Consultancy Service for the Development of an Inundation, Flooding and Landslide National Risk Profile, Strategic Framework and Action Plans for Disaster Risk Management for the Republic of Mauritius

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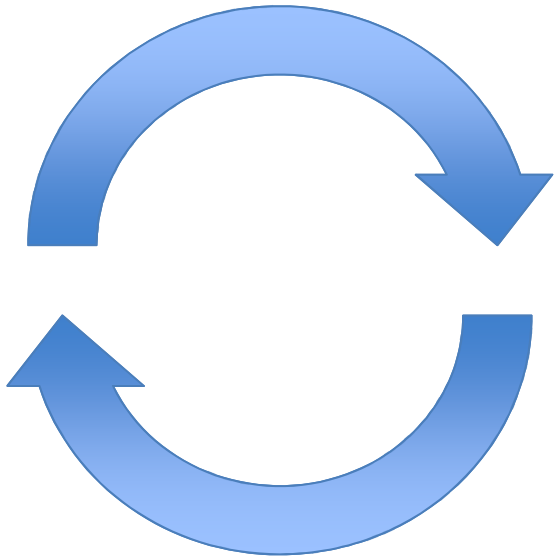
Risk management cycle

Response entails all emergency activities aimed at protecting human life, property, environment, and cultural heritage

Preparedness measures include recognition of the imminent danger (i.e. early warning system) and communication of risk. These measures include also flood, inundation, landslide forecasting, warning and emergency plans



Recovery addresses activities in the aftermath of the emergency helping to restore normal/ordinary conditions and to help to bear the inflicted hardship.

Protection addresses both structural and non-structural measures reducing the likelihood and/or impacts of flood such as flood defence works, temporary flood storage areas etc.

Prevention includes non-structural activities reducing the flood impacts such as restricting the development of flood plains; risk-proofing of buildings and infrastructure; flood-sensitive land use, agricultural and forestry management practices

DRR Action plan

Action 1: Reduce risk in areas prone to very high and high risk

Action 2: Implement a DRR National Platform along the principles of Hyogo Framework for Action.

Action 3: Adopt a sound development strategy

Action 4: Preserve healthy natural environment

Action 5: Embrace the culture of risk

Action 6: Sound (spatial) data infrastructure

Action 7: Early warning and alerting system

Action 8: Emergency response

Action 9: Emergency fund and insurance scheme

Action Plan

AREA OF INTERVENTION	PRIORITIES OF ACTION
HORIZONTAL = H	*1) Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation*
FLOOD = F	*2) Identify, assess and monitor disaster risks and enhance early warning*
LANDSLIDE = L	*3) Use knowledge, innovation and education to build a culture of safety and resilience at all levels*
INUNDATION = I	*4) Reduce the underlying risk factors*
	5) Strengthen disaster preparedness for effective response at all levels

Action plan

DRR Phase	Action sheets	Title	Brief description
Protection and prevention	L1-3, LR, F1-7 I1-7, IR	Reduce risk in areas prone to very high and high risk	Substantial investments are needed to safeguard areas prone to very high and high risk to flood, inundation and landslide hazards. The current vulnerabilities are to some extent results of unsound development practices and insufficient preservation of environment including wetlands and coral reefs.
	H4	Establish and implement a DRR National Platform along the principles of Hyogo Framework for Action	A seamless horizontal and vertical integration of all DRR institutions is a critical priority for risk governance in Republic of Mauritius. It is highly recommended to implement a DRR Platform conform to the recommendation of the Hyogo Framework for Action and streamline climate adaptation and DRR strategy into existing politic,legislation and organisational division.
	H2, H3	Adopt a sound development strategy	Spatial planning and land management play an important role in risk prevention, by limiting the development in flood prone areas, and by encouraging flood risk-sensitive land use and management practices. High proportion of areas identified for future development are placed in areas prone to very high and high risk.
	H6	Preserve healthy natural environment	Healthy environment and ecosystems provide (regulatory) services reducing the impact of natural hazard events. Nevertheless the area occupied by coastal and inland wetlands has declined. This trend should be reverted and more emphasis should be paid to ability of ecosystems to mitigate or offset the effects of the natural hazard.

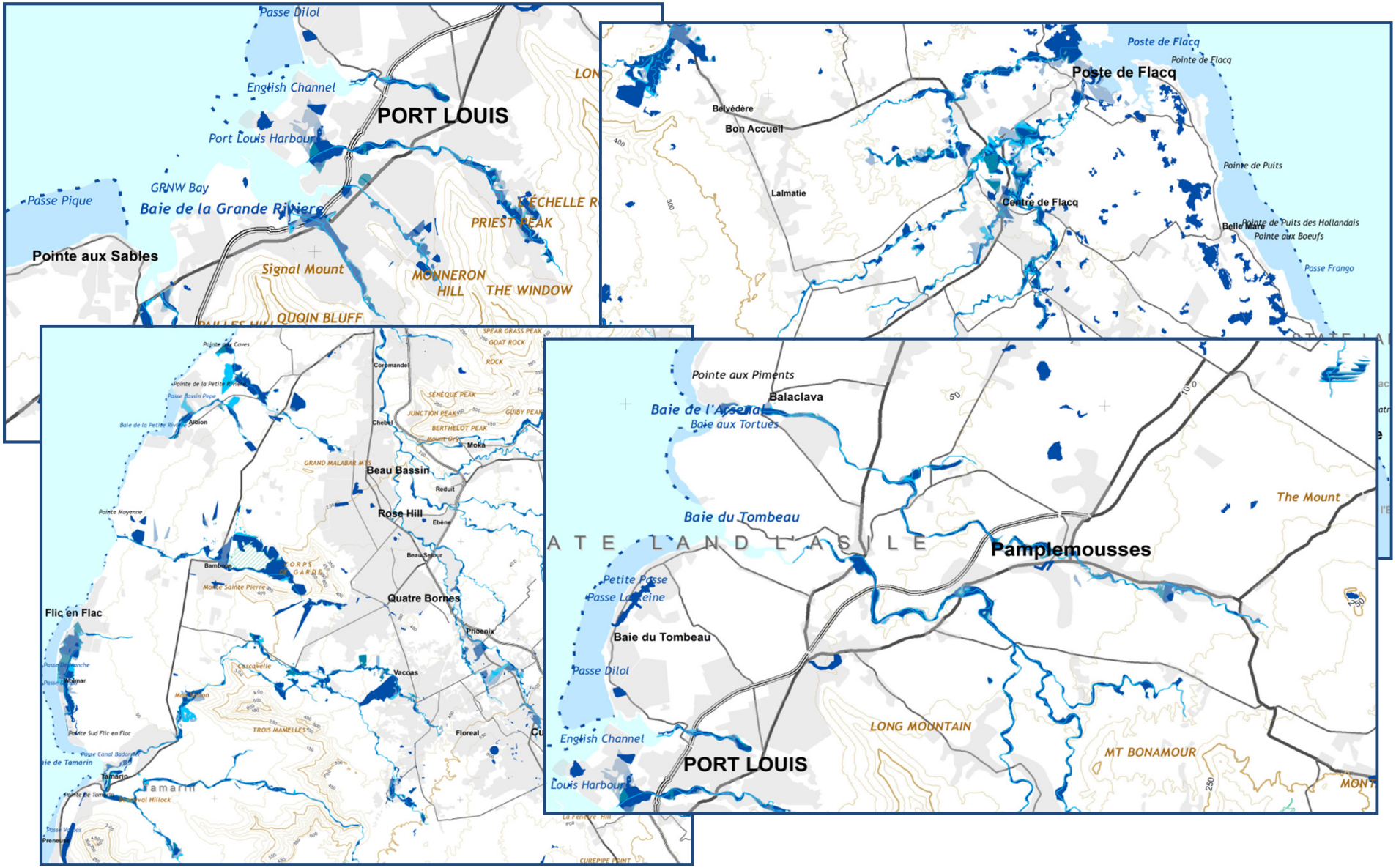
Action plan

DRR Phase	Action sheets	Title	Brief description
Preparedness	H5	Sound (spatial) data infrastructure	A sound disaster risk management is data-intensive. Monitoring of precipitation (regimes), surface run-of, river discharges, wave heights, cyclone activity should be centrally stored and made accessible to all relevant institutions. The lack of a consistent spatial data infrastructure obstructed the conduct of this risk assessment. The acquisition of detailed topographic data in very high and high risk areas should become a high priority.
	H1	Early warning and alerting system	The existing early warning system for tsunami and cyclones should be extended to include river discharge and high tide, as well as other natural hazards such as drought. The issued alerts should find an easier way to all concerned citizens through media, internet, and Internet-based social networks.

Action plan

DRR Phase	Action sheets	Title	Brief description
Response	H4	Emergency response	The emergency operations focus primarily on the protection of human live and limiting the impact of disasters. The emergency plans contain specification of the roles and coordination between various actors, specification of the shelter places for the evacuated population, emergency equipment and facilities, disaster contingency plans etc. It is a best practice to develop emergency plans at all administrative levels (from municipal up to the national level) with different level of detail and partly content.
Recovery	H4	Emergency fund and insurance scheme ()	Post-disaster recovery should be facilitated by a national solidarity/recovery funds and private insurance schemes

Action1: FLOOD RISK



ACTION 1: FLOOD RISK

Action plan for flooding risk mitigation						
Action	**2012-2015**	**2015-2018***	**2018-2021***	**2021-2024***	**Total [million MUR]**	
Port Louis river basins flood management plan	30	157	157	157	**500**	**Million of MUR**
Poste de Flacq – Rivière Sèche river basins flood management plan	40	180	180	180	**580**	
GRNW river basin flood management plan	165	385	385	385	**1,320**	
Rivières Citron and Pamplemousses river basins flood management plan	30	190	190	190	**600**	
L'Escalier - Gran Bois river basin flood management plan	30	73	73	73	**250**	
Land drainage works in Mauritius	617	617	617	617	**2,466**	
Flood management plan in **Rodrigues island**	25	77	77	77	**255**	

Action 1: FLOOD RISK

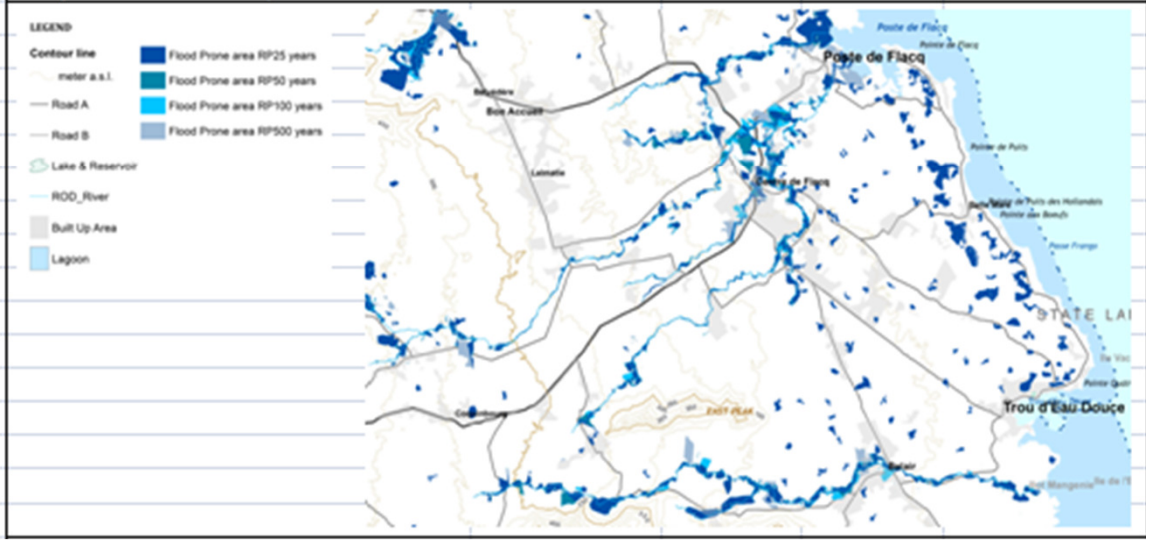
- structural and non-structural measures				
Flood peak retention works				
Restoration of wetlands that can be used to store water during floods				
Construction of enbankments near urban areas and critical areas to protect				
Channel widening (check dam, sill)				
Reconstruction of critical bridges				
Bank protection works (reef) along critical river reach in urban area				
Non-structural measures				
Competent Authority: Government of ROM and local authorities				
Cost of intervention [mil MUR]:				
- cost of planning activities	60			
- cost of structural and non-structural measures	-			
Budget of intervention:				
Year	**2012-2015**	**2015-2018**	**2018-2021**	**2021-2024**
Amount	40	20	-	-
**: Costs can be evaluated just after planning activities and more detailed studies. A prioritization of structural measures could be more precise after more detailed studies*				

ACTION F_2/1,4,2

Post de Flacq and Seche basins flood management plan

Type of intervention: Action plan to mitigate flood risk in urban area

Study area: Post de Flacq and Seche basins area



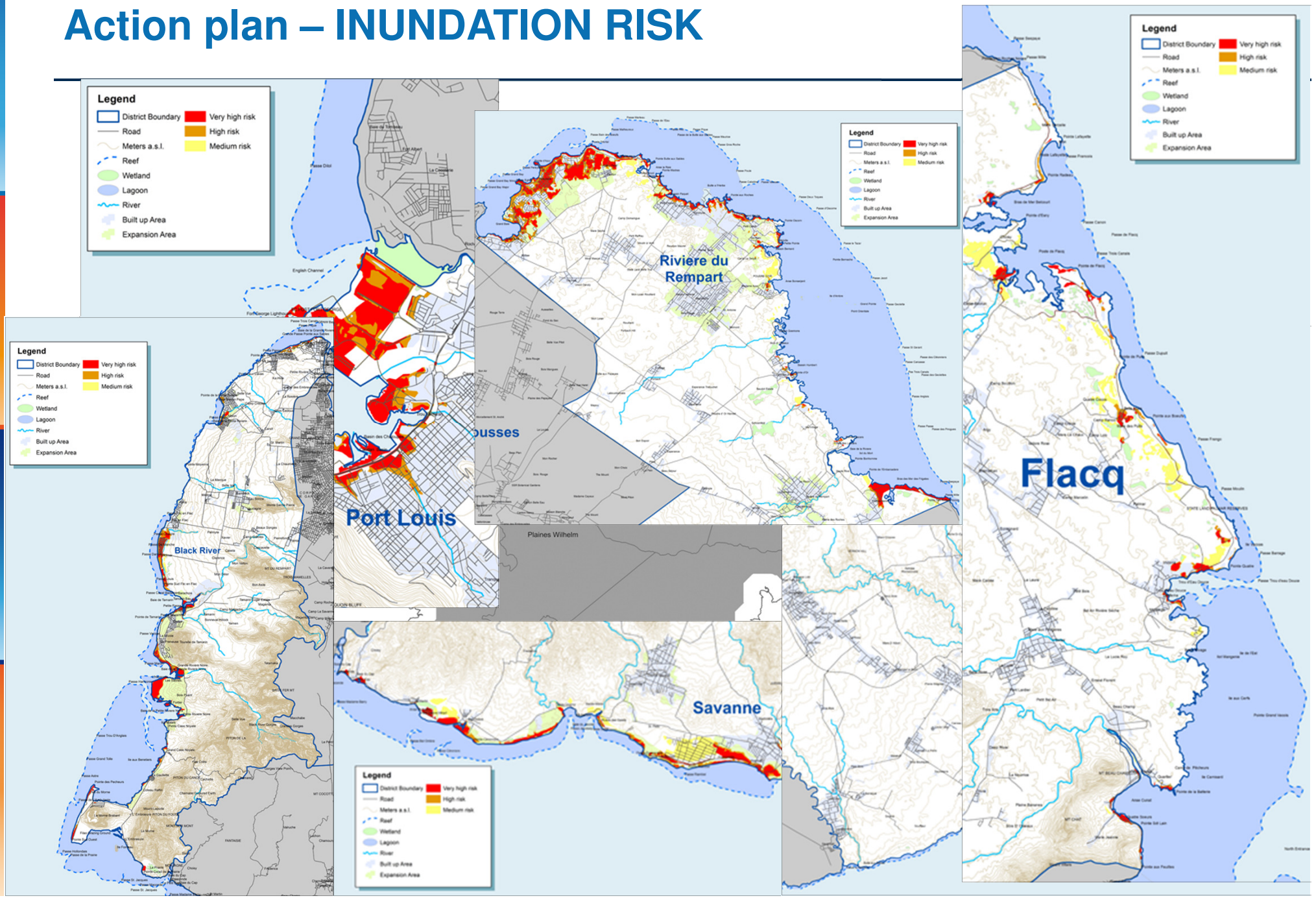
Description of interventions:

Flood management plan defined for Poste de Flacq basin, located on the East Coast of Mauritius, takes into account actions to reduce the frequency and severity of floods in very high populated urban area of Centre de Flacq and Belair. Inside the urban areas ,Poste Flacq, Colgnard Minor river and Rivulet Sèche lead flooding area when extreme flood events occur (RP of 25/50/100/500 years). Plan of interventions defines various steps to reduce, or mitigate, the damage caused when floods happen including:

- planning activities

River Basin Master Plan containing a detailed hydrologic study and topographics survey of interest area. The river basin study and programmes of measures (field data collected and included in a comprehensive database) are not intended as a once-only exercise, but as a dynamic process based upon a periodical updating. In this way, critical issues on a water body, can be recognised and new measures developed to overcome them. Furthermore, refinements to the monitoring programme, and the availability of further data, will enable fine-tuning to existing measures and give early warning of new problems so that appropriate action can be taken.

Action plan – INUNDATION RISK



Action plan – INUNDATION RISK

Identified vulnerabilities

Port Louis District is the most urbanized District of Mauritius. With almost 1.8 km2 of built-up area situated in areas prone to very high and high risk the district is not among those mostly exposed in absolute terms. However, thirteen per cent of total urbanized area is prone to very high and high risk. The District at the moment has no urban expansion plan. Compared to other Districts, Port Louis has the lowest extension of primary roads subject to risk of inundation, but within the City of Port Louis, more than four km of motorway are subject to high risk of inundation. This motorway is the principal connection between the South and the North, and as such, a piece of critical infrastructure. Two hotels and one medical facilities are prone to high risk of inundation.

Catalogue of measures

Seawalls, bbreakwaters, break waves or in general artificial reefs, groynes, gabions and riprap revetments; stabilizing coastal dunes; transgression of sea in wide dune areas, allow wash over of dikes; Seawalls, Breakwaters, Overtopping dike or extending the existing dykes, Stabilizing coastal dunes, Planting or restoring vegetation

Budgetary matter

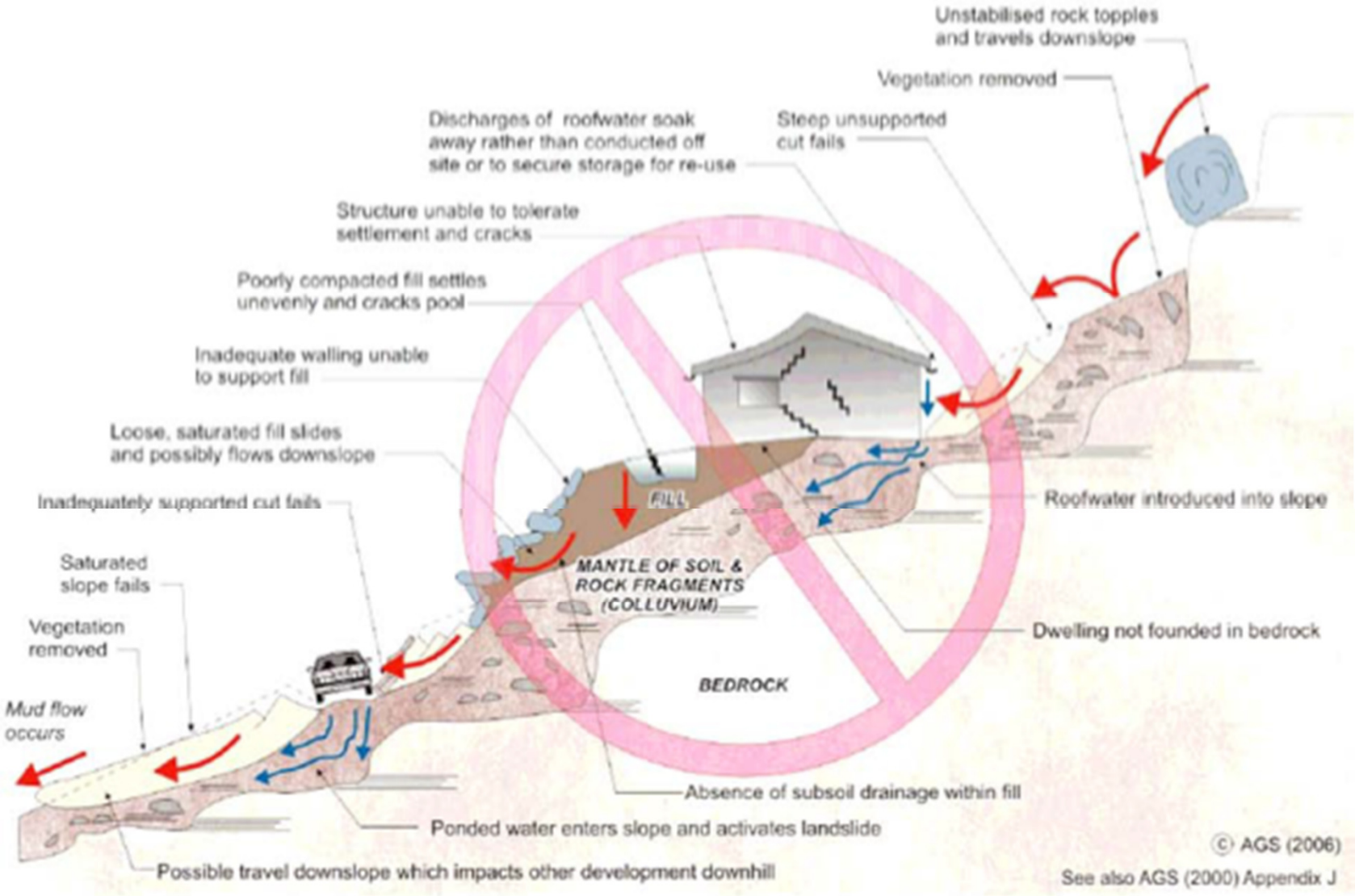
The proposed budget includes costs of successive detailed planing and development of the coastal line management plan only, the costs of measures envisaged therein are not included. The plan should be revised every 6 years.

Year	2012-2015	2015-2018*	2018-2021*	2021-2024*
Amount	10.5	10.5	5.25	5.25

Costs of the intervention for inundation risk mitigation

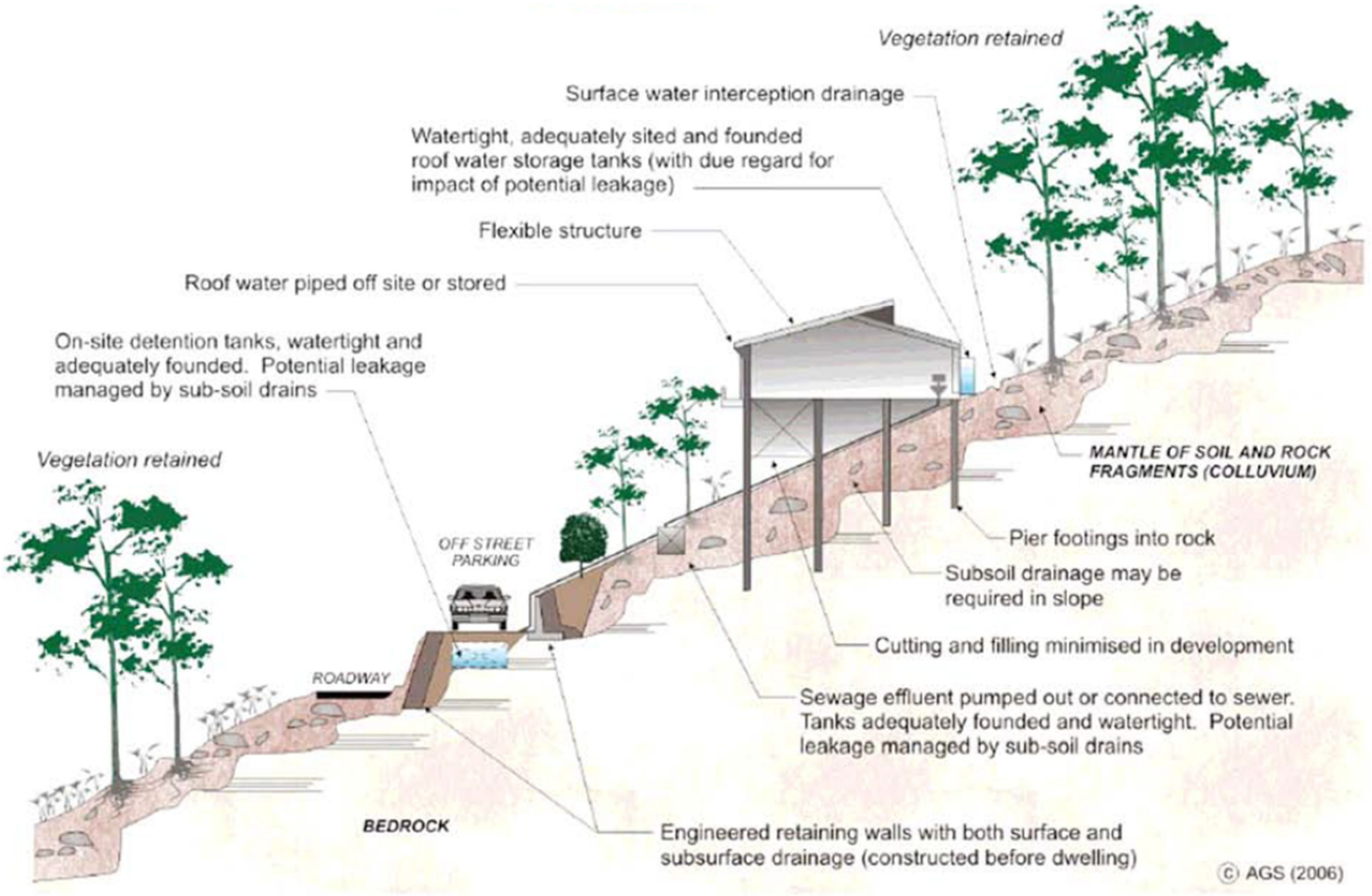
INUNDATION MITIGATION PLAN							
MAURITIUS							
Port Louis coastal line management plan							
I	1	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**21**
Black River coastal line management plan							
I	2	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**18**
Savanne coastal line management plan							
I	3	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**10**
Grand Port coastal line management plan							
I	4	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**11**
Flacq coastal line management plan							
I	5	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**18**
Riviere du Rempart coastal line management plan							
I	6	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**18**
Pamplemousses coastal line management plan							
I	7	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**19**
RODRIGUES							
Rodrigues Island coastal line management plan							
I	R	1,4,2	ROM	an	Development and implementation f a coasta	The action incude food risk mitigation measures including structural and non structural int	**10**

Example of poor hillside practice



from Australian Geomechanics Journal and News of the Australian Geomechanics Society Volume 42 No 1 March 2007

Example of good hillside practices



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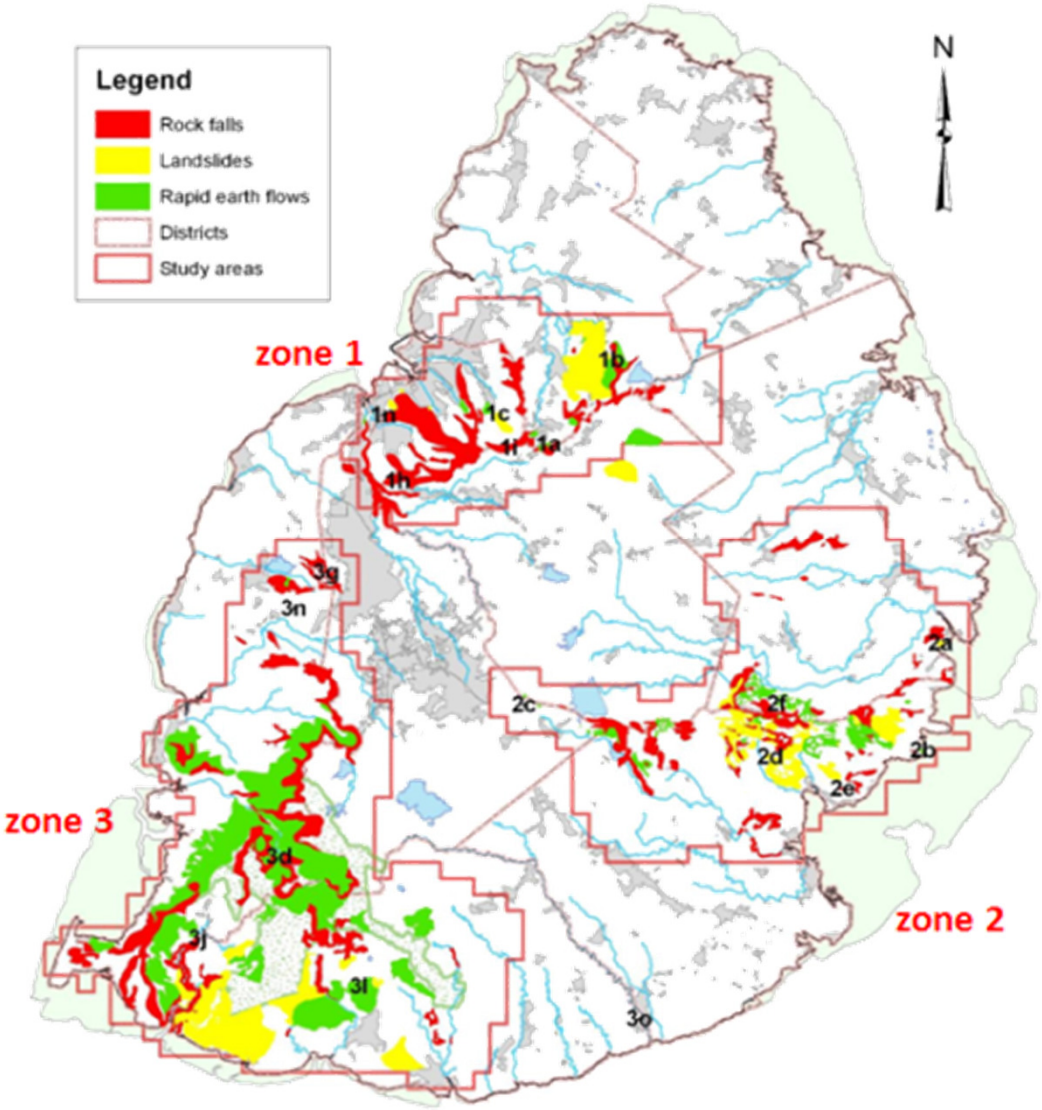
Action 1: LANDSLIDE RISK



The island of Mauritius has been divided into three main mountainous/hilly zones, according to the potential contribution to slope instabilities

For each zone has been calculated the budget for geological and geomorphological studies, amounting to 110 million of MUR

Action 1: LANDSLIDE RISK

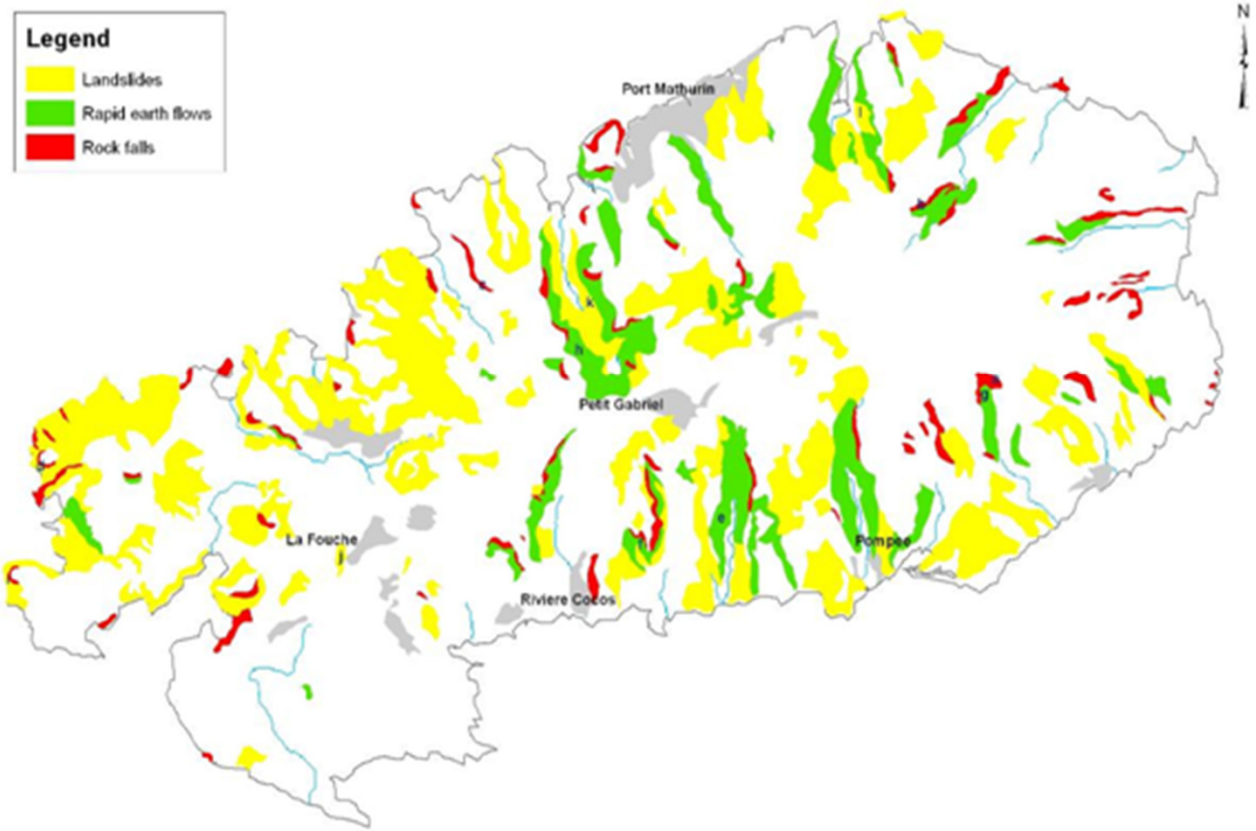
Measures for landslide prevention and protection :

1. **Restricting development in landslide-prone areas.**
2. **Standardizing codes for excavation, construction, and grading.**
3. **Protecting existing development**
4. **Utilizing monitoring and warning systems**
5. **Providing landslide insurance and compensation for losses**

Action 1: LANDSLIDE RISK

			time [year]				TOTAL [MUR]	
LEVEL 1	**Studies at regional scale for geological and geomorphological mapping :**							
	1. survey and mapping of surface deposits in scale 1:10,000-1:25,000-1:50,000	**ZONE 1**	2012 10.000.000	2013	2014	2015		
	2. geomorphological survey and mapping scale 1:10,000-1:25,000-1:50,000 (preliminary census of sinkhole due by tunnel lavas)	**ZONE 2**			17.000.000			
		ZONE 3		24.000.000				
LEVEL 2	**Studies at local level for landslide area, landslide managemet plan and feasibility study of remediation works:**							
	– Geological map scale, 1:5,000 – Geomorphological map scale, 1:5,000 – Landslide hazard map of scale, 1:5,000 – Vulnerability and exposed elements (existing and / or planned), scale 1:5,000 -- Landslide managemet plan	**ZONE 1**		9.000.000				
	– Landslide risk map, scale 1:5,000	**ZONE 2**				9.000.000		
	– Feasibility study of intervention to mitigate the risk	**ZONE 3**			32.000.000			
			10.000.000	33.000.000	49.000.000	9.000.000	101.000.000	TOTAL [MUR]
			270.270	891.892	1.324.324	243.243	2.729.730	TOTAL [€]

Action plan – Planning activities



About Rodrigues it is important to improve the knowledge, considering the lack of geomorphological data since it is the first time that a landslide study has been carried out.

Action plan – Planning activities

		time [year]		TOTAL [MUR]	
LEVEL 1	**Studies at regional scale for geological and geomorphological mapping (entire island):**				
	1. survey and mapping of surface deposits in scale 1:10,000-1:25,000-1:50,000 2. geomorphological survey and mapping scale 1:10,000-1:25,000-1:50,000 (preliminary census of sinkhole due by tunnel lavas)	2012-2013	2014-2015		
		8.000.000			
LEVEL 2	**Studies at local level for landslide area, landslide managemet plan and feasibility study of remediation works:**				
	– Geological map scale, 1:5,000 – Geomorphological map scale, 1:5,000 – Landslide hazard map of scale, 1:5,000 – Vulnerability and exposed elements (existing and / or planned), scale 1:5,000 -- Landslide managemet plan – Landslide risk map, scale 1:5,000 – Feasibility study of intervention to mitigate the risk		12.000.000		
		8.000.000	12.000.000	20.000.000	TOTAL [MUR]
		216.216	324.324	540.541	TOTAL [€]

Next step for Rodrigues is the activation of 8 million of MUR to have during the 2013 a geological/geomorphological study at level 1; then, another 12 million of MUR to have a complete landslide characterization at level 2

Action plan –Structural interventions

The study allows having a preliminary knowledge of the existing landslide and assessing the area of the landslide that involve the element at risk; in this direction, for the protection works we calculated the costs of the structural measures for landslide risk mitigation.

The following matrix relates different typical intervention works with the landslide type

STRUCTURAL MEASURES (intervention works)	Rapid earth flow	Rock fall	Landslide
Groundwater drainage: adit and drainage well, etc.			X
Direct consolidation action : pile wall, caisson or beam and active anchor			X
Underground drainage : gabion and drainage trench	X		X
Sediment control dam, dikes, embankment, etc.	X		
Rock slope protection works: wire mesh, anchor, grouting, etc.		X	

Action 1: LANDSLIDE HAZARD

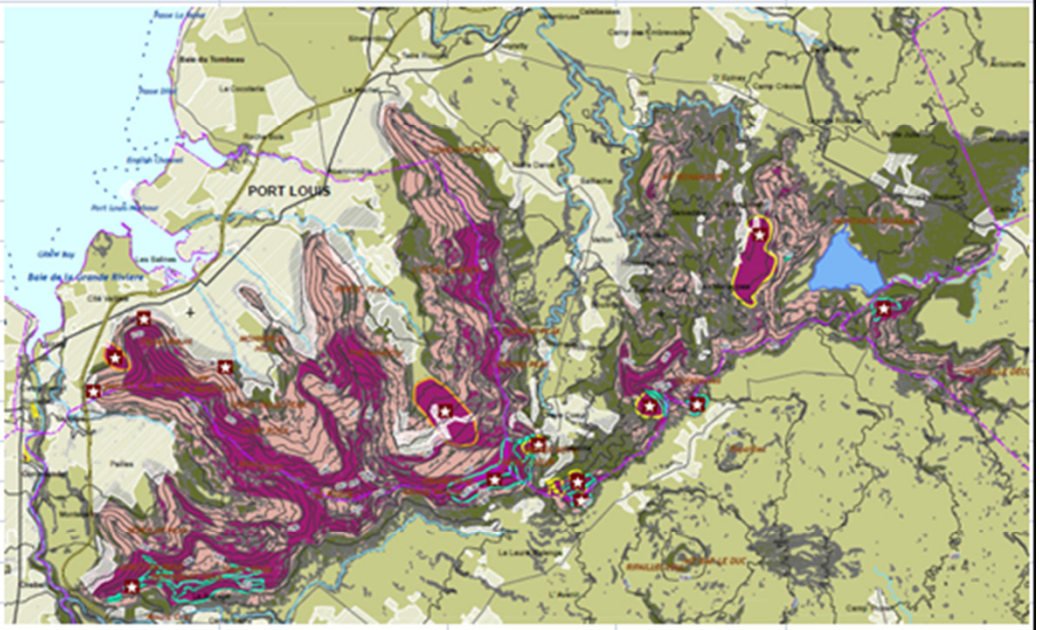
ACTION L_1/1,4,2	
Port Louis and northern mountainside (zone 1)	
Type of intervention:	Action plan to mitigate landslide risk in urban and suburban area
Study area:	Port Louis and part of Pamplemousses, Moka Flacq Districts

Landslide Hazard

- Level 1_ Low
- Level 2: Medium
- Level 3: High
- Level 4: Very High

LANDSLIDE AREAS

- Landslides
- Rapid earth flows
- Rock falls



Description of interventions:

Landslide management plan defined for Port Louis takes into account actions to reduce the risk and severity of landslide hazard in very high populated urban area of Port Louis city and surroundings (Vallée des Petres - Chitrakoot, Temple Road Creve Coeur). Indeed, around the urban area of Port Louis there are many existing landslides and other potential areas with high hazard. It will be very important to increase the knowledge on these areas. Plan of interventions defines various steps to reduce, or mitigate, the damage caused when the landslide events happen including:

Action plan –Structural interventions

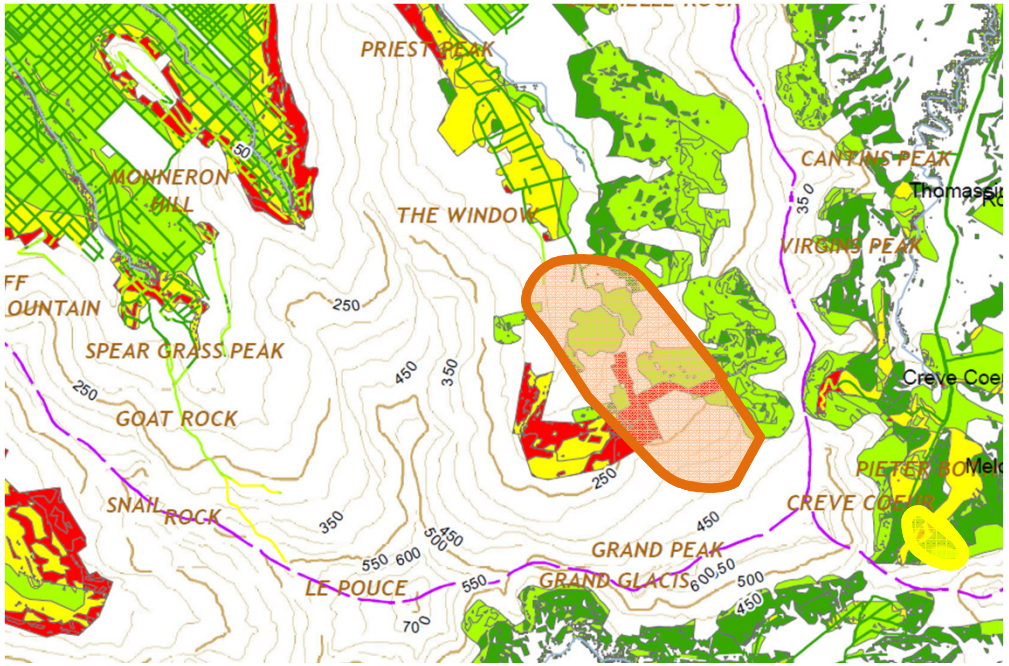
The estimation of intervention costs considers each landslide that involves high risk areas, than we have calculated the preliminary costs of the interventions works to mitigate the risk.

An example in the following picture

Landslides

Rapid earth flows

Rock falls



Action plan –Structural interventions

The costs starts from the matrix intervention works/landslide type.

The unit costs of the interventions consider similar experience regard works on landslide risk mitigation.

Intervention to mitigate the landslide risk:	Unit cost MUR	unit
Underground drainage (adit, drainage well)	15	m^2
Pile wall or other consolidation action (beam and actif ancor, caisson)	110	m^2
Gabbion and drainage trench	90	m^2
sediment control am	105	m^2
Wire mesh, anchor, grouting*	1000	m^2

* : this value consider a sector of intervention of 10% of the total high risk to rock fall area

Considering the landslide areas and the unit costs it was possible estimate the costs of the intervention works.

Action plan –Structural interventions

- the planning activities,
- the actions in terms of structural measures,
- the competent authority,
- the related costs.

- planning activities				
LEVEL 1 : Studies at regional scale for geological and geomorphological mapping including survey at scale 1:10,000-1:25,000-1:50,000 and a preliminary census of sinkhole due by tunnel lavas LEVEL 2 : Studies at local level for landslide area and preliminary design of remediation works at scale 1:5,000 including landslide managemet plan and feasibility study of remediation works				
- structural measures				
Groundwater drainage: adit and drainage well, etc.				
Direct consolidation action : pile wall, caisson or beam and actif ancor				
Underground drainage : gabion and drainage trench				
Sediment control dam, dikes, embankment, etc.				
Rock slope protection works: wire mesh, anchor, grouting, etc.				
Competent Authority: Government of ROM and local authority				
Cost of intervention [mil MUR]:	**1.480**			
- cost of planning activities (LEVEL 1 + LEVEL 2)	20			
- cost of structural and non-structural measures	1.460			
Budget of intervention:				
Year	**2012-2015**	**2015-2018***	**2018-2021***	**2021-2024***
Amount	20	487	487	487
**: a prioritization of structural measures could be more precise after the studies at level 1 and 2*				

Action plan

Action plan for Mauritius and Rodrigues and related cost divided into four terms of three years.

ACTION	PLANNING ACTIVITIES	INTERVENTION COTS	
Intervention L1 **Mauritius zone 1**	20	**1.480**	**Million of MUR**
Intervention L2 **Mauritius zone 2**	25	**805**	
Intervention L3 **Mauritius zone 3**	55	**2.050**	
Intervention LR **Rodrigues**	20	**330**	

*** More precise costs can be evaluated just after planning activities and more detailed studies. A prioritization of structural measures could be more precise after the studies at level 1 and 2**

Actions 2- 9 Horizontal measures

PROGRAM OF ACTIVITIES						
AREA OF INTERVENTION*	CODE N°	PRIORITIES OF ACTION**	COMPETENT AUTHORITY	ACTION	SHORT DESCRIPTION OF RECOMMENDED INTERVENTION	COST*** [mil MUR]
HORIZONTAL ACTIONS (MAURITIUS AND RODRIGUES)						
Hydrological forecasting and warning systems						
H	1	1,4,2	Government of ROM	Development and implementation of a modernized, national-level Flood Forecasting and Early Warning System	Existing measurements network must be upgraded and strengthen with new telemetric stations able to collect data in real time. Thus, using observations to feed models could be a very useful tool to forecast events and to alert population. It is necessary to improve the weather stations, the flow gauging stations in the largest basins and the buoy stations around Mauritius and Rodrigues islands.	**22**
Developing of danger zoning plans						
H	2	1,4,2	Local authority	Zoning of danger areas and developing of related maps	The development of danger zoning plans includes first of all the improvement of a suitable topographic base (with detailed scale) and consequent hydrologic and hydraulic studies that allow to quantify the intensity of involved phenomena. Maps will represent a detailed tool for planning, justification of measures to be adopted and risk assessment studies.	**230**
Dams Safety Project						
H	3	1,4,2	Government of ROM	Improving of dams' safety through specific studies and consequent remedial works	The developing of a Dams Safety Project needs the realization of a feasibility study, first. It will be important to conduct specific studies regarding current dams state and safety, install measuring equipment for monitoring, plan and implement remedial works and improve O&M manulas.	**50**
DRR Strategy and National Platform						
H	4	1,4,2	Government of ROM	Implementation of a DRR Strategy and National Platform along the principles of the Hyogo Framework for Action (HFA) 2005 - 2015	The Disaster Risk Reduction Strategy should be drafted along the key objectives described in the report. The National Platform for DRR should evolve around the Cyclone and other Natural Disasters Committee and the National Disaster and Operations Coordination Centre, whereas the former shall play a coordination and supervision role, while the latter should invest a executive role, supported by a permanent office with adequate number of staff members.	**900**
Sound (spatial) data infrastructure						
H	5	1,4,2	Government of ROM with particular role of Ministry of Environment and Sustainable	Implement a sound (spatial) data infrastructure	A modern disaster risk governance is hardly conceivable without an effective data infrastructure. A (spatial) data infrastructure (SDI) comprises a framework of (geographic) data and information, metadata, users and tools that are interactively connected in order to use (spatial) data in an efficient and flexible way. It includes technology, data acquisition and distribution policies, standards, human resources, and other activities necessary to acquire, process, distribute, use, maintain, and preserve (spatial) data.	**270**
Preserve healthy natural environment						
H	6	1,4,2	Government of ROM	Protection and restoration of wetlands, riparian vegetation and other environmental sensitive areas	Healthy environment and ecosystems provide (regulatory) services reducing the impact of natural hazard events. As such, preservation of ecosystem services for DRR should be an integral part of DRR strategy. Integrated flood management should consider environmental stewardship as part of their management intervention.	**45**

Action plan – Horizontal measures

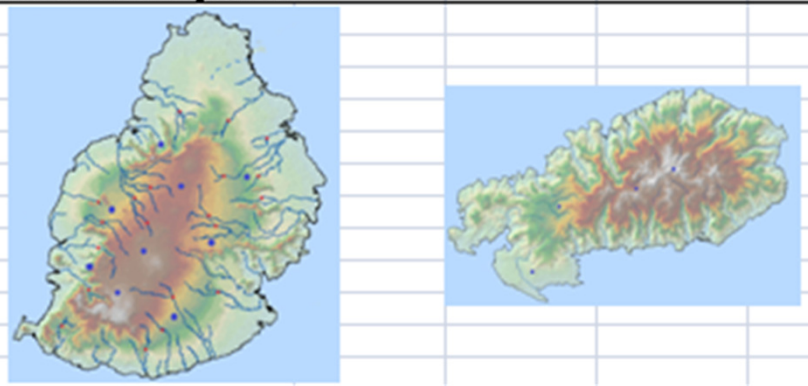
The development of hydrological forecasting and warning systems is an essential element in regional and national strategies. Introduction of a new real time hourly network with automatic stations for extreme rainfall and river flood, coastal hydrology measurements in ROM is a priority action for flooding, inundation and landslides risk management strategy.

ACTION H_1/1,4,2

Hydrological forecasting and warning systems

Type of intervention: Improving forecasting and warning systems

Study area: Mauritius and Rodrigues islands



Necessary instruments to integrate existing network:

- Weather stations and radars

The improvement of existent weather stations with a telemetric system it is very important in order to have real time data collection. For Mauritius Island, weather stations must be placed in the west part of the island (at least 3), in the east part (at least 3) and in the central mountains (at least 3), in order to be able to register the different climatic features of the island and characterize each basin with proper rainfall events. For Rodrigues Island, telemetric weather stations must be at least 4, being placed in such a way that it will be possible to register the differences of rainfall in the different parts of the island. Also a weather radar can be placed in Mauritius Island, while for Rodrigues Island a small weather radar

- Flow gauging stations

In Mauritius Island, it will be fundamental to have telemetric monitoring of flows in most important rivers, expecially for large basins, since the observations could help to alert population in case of extreme events. Flow gauging stations need to be placed in the upper part of the basin, in order to register the event at its early stage and have enuogh time to alert population, but at the same time it is important to place the flow gauging stations where the area draining there is enough to make the measure significant (for example after confluences). About 20 telemetric flow gauging stations must be placed, taking care to place more than one station in largest basins (such as basins W, C and E), while in very small basins it is not necessary to have real time flow measurements, since the flood is too rapid to give time for any alert system. For this reason in Rodrigues it is not necessary to put in place any real time flow gauging station.

- Coastal measurements

Integration of existing system of coastal monitoring could improve the forecasting and warning system. The number of buoys and tidal level sensors will be defined after the development of the planning activities.

Competent Authority: Government of ROM

Cost of intervention [mil MUR]:

- cost of planning activities	22
measures	*

Budget of intervention [mil MUR]:

Year	2012-2015	2015-2018	2018-2021	2021-2024
Amount	15	7	*	*

** a feasibility study and design is necessary to define with more details the parameters and the costs of the system, which has to take into account the system currently operating in ROM*

SUMARY COSTS OF PLANNING ACTIVITIES

ACTION	PLANNING ACTIVITIES AND INSTITUTIONAL IMPLEMENTATION	
Horizontal	1,517	**Million of MUR**
Landslide risk	140	
Flood risk	475	
Inundation risk	125	
TOTAL	2,257	

ROUGHLY COSTS ESTIMATION OF THE STRUCTURAL INTERVENTIONS :

Risk mitigation interventions: 10,000 mil of MUR

The unit costs of the interventions are based on similar works for risk mitigation

Action: Sound development strategy

Spatial planning and land management play an important role in risk prevention, by limiting the development in flood prone areas, and by encouraging flood risk-sensitive land use and management practices. High proportion of areas identified for future development are placed in areas prone to very high and high risk.

***Danger zoning plans**: In order to face up efficiently the land-use planning and the propose of measures to reduce risk, taking into account the flood, landslide and inundation hazard, it is necessary to develop a proper instrument represented by the danger zoning maps and plans. Danger maps have a detailed scale (1:5,000 to 1:10,000) which allows to identify with good precision areas exposed to hazard. Moreover they contained information that allows to quantify the intensity of involved processes (water depth, flow velocity, rock fall energy, etc.).*

*Stress test of the critical infrastructure - **dam safety and operational efficiency**. The direct benefits of the action include reduced vulnerability of the downstream population; extended service life and serviceability of high risk dams; enhanced institutional capacity for dam operation.*

Action: Healthy natural environment

Healthy environment and ecosystems provide (regulatory) services reducing the impact of natural hazard events. Nevertheless the area occupied by coastal and inland wetlands has declined. This trend should be reverted and more emphasis should be paid to ability of ecosystems to mitigate or offset the effects of the natural hazard.

Preservation of ecosystem services for DRR should be an integral part of DRR strategy. Integrated flood management should consider environmental stewardship as part of their management intervention. Preservation of wetlands and natural floodplains improve flood protection and provide other benefits. Restoration of riparian vegetation helps to regulate river flow (stages and speed), trap sediments and other materials carried by floodwaters and, and provides habitat and migratory paths for a diversity of organisms. Riparian buffers may be constituted by any type of vegetation along riverbanks, lakeshores, or other adjacent land to other surface waters. The restoration of the natural vegetation in the seashore has been proved successful as an effective solution against coastal erosion and, in cases of mangrove forest, as an efficient barrier against the storm surges. Over the past years the area occupied by coastal and inland wetlands and riparian vegetation has declined. This trend should be reverted and more emphasis should be paid to ability of ecosystems to mitigate or offset the effects of the natural hazard.

Action Sound (spatial) data infrastructure

A sound disaster risk management is data-intensive. Monitoring of precipitation (regimes), surface run-of, river discharges, wave heights, cyclone activity should be centrally stored and made accessible to all relevant institutions. The lack of a consistent spatial data infrastructure obstructed the conduct of this risk assessment. The acquisition of detailed topographic data in very high and high risk areas should become a high priority.

A modern disaster risk governance is hardly conceivable without an effective data infrastructure. A (spatial) data infrastructure (SDI) comprises a framework of (geographic) data and information, metadata, users and tools that are interactively connected in order to use (spatial) data in an efficient and flexible way. It includes technology, data acquisition and distribution policies, standards, human resources, and other activities necessary to acquire, process, distribute, use, maintain, and preserve (spatial) data. Underlying the SDI is the principle of a single data storage and maintenance at places where this is most effectively; seamless combination and sharing of data from various sources; easy access to the existing data by all pubic administration and authorised citizens. The geodatabase developed in the context of this project should be integrated in the SDI and represent the early stock. Environmental data such as whether observation, river flow and quality monitoring, storm activity, monitoring of environmental sensitive areas etc. should be attached a high priority within the SDI.

Action: Early warning and alerting system

The existing early warning system for tsunami and cyclones should be extended to include river discharge and high tide, as well as other natural hazards such as drought. The issued alerts should find an easier way to all concerned citizens through media, internet, and Internet-based social networks.

Development and implementation of a modernized, national-level Flood Forecasting and Early Warning System based on the most advanced technology available, including hardware, software, Relational Database Management Systems (RDMSs), radar stations, sensors, weather and water monitoring equipment, communications equipment, and modelling systems. The introduction of a new real time hourly network with automatic stations to measure rainfall (especially extreme events) is fundamental and it will be necessary also to upgrade hydrometric stations to supplement and strengthen the existing hydrometric network to collect reliable water level records and compute river flows; it will be fundamental also establishing procedures and providing tools and training to the staff for real-time analysis of flood situations of main streams and influent streams of major reservoirs. The improvement of a telemetric monitoring network in order to use observations to feed models could be a very useful tool to forecast events and to alert population.

Thank you for your attention