4.10 Vulnerability and Adaptation of Human settlements and Infrastructure

4.10.1 Methodology

Scope of assessment

The assessment examines the vulnerability and likely impacts on human settlements and public infrastructure such as wastewater, solid waste and transportation caused by increase in rainfall intensity, increase in temperature and extended heat waves, sea level rise and increase in the frequency and intensity of storms. It focuses on 1) coastal areas that are vulnerable to sea inundation and harbor major infrastructure and investments, 2) mountainous areas that are vulnerable to landslides, rockslides and mudslides, and 3) urban agglomerations that are prone to flooding or are sensitive to extreme climatic events.

Development of the sector under socio-economic scenarios

Under scenario A, Lebanon will be counting on tourism and commercial services as the major income-generating economic sectors to secure its growth in the face of integrated international trade. Despite the moderate economic growth, investments will go into improving Lebanon's infrastructure in order to be capable to host international fairs, exhibitions and luxury tourism. Beirut Rafic Hairir Intenational Airport will be able to reach a satisfactory level of passengers per year, commercial ports will be competent with other ports in the region and new highways and roads will be established (CDR, 2005). By improving the means of transportation and as Lebanon's touristic assets are expanded over the country, population density in urban agglomerations will decrease to be slightly increased in rural areas. Improvements in the infrastructure sector will lead to a better access to sanitation and clean water.

Under scenario B, Lebanon will be counting on its industrial and agricultural sectors to face competition induced by imported products and increase its income from exports of goods. Improving the means of transport will allow the relocation of certain activities of the capital towards different regions. Nevertheless, the high population growth and the low migration rate will contribute in high population densities in all rural and urban areas, which makes human settlements more vulnerable to climate change in this scenario B. Nevertheless, the increase in GDP and the balanced economic development in this scenario could instigate the adoption of suitable adaptation measures to climate change.

4.10.2 Vulnerability assessment

The sensitivity of human settlements and infrastructure to climate change is related to the poor and old infrastructure that varies across regions, sectors, and communities. The sensitivity of public infrastructure is considered low to moderate, but increased investments could render it more resilient to changes in climatic and climate-related factors. Table 4-17 presents information on the likely risks of the different infrastructure/human settlements types to projected changes in climatic and climate-related factors.

Adaptive capacity of human settlements and infrastructure in Lebanon is more variable than its sensitivity. The community's adaptive capacity largely depends on how it is designed, the state of its infrastructure and its ability to adapt to new climatic conditions; it is affected by the social, economic and technological conditions. The lack of sufficient infrastructure to carry out the daily functions of the Lebanese community reduces its capacity to adapt to changing environmental conditions. Moreover, the absence of proper planning and implementation in the different infrastructure subsectors results in a low adaptive capacity, unless significant investments are made to improve the current infrastructure. The adaptive capacity of specific settlements and infrastructure are described below:

- **Human settlements:** The adaptive capacity is lower in poor communities that tend to reside in areas that are densely populated, haphazardly built and lack proper services such as slums;
- **Wastewater Infrastructure:** There is a total absence of a proper sewage control or treatment prior to disposal. Sewage networks lack proper maintenance and operational control. The current low adaptive capacity is expected to improve gradually with the increasing investments in wastewater infrastructure and treatment;
- **Solid Waste Infrastructure:** The disorganized management of MSW in Lebanon is characterized by rudimentary "collect and dump" approaches. Although at the moment, the adaptive capacity is considered low, it is expected to increase with time due to better awareness and larger investments streaming into improving the management of solid wastes;

Table 4-17 Climate change exposure and the sensitivity of human settlements and infrastructure

	Increase in hot summer days	Increase in rainfall intensity	Increase in extreme phenomena such as violent winds and storms	Sea level rise of 12-25 cm by 2030 and 22-45 cm by 2050
Human settlements				
Buildings and structures	Definite risk especially in urban areas where the increase in hot summer days may lead to intensification of existing phenomena such as the urban heat island	Negligible risk except for slums and poor settlements High risk in built-up, flood-prone areas	Negligible risk except for slums and poor settlements	Negligible risk except for slums built on beaches
Infrastructure				
Wastewater	Potential risk for additional odor problems	The risk is limited to the capacity of treatment works through greater volumes of storm water	Negligible Risk	Negligible risk
Solid waste	Negligible risk – more rapid degradation of organic material in landfills and open dumps, and more days of odors	Negligible risk	Negligible risk – More frequent blowing of garbage and more days of odors in the vicinity of open dumps	The risk is limited to coastal dumps such as Sidon and Tripoli solid waste dumps
Roads	Negligible risk: The risk is limited to a decrease in the viscosity of asphalt	Negligible risk: The risk is limited to an increase in the formation of potholes	Potential risk to mountainous roads with no adequate structure to prevent road blockages from trees and debris	Negligible risk
Airports	Negligible risk	Definite risk as B-RHIA is a coastal airport that is sensitive to storm surges that may disrupt operations and pose hazards to passengers		
Ports	Negligible risk	Potential risk of future flood risk with sea-level rise which may cause interruptions to goods movement at ports		

- **Transport Infrastructure:** Despite the investments in road transport infrastructure, the low adaptive capacity of the transport infrastructure is not expected to improve above its current low levels;
- **Areas prone to floods and landslides:** The areas prone to floods and landslides are highly vulnerable, especially the Nahr Abou Ali area which experiences exceptionally violent torrential floods (CDR, 2005), and the areas located around rivers (Abou moussa, El kaleb, Kadisha, El jaouz, Ibrahim) and along faults (Yammouneh, Wadi el Taym) that are affected by landslides. Figure 4-44 and Figure 4-45 show the areas that are naturally vulnerable to floods and landslides. However, the improvement in construction standards and adherence to building codes can mitigate the risk which buildings in those areas might face.

The vulnerability of the human settlements and public infrastructure is exacerbated by different risks and threats as well as by the communities' low adaptive capacity. People living in poverty are more exposed to the potential damages to infrastructure from extreme events. Urban agglomerations such as Beirut, Tripoli, Saida, Nabatieh, Baalbek, Zahle, are highly vulnerable due to the presence of a large percentage of extreme and overall poverty, the proliferation of slums, and the urban heat island effect of these agglomerations. Under both socio-economic scenarios, investment in public infrastructure is expected to increase. However, even though it is more likely that the increase in investment

Figure 4-44 Flood risk areas versus population distribution

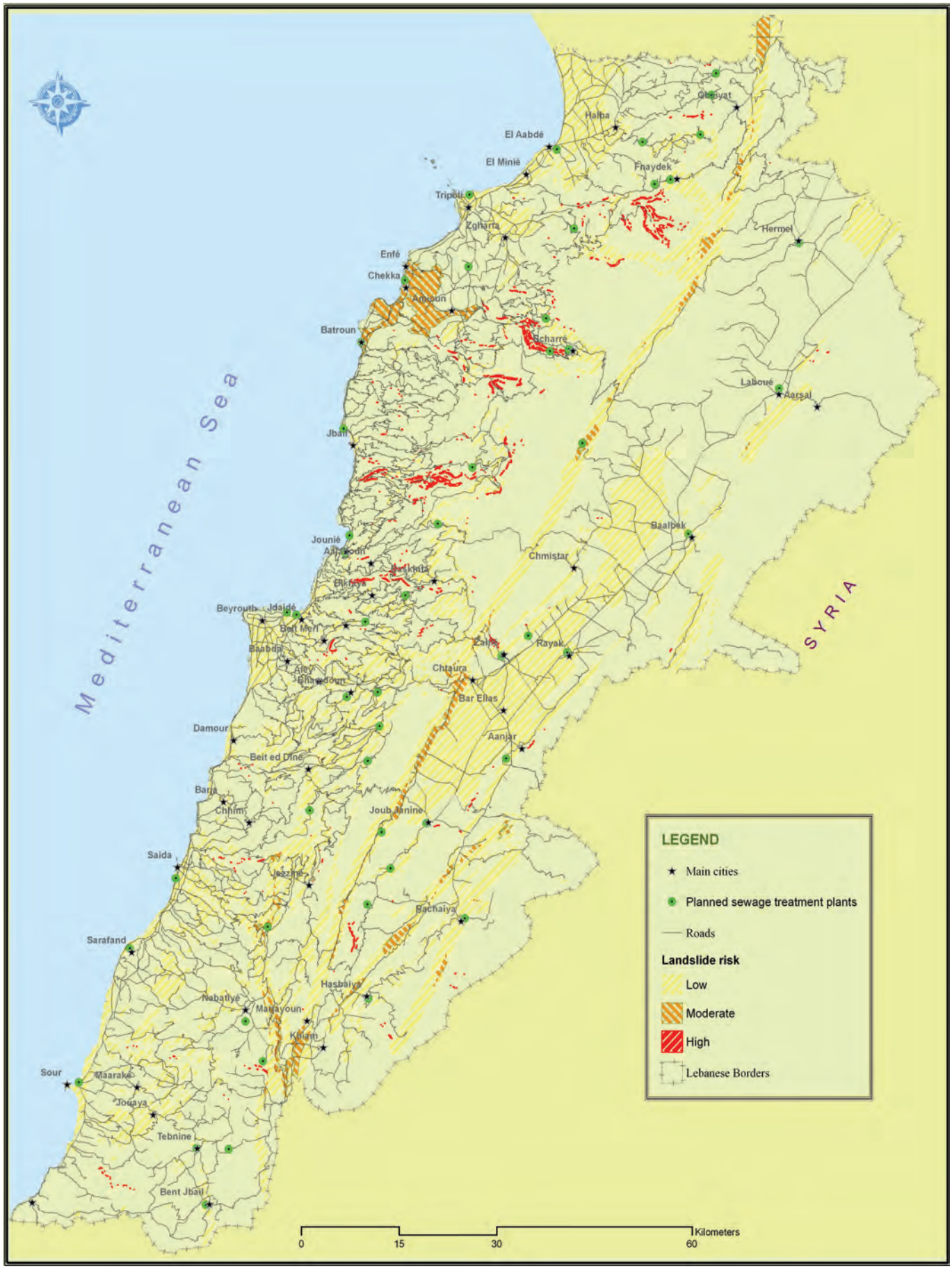

Figure 4-45 Landslide risk versus roads and sewage treatment plants

would be larger under Scenario B, urban communities will experience higher population densities and increasing pressures on the public infrastructure which might not be met with these increased investments. Hence, human settlements could be more vulnerable to climate change under scenario B.

4.10.3 Impact assessment

Physical infrastructure is directly affected by climate related changes while the economy of the areas of concern is affected in an indirect way. However, the uncertainty in the predictions of rainfall intensity and storms' frequency does not allow for an accurate determination of the climate change impacts. Nontheless, the most likely impacts are presented below:

Impacts on urban agglomeration

Financial losses in the infrastructure that supports the different economic sectors, resulting from climate change will reduce the quality of life, the level of income and induce a loss or a reduction in employment opportunities.

Impacts on buildings

A rise in sea level would place coastal settlements and buildings are a risk o inundation. The situation would be aggravated in case of a combination of storm surges with sea level rise. Furthermore, extreme weather events would jeopardize old buildings and facilities due to accelerated degradation of materials. Hence the maintenance costs and the potential of structural failure during extreme events are expected to increase (Assaf, 2009).

Impacts on public and service infrastructure

The projected changes in climate could lead to several damages in the transport infrastructure, water, and wastewater networks. Most of the expected damages are already being witnessed in different regions in Lebanon due to the poor and aging infrastructure which is highly vulnerable to snowy or sandy storms and to torrential rain.

An increase in the frequency and intensity of hot days could lead to a decrease in asphalt viscosity, resulting in a degradation of the quality of paved roads, e.g. potholes and cracks, and an increased risk of traffic and traffic accidents. Moreover, an excessive expansion in bridge joints and a deformation of the metal components of bridges are expected to occur as a result of the projected extreme hot waves.

High tides and storm surges in the winter season may cause the closure of coastal roads and bridges that could be threatened by inundation and the collapse of coastal waste dumps into the sea. These surges coupled with a high frequency and intensity of sandstorms or thunderstorms can also disrupt the operations at the Beirut Rafic Hariri International Airport.

Extreme cold events such as intense rainfall events and snowy storms could threaten mountainous roads due to an increased risk of mudslides and rockslides. Such events could increase peak volume and sediment loading into wastewater treatment plants leading to inadequate efficiency in treatment and overflows, if the capacity for treatment is exceeded (Assaf, 2009).

Impacts in socio-economic systems

Any financial losses in the infrastructure that supports agriculture, fishing and tourism and that might result from climate change will reduce the quality of life, the level of income and induce a loss or a reduction in employment opportunities. Moreover, areas where the population relies on artificial cooling during the summer season may see increased pressure on household budgets as average temperature is predicted to rise with time. Less-advantaged populations might not afford adaptation mechanisms such as artificial cooling/heating or climate-risk insurance. Although the poor might already have in place certain coping mechanisms, they might not be sufficient if climate change impacts transcend their ability to adapt (Wilbanks, 2007).

4.10.4 Adaptation measures

The adaptation measures for human settlements and infrastructure revolve around three main activities: 1) increasing the resilience of infrastructure to climate change impacts, 2) anticipation of floods and extreme events in vulnerable areas and 3) improving the efficiency and readiness of relief commissions during climate change induced catastrophes for a better intervention. More specifically, adaptation measures for human settlements and infrastructure include:

- Integrating climate change risks in SEAs and EIAs, especially in the planning phase and contingency plans;
- Taking into consideration the high-risk areas in urban planning and construction activities through restricting development and settlement in regions at risk of landslides or flood, adopting flood-sensitive

urban planning and adopting water-sensitive urban planning that may reduce surface runoff;

- Adopting flood sensitive urban planning through taking into consideration in the design of buildings, roads, solid waste and waste water treatment plants the potential impacts of climate change such as floods, landslides, rainstorms high tide, etc.;
- Adopting a better design of building envelopes to reduce cooling demand and render constructions capable of withstanding more extreme climatic conditions;
- Preparing an emergency management plan in case of extreme weather conditions and events, to be incorporated into routine operations in collaboration with emergency management agencies. This plan could include forecast techniques and information systems between weather bureau/meteorological offices and individuals through local government/offices (Jáuregui et al., 2001);
- Anticipating floods in vulnerable areas through hard engineering measures (dams, levees, diversions, etc.) and/or nonstructural methods (acquisition of properties, fiscal and financial incentives, regulations, warning systems/evacuation plans, etc.) (Jáuregui et al., 2001).
- Ameliorate the coordination between the High Relief Commission (HRC) and other governmental committees, regional offices or NGOs and establish regional offices of the HRC;
- Establish the "Unit Management Disaster" that should include NCSR, Order of Engineers, HRC as well as the relevant ministries;
- Periodically train or build capacity of technicians, employees, municipal members etc. on emergency intervention in case of floods/landslides or any other climate induced impact.