Executive summary Phase 1 Report Alexandria

Background

The World Bank is directing and financing a Regional Study on Adaptation to Climate Change and Natural Disasters in the Coastal Cities of North Africa (Alexandria in Egypt, Tunis in Tunisia and Casablanca in Morocco and on the Bouregreg Valley between Rabat and Sale in Morocco). The Alexandria part of the study is being carried out by the Arab Academy of Science, Technology and Maritime Transportation (Arab Academy) and the international consulting consortium led by Egis BCEOM of France. Arab Academy is generously contributing its expertise and resources in a partnership agreement with the World Bank. This first volume of the study constitutes the Phase 1 report, covering risk assessment in the current situation and in 2030.

With a population of about 4 million and an area of over 230,000 ha, Alexandria is Egypt's second largest city and its largest seaport. The city is built on a narrow and partially elevated coastal ridge facing the sea and is exposed to marine submersion, coastal erosion, earthquake, flooding and water scarcity risks. Informal areas, which house one third of Alexandria's total population, deteriorating buildings and infrastructure in old and dense part of the city; and fast urbanization of surrounding areas over reclaimed wetlands and other low-lying areas make the city particularly vulnerable to these risks.

Compared to the current situation, disaster and climate change risks are expected to worsen by 2030 due to climate change, and continuing urban expansion in new sites exposed to natural hazards. The city may face higher marine submersion, coastal erosion and water scarcity risks, along with an increase in seismic, land subsidence, and flooding risks. Additionally, climate changes may negatively affect public health. It is estimated that natural disasters and climate change impacts would cost the city of Alexandria approximately $1.72 billion (in Net Present Value) during 2010 to 2030 period[1]. Climate Change related impacts are estimated to be around 18% of the total estimated cost.

While natural risks are growing, the institutional capacity in Alexandria to manage these risks and prepare communities for potential future disasters and climate change impacts is limited. The current organizational set-up of the emergency response systems remain highly centralized with limited coordination between agencies horizontally, and vertically down to the level of communities. The analysis undertaken as a part of this study shows the need for greater financial and decision making authority at the local level, as well as for better inter-agency coordination to ensure local ownership and effective implementation.

[1] Initial approximation based on the impacts of water scarcity, earthquake damage scenarios, and climate change related impacts on public health.

Study Area

With a population of about 4 million and an area of over 230,000 ha, Alexandria is Egypt's second largest city and its largest seaport. It is located along the coast of the Mediterranean Sea in the north central part of the country and has a semi-arid Mediterranean climate characterized by mild, variably rainy winters and hot, dry summers. The city is built on a narrow and partially elevated coastal ridge facing the sea and has historically expanded in a linear fashion with very high densities along its water-front.

Greater Alexandria currently spans over 230,000 ha with its 2006 population estimated at 4.3 million by the national census. The current boundaries of the urban agglomeration of Alexandria consist of seven districts, Al-Montazah, Shark (East), Wasat (Middle), Gharb (West), Al-Gomrok, Al-Agamy and Al Amreya, along with the Borg Al Arab city and three villages. Evolving from a small settlement built by Alexander the Great in the year 331BC, the urban agglomeration has historically expanded in a linear fashion, and currently reaches from the coastal village of Abu Quir in the North-East to the village of El-Deir in the South-West. The city, which shows very high densities along its water-front, is built on a narrow and partially elevated coastal ridge facing the sea, behind which the lakes, low-lying rural areas, and wetlands are located..

The review of the geological and topographical context shows that Alexandria is built on a coastal plain. The area is characterized by irregular hills in the southern parts with an elevation from 0 to 40 meters above mean sea level and slopes towards the Mediterranean Sea northward. Areas below Mean Sea Level (MSL) are Abu Quir natural depression (former lagoon), Maryut lagoon south of Alexandria, and aquaculture ponds bordering the southern margins of the coastal lagoon. Large parts of the beach and coastal flats expand between zero and two meters above MSL. Areas above three and four meter lie within the coastal dunes at the backshore of Abu Quir bay and the southern part of the lower delta plain, about 35 km from the shoreline. In the framework of the present study, a digital elevation model (DEM) has been generated, using all available topographical data. Its precision is however insufficient to enable accurate erosion, flooding or submersion simulations.

Alexandria has a semi-arid Mediterranean subtropical climate characterized by mild, variably rainy winters and hot, dry summers. January and February are the coolest months with daily maximum temperatures typically ranging from 12°C to 18°C. July, and August are the hottest months of the year with an average daily maximum temperature of 30°C. Alexandria experiences violent storms, rains (up to 100 mm/day), and sometimes hail during the cooler months. Meteorological data collected over the last 30 years show trends of increasing frequency of heat waves and precipitations, and decreasing frequency of cold waves. For the purpose of this study, the *study area* is defined by the perimeter of the available master plans of the Greater Alexandria.

A city threatened by various natural risks

Evaluation of natural hazards in the present situation highlights that Alexandria is at a 'medium' risk[2] of marine submersion and coastal erosion, and acomparatively lower risk of earthquake, tsunami, flooding, and water scarcity. The city of Alexandria faces following hazard risk in the current situation :

Land Subsidence

Based on the study of radar satellite images[3], Alexandria city is affected by terrain deformation such as subsidence[4] and uplift. Land motion mapping over the entire city of Alexandria, which was supported by the European Space Agency (ESA), found that:

- Between 5 to 9% of the measured points correspond to negative movement or land subsidence. The natural (i.e. not tectonic) rate of subsidence is estimated to range from 0.04 cm/ year (based on ERS satellite images from 1992 to 2000) to 0.9 cm /year (based on ENVISAT images from 2003 to 2009). A rate of 0.6 cm/year was estimated based on ALOS images from 2007 to 2009.
- Less than 1.2% of the measured points show positive movements or uplift.
- The most affected areas within the Alexandria city are along the northern border of Lake Maryut, and in the southern part of the city between Gharb district and Abu Quir.

In the absence of in-depth ground based observations, the most probable explanation concerning the land subsidence in the study area remains the compressing of the recent deposits. Further studies will be necessary for a better understanding of all the deformation phenomena affecting the city of Alexandria and its surroundings.

Earthquake

Being close to two major fault zones in Egypt (Eastern-Mediterranean Cairo-Faiyoum and Suez-Cairo-Alexandria), Alexandria City has suffered significant damages due to earthquakes in the past. The city was shaken by five earthquakes in the last century, the most recent one being in 1998. Although details about the economical values of damages from past earthquakes are not known, it is estimated that old, non-reinforced masonry or adobe buildings, and structurally weak reinforced concrete buildings suffered majority of damages.

Probabilistic assessment of **earthquake risk** shows that the Alexandria urban area faces a **moderate risk**, corresponding to an intensity of around V-VI MSK[5] for the 100-year return period and around VI MSK for a 475-year return period. The resulting potential damage from this level of earthquake risk can be very light to light (slight damage to a few poorly constructed buildings). However, given the poor geotechnical quality of Alexandria's soils, an increased degree of intensity can be considered for some of the urban areas, with "moderate" potential damage (serious damage to older buildings, masonry collapse) for the least frequent events. Subsidence areas detected by satellite interferometry can be considered as sensitive to such "site effect".

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[2] It is important to note that the risk level presented in the report are developed as a rough and simplified measure to facilitate the comparison between the present situation and the 2030 situation, between the various hazards under consideration, and between the studied sites (4 urban areas distributed in 3 countries). This rating exercise includes some subjectivity and cannot reflect uncertainties regarding risk assessment. Therefore, it cannot be used (and/or correctly understood) outside the framework and context of the present study.

[3] Within the framework of this study, the European Space Agency (ESA) supported land motion mapping over the whole city of Alexandria through the application of Interferometric Synthetic Aperture Radar (InSAR) technologies, using images from ALOS, ERS and ENVISAT satellites. ALTAMIRA Company carried out the study in 2009 by reconstituting monthly historical ground displacement for the urban and rural areas of Alexandria to measure and map the evolution of the actual urbanized coastline during the last two decades.

[4] Subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea-level.

[5] Based on the Medvedev-Sponheuer-Karnik (MSK) scale of seismic intensity

Tsunami

Currently, the risk of damage by tsunami is considered to be low in Alexandria, as these events have very long return periods in the city. Tsunami has a probability of 12% of occurrence in 100 years, 6% in 50 years, and around 2.5 % in 20 years. The two known historic incidents of tsunamis in Alexandria occurred in the years 365 and 1303 AD, with reported wave heights of 1m and 2.9m respectively. Return period of a similar magnitude of tsunami event in Alexandria is estimated at 800 years.

Marine Submersion

The annually averaged variations of water level (tide-gauge records) measured at Alexandria Western Harbor from 1944 to 2006 (60 years) and the data measured at Abu Quir Harbor (1992 through 2005; 14 years) shows that **the mean sea level at Alexandria, and Abu Quir has risen 1.8 and 3.4, mm/yr, respectively**. Difference between the two measurements can be explained by local ground subsidence or uplift.

The coastal area is also subject to **submersion risk**, most evident during stormy periods. Storm surges in association with spring tides (high tides) raise water levels by 60cm above normal. Occasionally, high tides occur in combination with storm surges, and sea level can produce **wave set-ups of 1.6 m**. Such storm surges can submerge the shoreline but low lying areas expanding around Lake Maryut and South of Abu Quir are protected by natural ridges or sea walls.

Coastal Erosion

Based on the analysis carried out as a part of this study, t**he risk of coastal erosion hazard is 'medium to high'** between the Dekhiela harbor and the Western port of Alexandria, as well as at the El Montazah, El Maamoura and Abu Quir beaches due to the absence of coastal protection devices along these beaches of low width and slope. Overall, the coastline of Alexandria can be divided into three categories:

(i) Naturally vulnerable coastal areas or 'seriously eroding areas':

- Flat and low-lying coastal plain such as the western backshore zone of Abu Quir Bay and El Tineh plain
- Deltaic coastal plain areas affected by subsidence such as Abu Quir
- Beaches of Alexandria, from Mandara to El Silcila, are experiencing **chronic long-term erosion of ~20 cm/yr** because of ongoing natural coastal processes. More than 50 % of the sandy beaches between El Montaza and El Silcila, 14.5 km long, have significantly disappeared following seaward widening of the Corniche highway constructed between 1998 and 2002, creating "sediment starved" coastal cells.

(ii) Artificially protected coastal areas. These areas are at risk of any structural failure during a major tsunami or coastal storm. Examples of such areas in Alexandria are:

- Abu Quir seawall along the Nile delta coast: this old structure has an elevation of 1.4m above mean water level and is 10 km in length. It was initially built in 1780 to protect the low-lying land behind it from sea flooding, for agriculture purposes. Between 1983 and 2010, this wall was reinforced many times. However, possibility of breach or break during a major tsunami or coastal storm cannot be excluded.
- Corniche Road and adjacent beaches:are artificially protected by structures (breakwaters, groins, concrete or rock armor layers) that require periodic maintenance. These structures are also at risk of failure in case of severe storm.

(iii) Remaining areas along the Alexandria coast can be considered safe or 'naturally protected safe areas. These inlcude:

- The rocky carbonate ridges acting together to protect the low-lying areas south of the city and west of Abu Quir land.
- The coastal dune defense system fronting the backshore of Abu Quir Bay.

- Shore parallel-accretion sandy ridges exist at some localities along the Nile delta coast particularly the central part of Abu Quir Bay.

Flooding

Overall, Alexandria faces a low risk of floods due to heavy rains during winter storms (reaching 96 mm/ day for a 100 years event). Recently urbanized areas, which are below sea level such as those between the hydrodrome and Abu Quir, at the edge of the former Abu Quir lagoon, in Sharq and Al-Montaza districts, are susceptible to flooding.

Although the overflows at manholes or pumping stations during winter storms (squalls) are frequent, no significant damage because of flooding has been reported. The urban drainage basins of the Alexandria conglomeration do not show real hydrographical pattern with well-identified drainage channels (wadis). Due to the arid climate, rainfalls are scarce and do not require specific hydraulic facilities. In Alexandria, runoff water is therefore managed together with wastewater in a combined sewage and drainage network. This network has been improved and upgraded during the last decades, but its discharge capacity is low (equivalent to a 2-year flood event), so overflows at manholes or pumping stations during winter storms (squalls) are frequent. These floods are of limited extent and usually do not exceed a few hours. As a result, no significant damage because of flooding of the urban areas of Alexandria has been reported, but traffic can be temporarily disturbed.

Most of Alexandria's drainage waters flow towards Lake Maryut, together with the wastewater, through two treatment plants. The lake water level is kept between -2.8 to -2.6 m below sea level, in order to facilitate the drainage of the surrounding agricultural areas. The Lake Maryut pumping station discharges the excess water into the sea. Flood simulations carried out within the framework of the present study show that even for a 100 years event, the lake level does not rise more than a few decimeters, so the impact in terms of possible flooding of the lakeside urban areas does not seem significant, considering pumping stations are operational.

Water Scarcity

The water resources of Alexandria are becoming scarce, however the current risk of water scarcity is low as the current water supply meets current needs. The current water needs are estimated to be between 4.5 million m^3/ day (2.5 million m^3 drinking water, 1 million m^3 industrial water, and 1 million m^3 agricultural water) for the summer months and 3.80 million m^3/day (2.0 million m^3 drinking water, 1 million m^3 industrial water and 0.80 million m^3 agricultural water) for the winter months. Water supply from the Nile River through the Al- Mahmoudeya canal (5 million m^3/ day discharge) covers the current needs.

Surface-water resources originating from the Nile via the Al-Mahmoudeya Canal are now fully exploited, while groundwater sources are being brought into full production. With only 31 Million m3/year, compared to at least 1 825 M m3/year for the Al-Mahmoudeya Canal, groundwater resources do not count much. Moreover, aquifers are partially salinized and unsuitable for human consumption. Alexandria is facing increasing water needs, demanded by a rapidly growing population, by increased urbanization, by higher standards of living and by the agricultural policy, which emphasizes expanded production in order to feed the growing population. Moreover, almost half of the Egyptian industrial activity is located in Alexandria, and this sector is the major contributor of water consumption in the Alexandria urban area. In the last ten years, there has been a 50% rise in the water demand.

Climate change is expected to worsen the natural risks by 2030

Compared to current situation, natural hazard risks are expected to increase by 2030 due to climate change and urban growth, with high marine submersion and coastal erosion risk expected around El Dekheila, Western harbors, and at Abu Quir areas. Risk of water scarcity is expected to be high in future, as growing water demand would exceed the supply capacity by 2032, together with possible hydrological changes and uncertain geopolitical context in the upstream part of the Nile basin. Seismic risk may also increase with greater exposure and growing land subsidence effect. Risk of flooding is also expected to increase due to increased exposure and climate change impacts. Additionally, climate change may negatively affect public health, with a potential increase in diseases such as diarrheic diseases and malaria.

Climatic projections to a horizon of 2030 were made as part of this study using **dynamic downscaling methods** from the three ENSEMBLES European project models with IPCC scenario A1B, and the Météo-France ARPEGE-Climate model with IPCC scenarios A1B, A2 and B1. These modelling results estimate that the **city of Alexandria will get warmer, on an annual scale, by +1.2 C to +1.9°C**. There is, however, a very wide margin of uncertainty associated with increased heat waves. Changes in **rainfall events** are also accompanied by **high levels of uncertainty** (lack of coherence between models or wide ranges of values). In this context, it has been decided to consider results of the METOffice Hadley Centre model together with A1B scenario as a “worst case” scenario, for which extreme precipitation increases respectively by 7% and 30% for the 10 and 100 year return periods.

Based on a critical analysis of the IPCC's projections and the latest references in the literature on the subject, a **global rise in sea level of 20 cm by** 2030 is assumed for this study. It should be pointed out that this is a high projection, and that the trends in sea level rise currently measured on Alexandria are much lower. High projections will help in simulating and planning for worse scenario that can result from Climate Change.

Climate Change will affect natural hazards, except those of geological origin such as unstable natural terrain and earthquake risks. Climate changes will also result in aggravation of climate related diseases such as diarrheic diseases, and malaria. The following sections outline the effect on natural hazards by 2030, taking into account the impact of climate change:

Coastal erosion and marine submersion

Coastal erosion and submersion risks are expected to be high by 2030 due to **sea level** rise and urban expansion. **The risk of coastal erosion is expected to be highest between El Dekheila and the western harbors, and at Abu Quir**. The storm surges may increase, with resulting damages to sea walls and other shore-front structures. The coastal areas of Abu Quir are directly threatened by marine submersion, and the low-lying areas of the former Abu Quir lagoon by possible breakage of the old Mohammed Ali sea-wall, built in the 18th century. This situation requires preventing any new settlements in this agricultural area.

In spite of numerous projects for coastal protection, **a rise in sea level will reactivate or amplify the process of coastal erosion,** and therefore receding of the coastline. The sandy beaches still in their natural state risk **receding on average by 10 to 15 m** by 2030. In the urbanised areas, which are already protected by structures or protective works (widening of beach by massive replenishment with sand, then periodic maintenance, installation of structures blocking the sand laterally), retreat will be slower but nonetheless inexorable. **In case of storms combined with high water levels**, beach head works in urbanised areas risk **severe damage**, as the width of the beach is not sufficient to dampen the effects of the swell as too close to the high tide line. The sandy beaches remaining in their natural state will be totally submerged and will recede significantly. However, they should be able to partially reconstitute in periods of fine weather, and almost entirely when the beach head consists of dunes.

Flooding

The conditions of flooding may worsen because of the combined effect of climate change (despite uncertainties, more extreme rainfall events may be expected with additional 30% for the 100 years event) and increasing urbanisation (non-absorbing soils). A ‘medium’ flooding risk (compared to low risk in current situation) can be expected in areas below sea level, between the hydrodome and Abu Quir, and at the edge of Abu Quir Lagoon in Sharq and Al-Montaza districts. Overflows of the present sewerage network may become more frequent, leading to damages to ground floor of buildings due to flooding.

The combined effects of climate change and urban growth may double the water level rise in Lake Maryut for a 100 years flood. Nevertheless, the situation should stay manageable with regard to the present pumping capacity and water level regulations.

Water Scarcity

The risk of water scarcity is ‘high’ for 2030 scenario as the 50% increase in water needs observed during the last 10 years is expected to continue. With a maximum supply capacity of 11 million m^3/ day, and taking into account the current consumption growth, the Al-Mahmoudeya Canal supply capacity would be exceeded by 2032. Although climate change projections for the Nile River basin are difficult to carry out, we can assume that the growing needs of all the countries of the catchment’s area will significantly affect the resource availability.

Current and future urban sensitive components

Urban components within Alexandria city, which are most vulnerable or sensitive to the impacts of climate change or future disasters, are (i) informal or slum areas, housing one third of Alexandria’s total population; (ii) old and deteriorating buildings and infrastructure; (iii); new construction over reclaimed wetlands and other low-lying areas, facing enhanced land subsidence and flooding risks and, (iv) buildings and infrastructure facing the coastline, which are at risk of marine erosion and submersion. Fast urbanization of surrounding areas will further increase the vulnerability of the city, with the appearance of new urban patches on sites exposed to hazards and by expansion of informal settlements in low lying areas exposed to flood and seismic risks.

The city of Alexandria, with over 230,000 ha area and a current population of about 4.3 million people (in 2006) is witnessing fast population growth. Urban sensitive or vulnerable components within Alexandria city are:

(i) *Informal or slum areas*: The informal or slum areas covers about 3.25% of the total area of Alexandria but represent about 35.4% of Alexandria’s total population. These areas are mainly located in the central city area (Al-Montaza and Sharq districts) and are characterized by high population density, bad building conditions, absence or bad conditions of infrastructure, and high percentage of people living below poverty line. Moreover, buildings within informal settlements are mostly made of masonry, which is more vulnerable to seismic risk. Their location coincides with areas of strong subsidence determined by interferometry analysis. Because of the bad geotechnical context, these areas are also at high risk of earthquake. It is also likely that some of these areas are below sea level (at the edge of the former Abu Quir lagoon), involving drainage and sanitation issues. (ii) *Deteriorating buildings and infrastructure in the central city*: Dense, old and deteriorating buildings and infrastructure from central city to the east as well as from the west at Al-Ameriya district to New Borg Al-Arab city, are at seismic risk. Despite poor standards of construction, residential buildings are mostly made with reinforced concrete, and can be considered – according to current seismic classifications (see Section 2.1. in Chapter 6 – Economic Evaluation) – at moderate seismic risk. However, the bad condition of some of these buildings, especially in the Gharb district constitutes an aggravating factor.

(iii) *New construction in hazard prone areas*: Reclaiming wetlands and other low-lying areas for construction, put future population at risk of damages from potential earthquake, land subsidence or flooding.

(iv) *Buildings and infrastructure facing coastline*: Urban components likely to be affected by the coastal erosion and marine submersion risks are port facilities, coastal roads, and dwelling houses on the coastline directly exposed to these risks. The sanitation system is highly sensitive to heavy rains, and in case of overflow, streets and tunnels may be flooded.

According to future population estimations from the Governmental Organization for Physical Planning (GOPP), Alexandria may reach a population of 6 million inhabitants in 2030, following a **40% population growth**. This major growth will translate itself in the urbanization of surrounding areas, threatening critical natural resources, such as Lake Maryut , which currently play a critical role in the management of drainage of water prior to their discharge into the sea. The strategic planning documents developed by the Governorate of Alexandria show major direction of urban expansion westwards, along both shores of Lake Maryut . However, given the recent trends, it is assumed that urban sprawl will also continue south of the city, between Maryut Lake and Abu Quir.

In terms of vulnerabilities, the cumulative effect of these changes may be an increased exposure of the poorer populations (precarious living conditions), the appearance of new urban patches (major projects) on sites relatively exposed to climatic risks (Abu Quir depression, Maryut Lake, shoreline) and by expansion of informal settlements in hazard prone areas. In particular, an urban expansion South of Al-Montaza and Sharq district is likely to occur in low-lying areas exposed to flood and seismic risks.

Cost of disaster risks and climate change impacts

Although full costing of potential economic impacts of climate change and disasters was not possible for Alexandria due to the unavailability of precise Digital Elevation Model, some quantitative estimates were possible for likely impacts on health, water resources, and earthquake risk. Based on initial estimates, natural disasters and climate change impacts would cost the city of Alexandria approximately $1.72 billion (in Net Present Value) during 2010 to 2030 period. Climate Change related impacts are estimated to be around 18% of the total estimated cost.

The methodology for assessing economic impact of climate change and natural disaster risks strongly relies on urban vulnerabilities projection for 2030 and a good characterisation of the hazards, based on GIS outputs. Since reliable Digital Elevation Model and quantitative estimates on future urban development scenarios were not available, a thorough economic assessment was not possible. . Some quantitative estimates were possible for health impacts due to climate change and water resources, since they do not directly rely on spatial data, as well as earthquake risk, which can be considered homogenous in the area considered.

The total annual costs of disasters considered by the study, and for which cost estimation was possible, taking into account climate change, is estimated at $1.72 billion or 10 billion Egyptian Pounds for 2010 to 2030 period.

With respect to climate change related health issues (mostly diarrhoeal diseases, and malaria), the total annual average costs are around 278 MLE, equivalent to about 0.30% of the city's annual GDP. The indirect costs are estimated at around three times the direct costs. It is important to note that the health costs due to climate change are based on a number of assumptions, and thus should be taken as very rough estimate.

An institutional set-up in need of improvement

While natural risks are growing, the institutional capacity in Alexandria to manage these risks and prepare community for potential future disasters and climate change impacts is limited. The current organizational set-up remains highly centralized with limited coordination between agencies horizontally, and vertically down to the level of communities. The analysis undertaken as a part of this study shows not only the need for greater financial and decision making authority at the local level, but also for inter-agency coordination to ensure local ownership and effective implementation.

Egypt is slowly moving from a reactive approach of managing disasters and climate change, which relies primarily on emergency response, to a more pro-active approach of risk reduction and preparedness. Till now, the Egyptian government has focused on post-disaster relief and rehabilitation activities, as evident in the rescue and relief efforts following past disasters. Less attention to adopting prevention measures against major natural risks may be because of relatively moderate impacts of past disasters in the country. However, recent disaster events, such as Cairo's Moqattam September 2008 landslide (rockfall and slope collapse leading to the loss of 107 lives) burying the Duweiqa informal settlement, points to rising vulnerability resulting from poorly constructed and maintained buildings and infrastructure, settlement of population in hazard prone areas, lack of infrastructure to ease rescue efforts, absence of early warning system and inter-agency protocols in case of crisis. Slow-onset disasters such as water scarcity and other risks resulting from climate change may further aggravate the existing vulnerability.

From 2000 onwards, the national government passed various decrees to establish the legal and institutional basis for disaster risk management and climate change adaptation. The current structure for disaster management and response follows a highly centralized organizational set up, with the Information and Decision Support Center (IDSC), under the Egyptian Cabinet, as national coordinator for Crisis Management and Disaster Risk Reduction, and the Civil Protection Administration, the Ministry of Interior, acting as the operational arm. The IDSC plays a pivotal role in the coordination of disaster-related crises, and more recently in managing risks related to disasters (in 2005 after Egypt signed the Hyogo Framework of Action in 2005) and climate change. Other scientific and technical entities active in the field of disaster and climate change risk assessments are the Egyptian Meteorological Authority and the Egyptian National Seismic Network (ENSN).

While the near-vertical geometry of the Egyptian State's structure minimizes horizontal overlap between the tasks and the duties of two or more neighboring entities, the local government appears to have limited resources and decision making power. For example, the Physical Planning Center for Alexandria Region is entrusted with the preparation of urban master plans, but their validation and issuing still remain with the central GOPP. The Civil Protection Administration plays an important role in emergency response with a focus on rescue and relief operations, and training of personnel in crisis management. At a local level, the Decree of the Minister of Interior gave the authority to establish regional Civil Protection units under the leadership of the Governor to respond to emergencies, with operational equipments and trained personnel for rescue and relief operations. Other national agencies that are involved in natural risk management at local scale in Alexandria are the Ministry of State for Environmental Affairs Agency, EEAA: Alexandria Regional Branch Office, the Coastal

Protection Authority, the Alexandria Sanitary Drainage Company, and the Lake Maryut Management Authority. These agencies' mission is to enforce laws, develop erosion, flooding, and marine submersion control projects.

Local authorities, which were interviewed in Alexandria within the framework of the present study, called for adopting a more decentralized approach in decision making, and for widening the mandate of the Governorate and local institutions in disaster management. Insufficient involvement of the Environmental Management Unit, lack of financial resources, lack of inter-authority coordination (no regular meetings held), and severe deficiency in law enforcement were also considered to be the most urgent faults to repair.

A case study of 2010 Sinai flash-flood was undertaken as a part of this study. This case study is comparable to 1972, 1979, 1991 and 1998 floods in Alexandria. The case study highlights the need for significant and continued investments in early warning and communication, together with a strong focus on emergency response needs. Overall, although there has been some progress in multi-agency coordination in the last decade, further improvements are required in timeliness, coordination, and effectiveness of the national system of monitoring and early warning. It is recommended that multiscale preparedness and response may still rely upon the present system(s), with the provision of a few key technical improvements targeting efficiency and robustness.