecast flows in the Leghvtakhevi River. It should be noted that stakeholders were provided with specific software tools to exploit the weather radar data and its link with the hydrological model.
  - Weather Monitoring: currently there are no weather stations in the Leghvtakhevi River. It is recommended that at least two automatic weather stations are deployed in this catchment. This would increase the accuracy of the forecasting, would provide more data to calibrate and validate the radar data and would enhance the knowledge of the catchment.
- Hydrological Forecasting: the use of a hydrological model is recommended. It is recommended that a hydrological model is run for five days, two days with historical data and three days with forecasting data. In this way it would be possible to predict the occurrence of any event for the next 72 hours. However, it is recommended that just warnings are issued for the next 48 hours due to the high uncertainty related to 72 hours predictions. It should be noted that within the project stakeholders have been provided with a hydrological model that can be used within the implementation of the flood forecasting early warning system for this catchment.
- Hydrological Monitoring: hydrological monitoring is being undertaken already in the Leghvtakhevi River. It should be noted, however, that the collected data is not operational, there is one station but the data is not being received and/or analysed. It is recommended that these data is made available to the system. The main purpose of the hydrological monitoring would be to validate and calibrate the results from the hydrological forecasting.
- Warning criteria and definition: as it can be observed, the use of hydraulic modelling is not recommended in this system. This is due to the short lead time available and to the long run time associated to the hydraulic modelling simulations. It is recommended that a thorough analysis of the hydrological and hydraulic modelling results is undertaken in order to develop a matrix of flows that would allow the issuance of warnings. Any flow (as predicted by the hydrological model) would have an associated water level (as predicted by the hydraulic modelling). A matrix of flow-warning should be developed using the information resulting from this assessment. Three different warning levels associated to different flows should be developed and implemented.

5.3.3 Communication and Dissemination

The main idea behind this system is that warning have to be issued as soon as they are predicted due to the short lead time in this catchment. There are several recommendations at this stage regarding this component.

- It is considered very important that the warning is issued from NEA to relevant stakeholders as soon as this is forecasted. It should be noted that the degree of uncertainty should also be conveyed.
- It is recommended that the Emergency Management Agency (EMA) implemented a communication and dissemination system within this catchment. At this moment, based on the information collected during meetings with EMA, there are no communication devices existing in the catchment. During Soviet times there were sirens deployed in Tbilisi in order to alert the population of any impending disaster, but these are not functional any more. At this stage there is no communication mechanism and therefore it is recommended this is fully addressed during the implementation of this system.
- Due to the short lead time available, the deployment of a remote siren system would be recommended. This is specially the case in the downstream end, due to the high number of tourist visiting this area and their supposedly lack of flood awareness.
- The implementation of a common alerting protocol is recommended. This is, however, not specific to this catchment and it should be implemented nationwide.

5.3.4 Response

The Emergency Management Agency (EMA) has the main responsibilities regarding the response component in Georgia and more specifically in Tbilisi City. There are some recommendations regarding the response component:

- It is paramount that the response component is fully implemented and embedded into the full EWS. Communication between NEA and EMA has to be improved.
- EMA has to make use of all the available information available from NEA, such as flood maps, access routes and flood duration.
- NEA has to be fully involved in the response component, providing information about the initiation and finalisation of any event, the duration and any significant predicted changes in the nature of the event.
- Flood evacuation routes and centres should be defined.
- It would be very beneficial if flood emergency response plans are implemented in all the communities (or neighbours) within the flood prone area.
- Due to the highly touristic nature of the downstream end of the Leghvtakhevi River, it is recommended that a specific plan is in place in order to ensure that this is properly addressed.

6. Overall Recommendations

In this section, overall recommendations provided throughout the whole technical assistance will be outlined. The objective of this is to provide a summary of all the recommendations and the subsequent analysis of those by relevant stakeholders. It should be noted that details about the recommendations have been provided in other deliverables during this technical assistance, of even within this deliverable. Therefore, in this section, just a summary of the recommendations will be provided.

- It is recommended that an appropriate database for enhancing the reliability of flood modelling in the region is obtained. This can be accomplished through the installation of sub-hourly and long-term, gauge-based precipitation observations, installation of sub-hourly and long-term water level and discharge observations, a longer overlapping time period of radar data and gauged rainfall data
- It is recommended that the Leghvtakhevi regime is observed, recording information about how often and when certain paths in the Leghvtakhevi gorge are unpassable or when, where and under which conditions pedestrian infrastructure becomes damaged.
- It is recommended the formation of a Flood Risk Management Committee with representatives from the Tbilisi City Council, NEA and EMA. It should be noted that these stakeholders have shown interest on the formation of this committee.
- It is recommended that mechanism are implemented in order to fully consider residual flooding in the flood risk management of the catchment, especially considering evacuation.
- It is recommended that the some structural measures are undertaken within the catchment in order to mitigate flooding. This includes the opening of the second culvert in the downstream end of the Leghvtakhevi and the increase in hydraulic capacity under some of the road crossings. It should be noted that Tbilisi City Hall has express its interest in considering these recommendations in the Tbilisi City Hall 2019 budget planning.
- It is recommended that these recommendations are fully embedded into new Master Plan of Tbilisi. This master plan is already developed and approved by the Tbilisi City Council and the Tbilisi City Hall has shown interest in including this recommendations as amendments to the master plan.
- It is recommended that NEA takes full ownership of the flood modelling products yielded by this technical assistance, and they are updated and reviewed periodically in order to ensure that the flood hazard maps are up to date.
- It is recommended that similar studies, replicating the approach, in all the relevant catchments in Tbilisi are undertaken. It should be noted that on this topic Tbilisi City Hall is soon announcing the development of master (sub) plans for specific territories of Tbilisi by next year and that one of the requirements for master (sub) plans will be development of the flood maps.
- It is recommended that the work and lessons learnt within this technical assistance by the stakeholders are applied within the future GCF project (Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia).
- It is recommended that a full flood forecasting early warning system is implemented in the Leghvtakhevi catchment. It is recommended that this system is implemented

following the typical four components of a people-centred early warning system (risk knowledge, monitoring and warning, communication and dissemination and response). It should be added that stakeholders have already expressed their interest in such a system being implemented and that the results from this technical assistance can be used as the basis for this implementation. Within this recommendation there are several additional recommendations:

- It is recommended that the flood modelling results and mapping are disseminated further within the affected population. There is interest within the stakeholders to disseminate the flyer produced within this technical assistance.
- It is recommended that mechanisms are implemented in order to ensure that risk knowledge exercises are periodically repeated. This should be addressed by the new legislation being put into place in Georgia regarding disaster risk management plans.
- It is recommended that meteorological forecasting, meteorological monitoring and hydrological forecasting capabilities within this catchment are enhanced.
- It is recommended that the warning criteria and definition for flood events in this catchment are developed and agreed among relevant stakeholders.
- It is recommended that a communication and dissemination system within this catchment is implemented, including the implementation of a common alerting protocol.
- It is recommended that the response component is fully implemented and embedded into the full EWS.
- It is recommended that flood evacuation routes and centres are defined.
- It is recommended that flood emergency response plans are implemented in all the communities (or neighbours) within the flood prone area.
- It is recommended that flood awareness campaigns are undertaken within this catchment too.

7. References

AUSTRALIAN INSTITUTE FOR DISASTER RESILIENCE (2015) *Australian Disaster Resilience Handbook Collection – Handbook 10 - National Emergency Risk Assessment Guidelines*

EUROPEAN COMMISSION DIRECTORATE-GENERAL ENVIRONMENT (2011) *European Water Framework Directive*

ISDR (Platform for the Promotion of Early Warning (PPEW)), 2006. Global early warning systems for natural hazards: systematic and people-centred. Phil. Trans. R. Soc. A (2006) 364, 2167–2182

QUEENSLAND RECONSTRUCTION AUTHORITY (2012) *Rebuilding a stronger, more resilient Queensland*

Appendix A – Ecological Considerations

According to the Water Frame Work Directive, the main environmental objectives according are:
• No deterioration of status for surface and groundwater and the protection, enhancement and restoration of all water bodies;
• Achievement of good status by 2015 and the following years;
• Progressive reduction of pollution of priority substances and phase-out of priority hazardous substances in surface waters and prevention and limitation of input of pollutants in groundwaters;
• Reversal of any significant, upward trend of pollutants in groundwater;
• Achievement of Standards and objectives set for protected areas in Community legislation.

A.1 Approach

According to the resolution was published in 2011 ("European Water Framework Directive"), at a meeting of the EU Environment Ministers in Hungary, under the discussion on Integrated Management of Extreme Hydrological Events, it was recommended that an integrated approach for the implementation of the FD and WFD should be promoted in order to "maximise synergies".
So according to this meeting a document was produced to promote coordination with input from those responsible for the implementation of both Directives, to achieve the available synergies and mutual benefits.

In general it is important to identify potential synergies in the implementation of both the 'Floods' Directive (FD) and Water Framework Directive (WFD). The FD is only in its first implementation cycle and Member States are on a steep learning curve to deliver the requirements of the Floods Directive. Member States generally have only limited experience to date in the coordination of the FD with the WFD, although some experience does exist, examples of which are set out in this document.

A.2 Data Collection and Analysis

Water quality can be described in terms of biological, hydromorphological and physical-chemical characteristics
Artificial (and in some cases natural) changes in the physical and chemical nature of freshwaters can produce diverse biological effects.

There are different procedures to check the water quality:

- Comparing historical data with new data
- Field work
- Laboratory results
- Bibliography and Expert knowledge

A.3 Ecological Assessment

According to the different international experts, it has been recognized that in the last years the emphasis on the importance of water-flow regulation services for flood prevention is growing up in the related literature about ecosystem services (e.g., Acharya 2000, Emerton 2005, Batker et al. 2010).

The European Water Framework Directive (Directorate-General Environment 2011) has encouraged interventions in flood mitigation that sought "to work with nature rather than against it", recognizing that mitigating flooding effects through land use adaptation measures are "better environmental options" (Article 4.7 of the Water Framework Directive). There is a wealth of literature on the benefits of adapting land use change processes for the mitigation of flood risks (e. g., Kousky et al. 2011).

There is a clear need to improve strategic long term flood risk management policies. Measures selected now to reduce flood risks need to be more robust and flexible in view of changes in climate and the uncertainties in foreseen impacts.

On 31st of January, the WFD Expert of the project, Romina Álvarez-Troncoso, PhD in Water Quality, with Mr. Kakha Bakhtadze, visited the river basin including the sites located downstream in the city to the upper part close to the source of the Leghvtakhevi River. Priority steps on defining the ecological assessment for the river: delineation, impact and pressure study, monitoring and results analysis, environmental measures.

Harnessing nature's capacity to absorb or control impacts in urban and rural areas, for instance by improving the soil's water storage capacity and conserving water in natural systems, helps alleviating the effect of droughts and preventing floods, soil erosion and desertification. This ecosystem-based approach is a more efficient way of adapting than simply focusing on physical infrastructure.

When managing rivers, lakes and coastal areas, the best environmental options need to be identified, especially when new flood defence structure are considered that could lead to a degradation of water resources.

Basic parameters (Tª, pH, conductivity, dissolved oxygen and discharge)

- Suspended particulate matter, (Total Organic Carbon - TOC), Biochemical Oxygen Demand - BOD and Chemical Oxygen Demand - COD.
- Indicators of pollution with oxygen consuming substances e.g. dissolved oxygen, BOD, COD and ammonium.
- Indicators of pollution with nutrients and eutrophication effects, e.g. nitrogen and phosphorus, and various biological effect variables, e.g. chlorophyll and Secchi-disc transparency.

- Indicators of retention time in a slow changing water body (lakes, reservoirs, impoundments)
- Indicators of acidification, e.g. pH, alkalinity, conductivity, sulphate, nitrate, aluminium, phytoplankton and diatom sampling.
- Indicators for the forecasting of the future eutrophication state of water bodies

Specific water issues that the RBMP: will have to focus on include ecological water flow, hydro-morphological balance between the surface waters and groundwater aquifers, floods prevention measures, pressure on ecosystem diversity and protected areas due to intensive agriculture activities, etc.

Pressures in the basin:

- Water abstraction
- Garbage
- Building materials
- Margin alterations
- Groundwater and surface water pollution
- Connectivity interruption
- Wastewater in the basin
- Old irrigation infrastructure in the basin
- Livestock
- Gravel/sand extraction
- Settlements without wastewater treatment plant

Some projects in the area were previously developed for identify the trans-boundary problems in the Kura-Aras river basin with regard to four key issues:
- Variation and reduction of hydrological flow;
- Deterioration of water quality;
- Ecosystem degradation in the river basin;
- Increased flooding and bank erosion.

Initial basic measures to do for flood mitigation in relation with ecological status in the river:

- Implementation of river bank erosion control/prevention activities (restoration of floodplain zones, putting of river bank reinforcement structures, rectification of river bed morphology, etc.)
- Construction of wastewater treatment plant (biological) for the settlement upstream of Tblisi or create a collector system to add the wastewater to the Tblisi system. This measure aims anticipating the future problem of increase in the inhabitants in the new areas.
- Reduction of nutrient and pesticides discharge by creation of riparian buffer zones.
- Morphological: river fragmentation/continuity interruption causes change in river morphology, impacts on aquatic biota (e.g. as a result of fish barriers): the lack of interconnectivity will cause isolated populations and future problems

Within its competencies Georgia may only enhance flood-carrying capacity of the river by implementing river bank reinforcement and flood plain enhancement measures (levying, damming, restoring floodplain vegetation, etc.) within 10-km section to the mouth.

Impacts in the basin according to the IMPRESS methodology (Analysis of Pressures and Impacts (IMPRESS) (2002). The key implementation requirements of the Water Framework Directive. Policy Summary to the Guidance Document. Fifth Draft, October 2002,151 pp.)

Deterioration of water quality during low flows, change in channel and bed shape, loss of habitats for macroinvertebrates and fish and, blockages to fish passes are some of main impacts.

A.3.1 Mitigation

To mitigate these impacts, the following mitigation measures are proposed:

- design and construction of control structures to allow release of an environmental flow up to 10% of the annual average
- sediment flushing arrangements designed to maintain the live storage in reservoirs and to maintain sediment transport down river
- siting of potential spoil deposit sites in a way not to cause localised increase in flood risk

- arrangement of fish passes for the dams and weirs specifically designed to effectively entice fish into the appropriate channel. The design of the fish pass will allow for upstream passage of fish and also consider measures for the safe passage of fish downstream.

Climate change Impact on Pressures

Pressure	Climate Change Impact on Pressure
Geohazards/geological disasters	Very high
Abstraction and other human pressures on the flow	Very high
Physical modifications	Very high
Organic pollution	Medium
Biogenic substances	Medium
Priority substances, priority substances and specific pollutants	Medium
Solid sediment	High
Biological and microbiological pressures	High

A.4 River Visit

During 31st of January 2018, the HYDROC team visited the section of the Leghvtakhevi River from the downstream end to the source of the river, in order to identify the significant environmental pressures in the basin according to the WFD definition of this term. The visit took place from upstream to downstream and in the following figures the status of the area is displayed.

Figure A.1 - Upstream Tsavkisi

Figure A.2 Tsavkisi (middle part of the stream)

The stream is very narrow in this area, there are old pipelines crossing the section of the river. Few houses are located in the area. The vegetation is well preserved and typical riverine trees. Garbage is found in the basin. The river watershed is altered with some trees but limited vegetation. One pipeline is found in the river basin. The pipeline seems to be abandoned but it is needed to confirm this.

Figure A.3 Tsavkisi (middle part of the river)

Garbage in the basin, some pipelines crossing the river, river watershed with limited vegetation but autochthonous.

Figure A.4- Shindisi (below the settlement)

Garbage in the basin and in the river; hydromorphological alterations in the margins, limited interconnectivity, water in tubes of concrete, presence of cattle in the river, no riparian vegetation in the watershed.

Figure A.5- Shindisi (downstream the bridge)

The river is embedded in the basin in rock, some natural riparian vegetation in the watershed, presence of green algae and macroalgae in the basin (organic pollution in the area).

Figure A.6 - Botanical Garden (upstream)

Water abstraction at a certain site of the river, some interesting woody debris that could be a refuge for macroinvertebrates and increase the biodiversity and abundance of some good indicators for future sampling, different dams or dikes present in the stream

Figure A.7- Botanical Garden (upstream)

Figure A.8 - Botanical Garden (downstream)

The river is embedded in the basin in rock as in the previous sections, natural riparian vegetation in the watershed, presence of green algae and macroalgae in the basin (organic pollution in the area), but in general the transparency of water is very high and there is no garbage in the river basin.

Figure A.9 - Downstream-confluence Kura

The river is embedded in rock in the low part of the old Tbilisi, close to the touristic area where the baths are located, 50m upstream from Kura River. It is clean and the water transparent, but there are many green algae (macrophytes) due to possible organic pollution in the water.

A.5 Institutional Visits

During January 2018, the HYDROC team visited the project area and had several meetings with the NEA officials responsible for monitoring in the country. In addition, a project presentation was given to the Deputy Tbilisi Mayor Mrs. Bitadze from the city council, the project official in the city council.

A.6 Ecological and WFD Status of the Leghvtakhevi River basin

During the meetings that took place the last week of January, the team collected from the National Environmental Agency - Environmental Pollution and Monitoring Department - Air,

Water and Soil Environmental Analysis Laboratory, the results available for the river from previous field campaigns in 2016.

National Environmental Agency
Environmental Pollution and Monitoring Department

Air, Water and Soil Environmental Analysis Laboratory
www.nea.gov.ge

National Environmental Agency

Environmental Pollution and Monitoring Department

Air, Water and Soil Environmental Analysis Laboratory

8th floor – 150 D. Aghmashenebeli avenue, Tbilisi, Georgia 112

- Test protocol –
№127-2016

National Environmental Agency
Environmental Pollution and Monitoring Department

Air, Water and Soil Environmental Analysis Laboratory
www.nea.gov.ge

Test protocol №127-2016

Registered sample N: #1312

Test protocol page number: 4

Client Name: Ministry of Ennvirnment Protection and Natural Resources

Client address: Tbilisi, 6, Gulua street

Tel.: (+99532) 272-72-24; 272-72-34

Label given by proposer: #1

Sample description and identification (Matrix, form): Surface water

Used method/instrument: Ion-chromatograph, Spectrophotometer, Titrometric, Weight, Mobile hardware

The date of receiving the sample-CR: 12.10.2016

The date of the examination: 12.10.2016 – 24.10.2016

Date of issuing the test protocol:

National Environmental Agency
Environmental Pollution and Monitoring Department

Air, Water and Soil Environmental Analysis Laboratory
www.nea.gov.ge

№1312 (1)

River Leghvtakhevi - Tbilisi

#	Ingredients	Unit	Result	Used methods
1	Temperature	^{0}C	17,4	Mobile device- pH 330i/340i
2	pH		8,67	Mobile device- pH 330i/340i
3	Conductivity	μsms/cm	1015	Mobile device- Oxi 330i/340i
4	Oxygen dissolved	mg/l	6,50	Mobile device- Oxi 330i/340i
5	Hydrocarbonate	mg/l	219,60	Titrometric
6	Carbonate	mg/l	2,25	Titrometric
7	Rigidity	mg-equiv./ l	12,84	ISO 6059-84
8	Ammonium	mgN/l	0,272	ISO 7150-1:2010
9	Nitrate	mgN/l	2,119	ISO 10304-1:2007
10	Nitrite	mgN/l	0,032	ISO 10304-1:2007
11	Phosphate	mg/l	0,014	ISO 10304-1:2007
12	Fluorine	mg/l	0,872	ISO 10304-1:2007
13	Bromide	mg/l	0,487	ISO 10304-1:2007
14	Sulfates	mg/l	491,61	ISO 10304-1:2007
15	Chlorides	mg/l	29,09	ISO 10304-1:2007
16	Calcium	mg/l	193,47	ISO 6058:2008
17	Magnesium	mg/l	38,78	ISO 6058:2008
18	Sodium	mg/l	38,5	ISO 9964-3:2010
19	Potassium	mg/l	1,6	ISO 9964-3:2010
20	Mineralization	mg/l	933,41	ISO 11885:2007
21	Iron	mg/l	0,0149	ISO 11885:2007
22	Copper	mg/l	0,0024	ISO 11885:2007
23	Zinc	mg/l	0,0106	ISO 11885:2007
24	Manganese	mg/l	0,0018	ISO 11885:2007
25	Cobalt	mg/l	0,0030	ISO 11885:2007
26	Molybdenum	mg/l	0,0301	ISO 11885:2007
27	Lead	mg/l	0,0036	ISO 11885:2007

National Environmental Agency
Environmental Pollution and Monitoring Department

Air, Water and Soil Environmental Analysis Laboratory
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შენიშვნა: გამოცდის შედეგები სადაოა გამოცდის ოქმის მიღების თარიღიდან 14 დღის განმავლობაში.

შემრულებლები:

გ.ჭუჭუა

მ.ჭიღიტაშვილი

მ.მიქავა

ე.ქიტოშვილი

ს.ხმიადაშვილი

ლაბორატორიის უფროსი: ელიზა ბაქრაძე

Figure A.10– Report with water quality results from NEA in 2016

A.7 WFD Recommendations

Apart from the Biological Elements and physico-chemical approach, hydromorphological processes are a key component of fluvial ecology, as they create the hydrodynamic and habitat conditions to support biota. Pressure on hydromorphology is one of the most common causes for water bodies to fail the WFD environmental objectives.
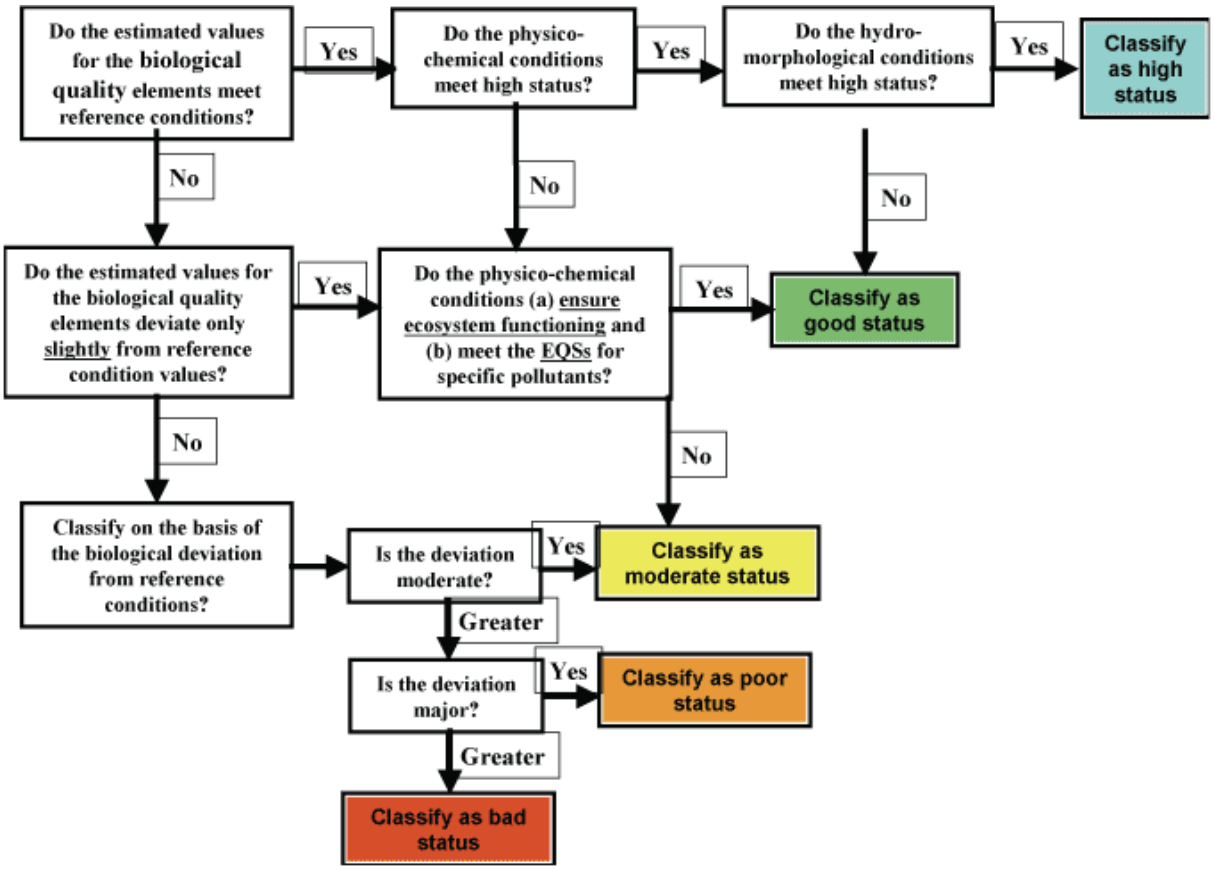
Figure based on Common implementation strategy for the water framework directive (2000/60/ec). Guidance for the analysis of pressures and impacts in accordance with the Water Framework Directive, 2003.