CLIMATE RISK AND VULNERABILITY ASSESSMENT, AND THE XIANGTAN CLIMATE- RESILIENT CITY TOOLBOX

I. CLIMATE RISK AND VULNERABILITY OF XIANGTAN

A. Background: Xiangtan Climate Risks

1. The climate risk and vulnerability assessment (CRVA) is prepared for the proposed Xiangtan low-carbon transformation sector development program in the People's Republic of China (PRC). Figure 1 and Figure 2 show the geographic locations of Hunan Province in the PRC, and the Xiangtan project area within the boundary of Hunan Province, respectively.

Figure 1: Location of Xiangtan city in Hunan Province in the PRC

2. Xiangtan, a prefecture-level city is located in the eastern-central part of the Hunan Province, on the lower reaches of the Xiangjiang River (part of the Dongting Lake system). The urban area of Xiangtan City is separated by the Xiangjiang River and its tributaries (the Lianshui River and the Juanshui River), with the Yuetang District on the right bank and the Yuhu District on the left bank. The river basin is 94,660 square kilometers (km^2), 90% of which is in Hunan, upstream of Xiangtan. More than 60 reservoirs have been built in the river basin with an adjustable storage capacity of 1.06 billion cubic meters (m^3), but most reservoirs are situated at the upper and middle reaches of the tributaries with no controllable reservoir on the trunk stream.[1]

[1] Hunan Hydro and Power Design Institute, 2007

3. Xiangtan is a semi-tropical city. The annual mean temperature is around 17.8 degree Celsius (℃). Rainfall in Xiangtan is concentrated in spring and summer, while the autumns are typically dry. Heavy rainfall events are often short in duration. Extreme precipitation events which result in flooding normally last between one to three days and usually occur between April and August, while the highest river levels occur between April and July, which is the design period for the dike/drainage infrastructure according to Hunan Hydro and Power Design Institute.

Figure 2: Location of Xiangtan city

4. Xiangtan is currently experiencing the impacts of climate change and associated risk and resilience issues. Future change in climate will exacerbate the current situation rather than introduce new and unfamiliar risks. For example, there are current issues with flooding for some parts of the City during extreme rainfall and without intervention(s) the area subject to flooding will increase as will the flood levels but the impacts of flooding on buildings, water supply, transportation and energy will largely remain the same, if no adaptations are implemented. Xiangtan is presently less impacted by fluvial flooding due to an extensive dyke system around the rivers. Yet, some areas of Xiangtan are impacted by pluvial flooding as drainage capacity in these vulnerable areas and potentially others is exceeded.

5. The same issues pertain to changes in the temperature profile for the City. Being a semi-tropical City, temperatures will increase at greater than the global average. Extreme temperatures are likely to rise in such semi-tropical areas but not as much as in continental centers and in temperate and arctic zones, where the greatest deviations from historical temperatures are already being felt. Therefore, temperature-related vulnerabilities will not be radically altered by climate change to 2050. While temperatures will rise, they are already high and it is the more subtle changes in seasonal temperatures, with rising temperatures in typically cooler seasons, that will pose some stress to some systems such as energy, yet these systems are already stressed.

6. For better understanding of climate change in the context of Xiangtan City, SimCLIM for ArcGIS tool was applied. Potential flooding has been mapped at a high-level, using a SRTM 30 meter resolution digital elevation model (DEM, available freely for download) for the landform, and overlaying a potential flood depth of 2m, in order to identified areas at potential risk of flooding. Site data analysis confirms that the moderate impact of climate change on extreme events in Xiangtan City. Precipitation amounts for each return period event increase but only by a small percentage by 2030 and 2050. Temperature extremes do increase and return periods shorten but extreme temperature already occur with a one in 50 year event becoming a one in five year event, which while more frequent is potentially not critically impactful for infrastructure unless it is already maladapted to current climate. There is evidence of roofs being lost in storms however extreme cyclone wind speeds change very little through to 2050 and risk from wind events changes very little from current risk levels.

7. Many of the climate risks faced by buildings, transport, water, energy and urban form in Xiangtan are already occurring. It is the increase in the frequency and magnitude of events that will become an issue and this is not as easily captured in the spreadsheets. Mean temperature and precipitation change very little from current levels by 2050 and if the City, its population and buildings, waste, transport, water, energy and urban form are not currently adapted then that is an issue that should be addressed, as there is little additional risk from climate variables going out to 2050.

B. CRVA Methodology

8. Data from the Coupled Model Inter-comparison Project Phase 5 (CMIP5) climate models for the area of this project were compiled and reviewed. The downscaled climate scenarios that were derived from the General Circulation Model (GCM) runs conducted under the CMIP5 were established for Xiangtan. The CRVA was conducted for greenhouse gas emission scenarios known as Representative Concentration Pathways (RCPs) used in the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC).

9. The CMIP5 climate projections were obtained through model simulations for four different scenarios, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, respectively, which represent different levels of greenhouse gas emission. The scenario of RCP2.6 represents the lowest level of greenhouse gas emission that corresponds to the agreed outcomes of the Paris agreement (no more than 2.0°C of temperature increase over pre-industrial). RCP4.5 and RCP6.0 are the medium and high scenarios but their differences are mainly in late of this century with little difference by 2050. RCP8.5 is the extreme case that represents the highest level of emission with the most significant degree of climate change.

10. In this project, a conservative approach was adopted to use the RCP4.5 as a reference scenario and RCP8.5 as a challenging scenario for this CRVA analysis. Future climate hazards, such as floods and temperature extremes, etc. were derived by analyzing these two scenarios at a local level. This is to ensure that both the climate change impact assessment and the resulting proofing measures are adequate for the proposed project components.

11. The simulated climate data from the GCM used in this assessment include both the historical baseline and future timeframes under both the RCP 4.5 and RCP 8.5 scenarios, respectively. The historical scenario covers the GCM precipitation data for a 55-year historical baseline period from 1950 to 2005, while the RCP4.5 and RCP8.5 scenarios include a 80-year projection period (2021 to 2100). The GCM model data for each period of time scale can be viewed as a statistical realization of that climatic period.

12. The precipitation and temperature data from the GCM were applied in the CRVA to project future climate change conditions. A combination of different RCP and climate sensitivities could be used to characterize the future climate change scenarios and their associated uncertainty ranges. The RCP4.5 scenario with low-climate sensitivity and RCP8.5 with high-climate sensitivity were used as an indicator of the corresponding low and high bound of the uncertainty range. Projected precipitation/temperature data were obtained for the following three climate change scenarios: Historical, RCP 4.5 and RCP 8.5 as shown in Table 1.

13. Three key period timeframes were defined for the CRVA: (1) PA, the past 30 years from 1976 to 2005; (2) NF, the near-term future from 2021 to 2050; and (3) LF, the long-term future from 2071 to 2100. Projected climate variables (such as maximum temperature, minimum temperature and precipitation) that may cause hazardous to the proposed project in Xiangtan were obtained for the three periods, respectively.

C. Temperature

14. The annual mean temperature based on the observed data between 1961 and 2012 is around 17.8℃. The temperature has increased significantly in Xiangtan, based on observed daily temperature. Figure below indicates that the mean temperature increased by 0.156℃, from 1961 to 2012 while the minimum temperature increased faster at 0.206℃. Figure 9 shows the future temperature change in Xiangtan using 40 CMIP5 GCM ensemble median, RCP8.5 projections. Mean temperature in 2030 could increase by 1.1℃ and 1.99℃ by 2050. The extreme temperature increase is a bit higher than the mean temperature.

Figure 3: Annual average temperature, maximum temperature and minimum temperature change in Xiangtan (℃)

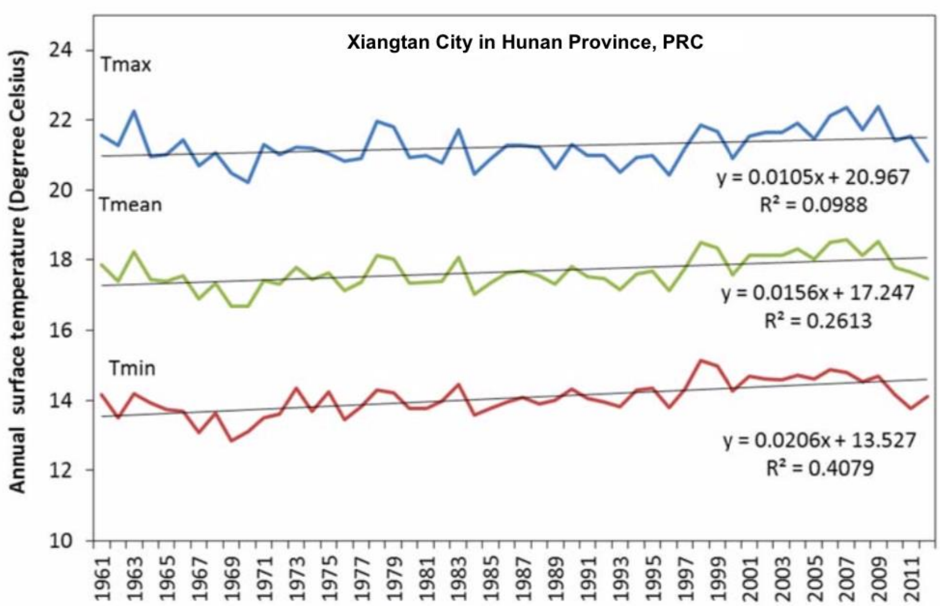


Table 1: Xiangtan's mean temperature (℃) and future change using RCP 8.5 CMIP5 GCM ensemble median

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Baseline	4.80	6.20	11.30	17.40	22.90	26.40	29.90	29.50	25.20	19.30	13.40	7.40	17.81
2030 RCP8.5	1.19	1.19	1.12	0.96	1.07	1.08	1.04	1.05	1.26	1.16	1.13	1.15	1.10
2050 RCP8.5	2.15	2.15	2.02	1.73	1.93	1.96	1.89	1.90	2.28	2.09	2.04	2.08	1.99

CMIP5 = Coupled Model Inter-comparison Project Phase 5, GCM = General Circulation Model, RCP = Representative Concentration Pathway.

Table 2: Extreme daily maximum temperature change (℃) extreme values analysis ensemble median

Return Year	Baseline	2030 RCP8.5	Change in 2030	2050 RCP8.5	Change in 2050
10	38.5	39.8	1.3	40.9	2.3
100	40.8	42.2	1.4	42.9	2.1

RCP = Representative Concentration Pathway.

15. Extreme heat events and high temperatures during summer droughts and in the pre-monsoonal season may have spillover impacts on water supply and cooling requirements for energy. Driving these impacts on energy and water demand will be a different extreme temperature profile with the potential extension of the pre-monsoonal period risk period and a shortening of the cooler wet season period.

Figure 4: Historic average annual mean temperature (℃) in Xiangtan

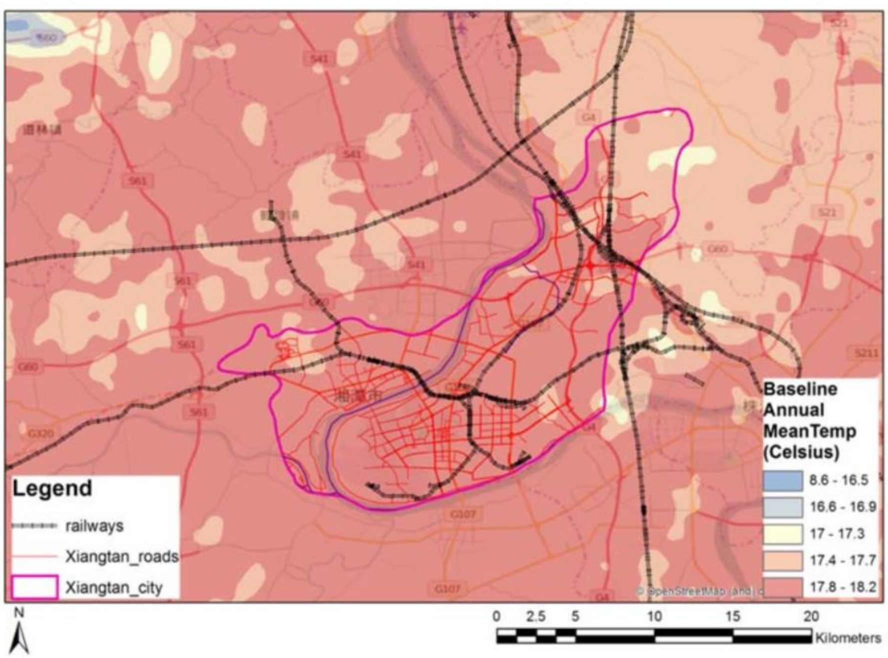
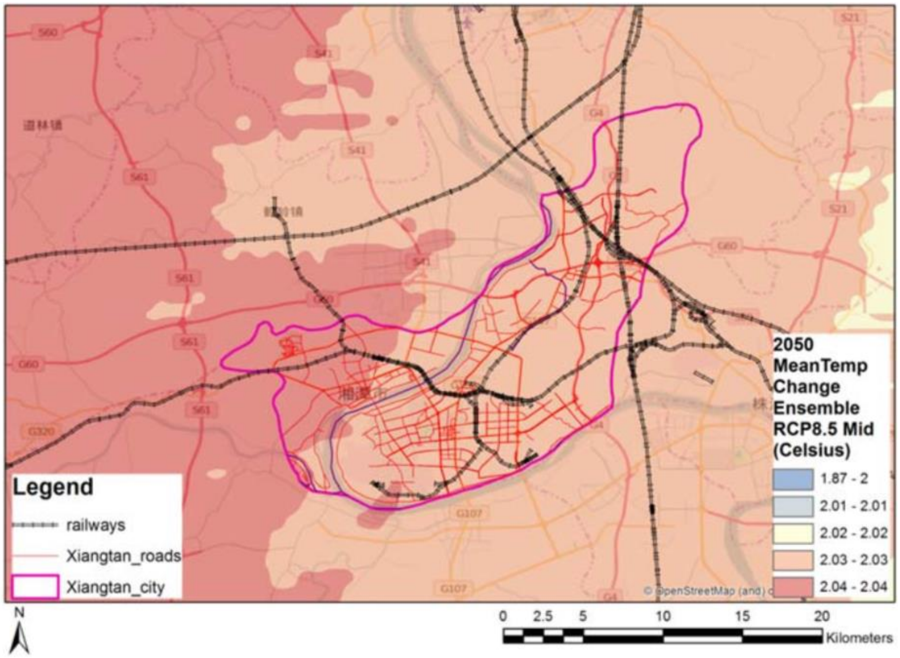


Figure 5: Xiangtan 2050 annual mean temperature change ()-GCM ensemble median RCP 8.5 Mid



D. Precipitation

16. Annual precipitation in Xiangtan is 1485.0 millimeters (mm), with May and June having the highest rainfall amounts with over 200mm in each month, and December and January lowest. Figure xx shows historic annual precipitation recorded between 1961 and 2012 in Xiangtan. Even though historic data do not show a clear precipitation change trend in Xiangtan but the annual variation can be significant. The projected annual total precipitation could increase by 2.4% in 2030 and 4.3% by 2050 under RCP8.5 GCM ensemble median scenario, with seasonal differences, the increase could be up to 5.0 % in April to a decrease of 1.6% in October. These results signify that the mean wetter months are likely to get wetter, and mean drier months are likely to get drier.

Figure 6: Historic annual precipitation between 1961 and 2012 in Xiangtan

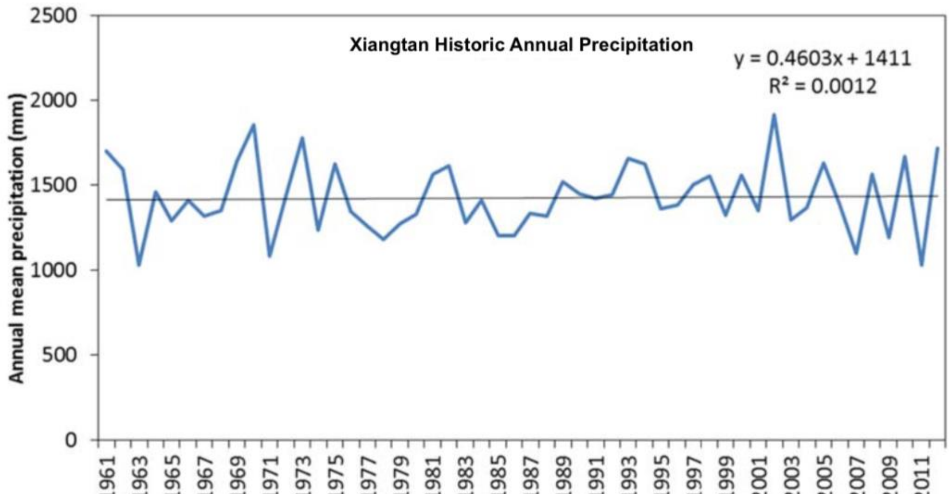


Table 3: Historic mean precipitation (mm) and future change (%) using RCP8.5 CMIP4 40GCM ensemble median

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Baseline	57.0	94.0	145.0	194.0	204.0	204.0	139.0	140.0	8.0	98.0	82.0	46.0	1485.0
2030 RCP8.5	2.2	1.9	5.7	5.0	4.8	1.4	-0.7	1.4	3.3	-1.6	-0.1	-0.5	2.4
2050 RCP8.5	4.0	3.5	10.3	9.0	8.7	2.5	-1.3	2.6	5.9	-2.9	-0.1	-0.9	4.3

CMIP4 = Coupled Model Inter-comparison Project Phase 4, GCM =General Circulation Model.

Figure 7: Historic average annual precipitation baseline map in Xiangtan

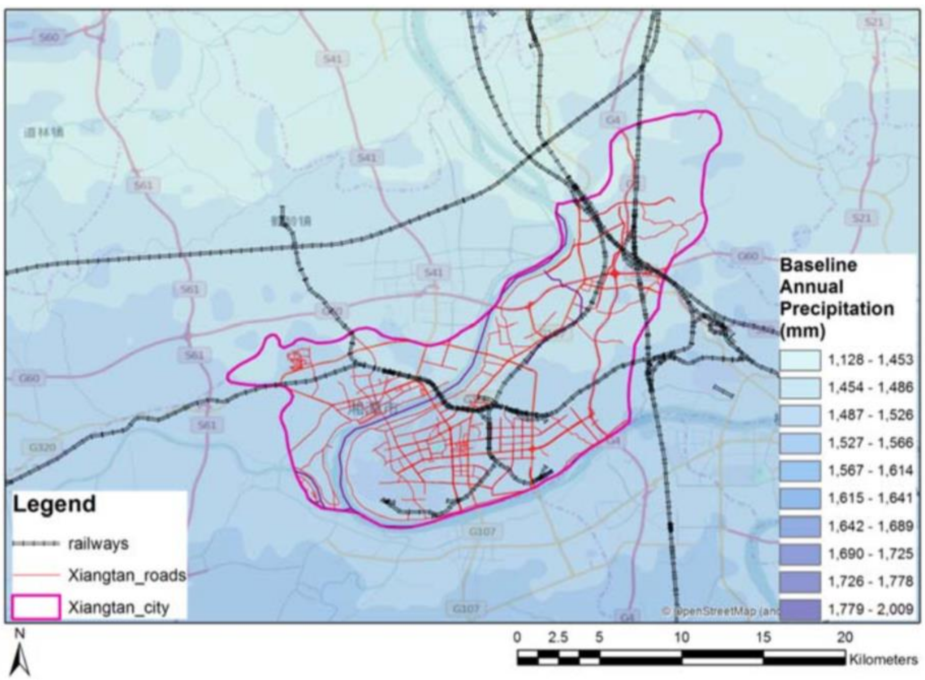
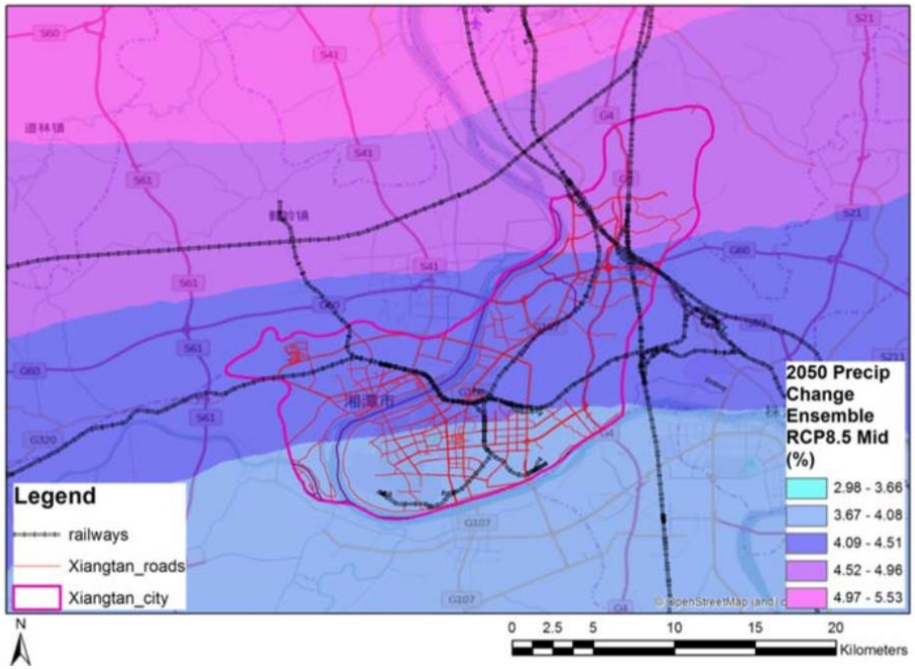


Figure 8: Xiangtan 2050 annual mean precipitation change (%) using RCP8.5, GCM ensemble median



17. Using generalized extreme value (GEV) analysis approaches, daily extreme precipitation was calculated based local historical observation data and from data derived from the CHIRPS dataset. 100 year return extreme precipitation is 123.8mm. More extreme values in different return intervals are listed in Figure below.

18. While different than mean precipitation, extreme precipitation was projected to increase more dramatically, in 2030, 100 year extreme precipitation could increase by 7.9% and in 2050 by as much as 14.3%. These results also exemplify the trend that extremes will increase more dramatically than annual and monthly mean precipitation. In 2050 the 300 year return extremes could increase by as much as 18.6%.

Figure 9: Daily extreme precipitation in Xiangtan, historic and future projections

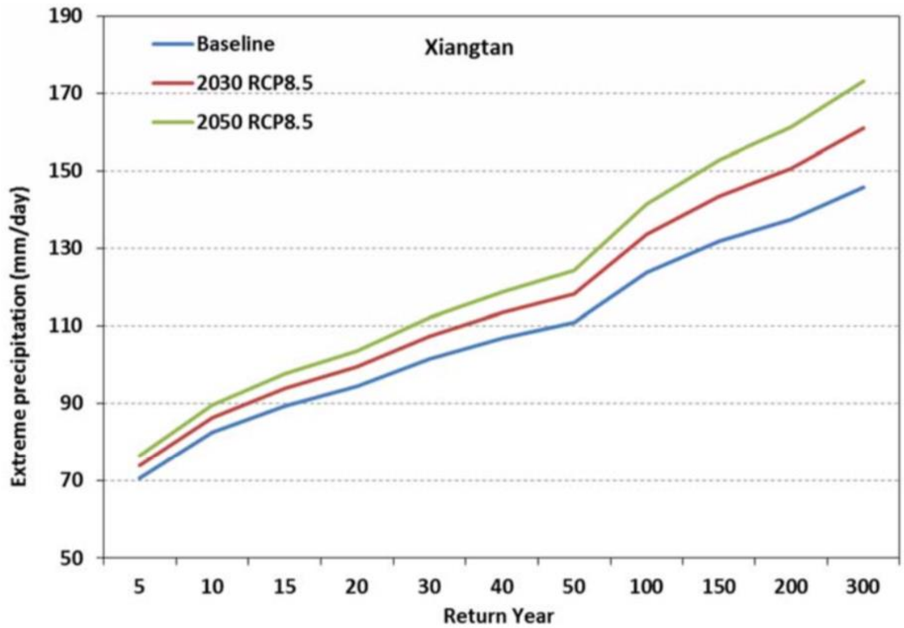


Table 4: Daily historic extreme precipitation and future change in Xiangtan

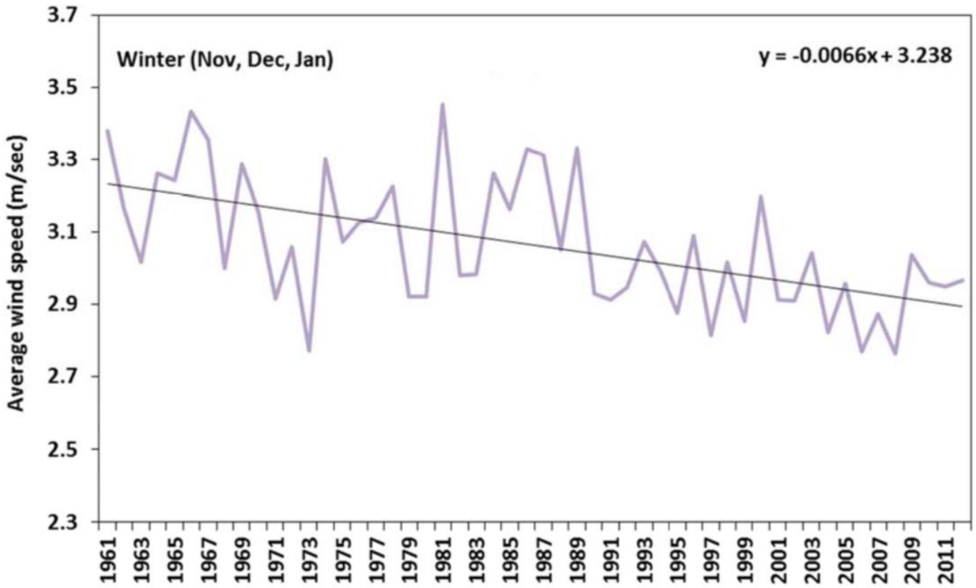
Return Year	Extreme precipitation(mm/day)	2030 RCP8.5 change (%)	2050 RCP8.5 change (%)
5	70.6	4.5	8.2
10	82.4	4.9	8.8
15	89.4	5.1	9.2
20	94.4	5.3	9.7
30	101.5	5.8	10.5
30	106.7	6.2	11.2
50	110.8	6.7	12.2
100	123.8	7.9	14.3
150	131.7	8.8	16.0
200	137.5	9.6	17.3
300	145.8	10.3	18.6

RCP = Representative Concentration Pathways.

E. Wind

19. Wind speed is an important climatic variable for dispersion of pollutants. Also of importance is the number of low or no wind days in the critical winter season when air inversions can occur. There is a clear trend in the reduction of the average winds during those critical winter months.

Figure 10: Historic average wind speed in m/s for winter months in Xiangtan



20. The Global Circulation Models (GCM) show the potential for a continued trend in the reduction of wind speeds in the winter months as shown in table 5 below. The months of December, January and February project a continued decline in wind speed as a percentage change from an ensemble of wind GCM models. Changes occurring in wind speed regimes, particularly in the winter months may have impacts for human health. The less frequent changes in pressure systems means that inversions are becoming longer in duration and this leads to the build-up of pollutants in the atmosphere. Climate have influence on air quality as longer periods of no or low winds would increase and may exacerbate high level of pollution problems as over daily or hourly emissions of pollutant decline.

Table 5: Percentage change in wind speed per degree of global warming in Xiangtan

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Average	1.85	2.26	3.81	3.84	6.14	9.39	6.47	8.69	4.64	3.70	4.44	1.23	4.66
Median	-1.16	-1.48	1.90	0.86	1.94	5.62	2.57	7.09	2.62	3.28	2.07	-1.19	1.96
Low %	-9.21	-9.18	-6.48	-8.95	-6.77	-1.42	-6.94	-4.30	-7.26	-3.72	-4.85	-7.70	-6.50
High %	11.7	10.3	9.4	16.7	16.2	17.2	16.5	21.1	15.6	8.9	10.5	6.5	13.4

21. Xiangtan experienced eight major flood events during the period 1906 to 1954, the largest of which was recorded in 1926 with a maximum discharge of 21,900 cubic meter per second (m^3/s). Since the establishment of Xiangtan Hydrological Station, the largest flood is recorded as one in 1994 with a maximum discharge of 20,800 m^3/s and a 41.95m flood height. Hunan Hydro and Power Design Institute estimated that a 1 in 100 year flood at Xiangtan Hydrological Station would be approx. 24,600 m^3/s, resulting in the submerged urban area for a 1 in 100-year flood is 9.5 km^2, with an inundation depth of up to 5.0m and an affected population of ~0.36 million, 2007).

22. The Flooding Prevention Report of Xiangtan in 2015 records that heavy rainfall in June 2015 also led some damage to 152 households and reallocation of 1453 residents. In Yuetang District of Xiangtan, some landslide also occurred in some areas. In 2016, total rainfall of Xiangtan between January to July exceeded 1200mm, which was, 30% higher than same period of last few decades and primarily falling in around 10 rainfall events. Inadequate spatial planning, and insufficient drainage capacity and maintenance of drainage systems increase the vulnerability of the city to flooding. This will be further exacerbated by increasing urban density, increases in the intensity, duration and seasonality for rainfall, rising sea level/storm surge and ongoing land subsidence in the future.

F. Drought

23. Standardized Precipitation Evapotranspiration Index (SPEI) is an indicator of the dry and wet condition, negative values represent drier than normal, positive values represent wetter than normal. Figure XX shows historical SEPI data in Xiangtan between 1961 and 2012. Figure 11 shows SPEI projections for 2030 and 2050 using RCP8.5, GCM ensemble median, which predicts insignificant change in SEPI under global climate change scenarios.

24. While drought frequency would not change much (only the extreme drought becomes more frequent), issues of development, population increase, impacts on water quality and limited current resilience to drought mean that the impacts of drought are likely to increase in the future.

Figure 11: Historic standardized precipitation evapotranspiration index (SEPI) variations in Xiangtan

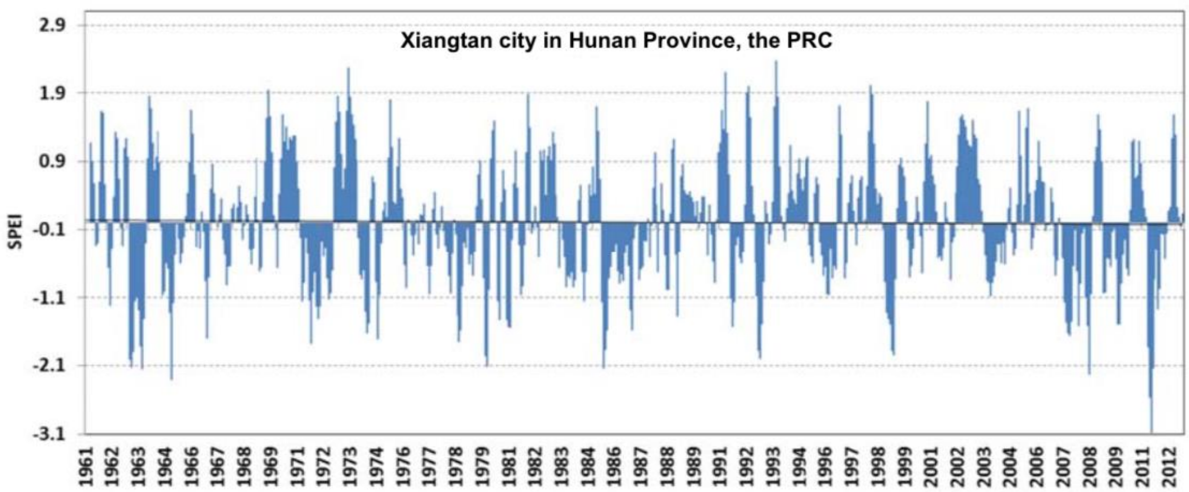


Figure 12: Xiangtan's Standardized precipitation evapotranspiration index (SEPI) projections for 2030 and 2050, using 8.5 GCM ensemble median

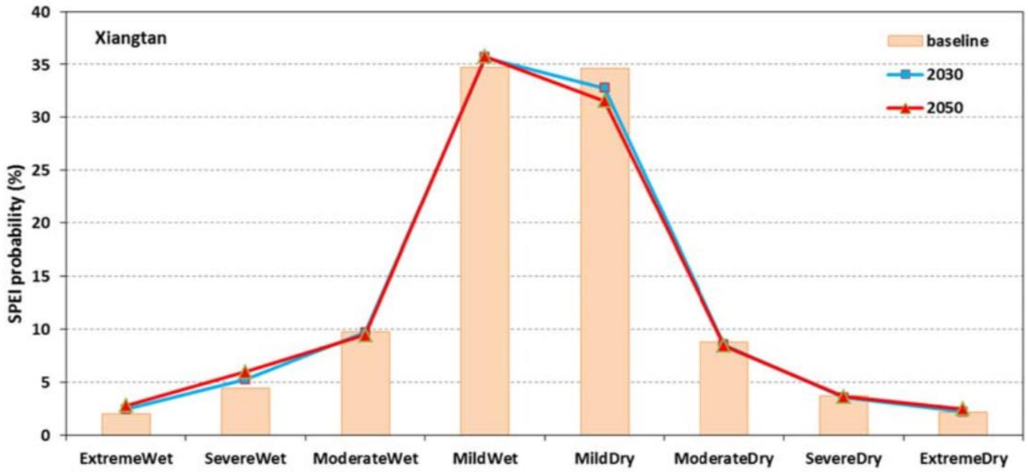


Table 6: Xiangtan drought and severity frequency baseline and projections (%)

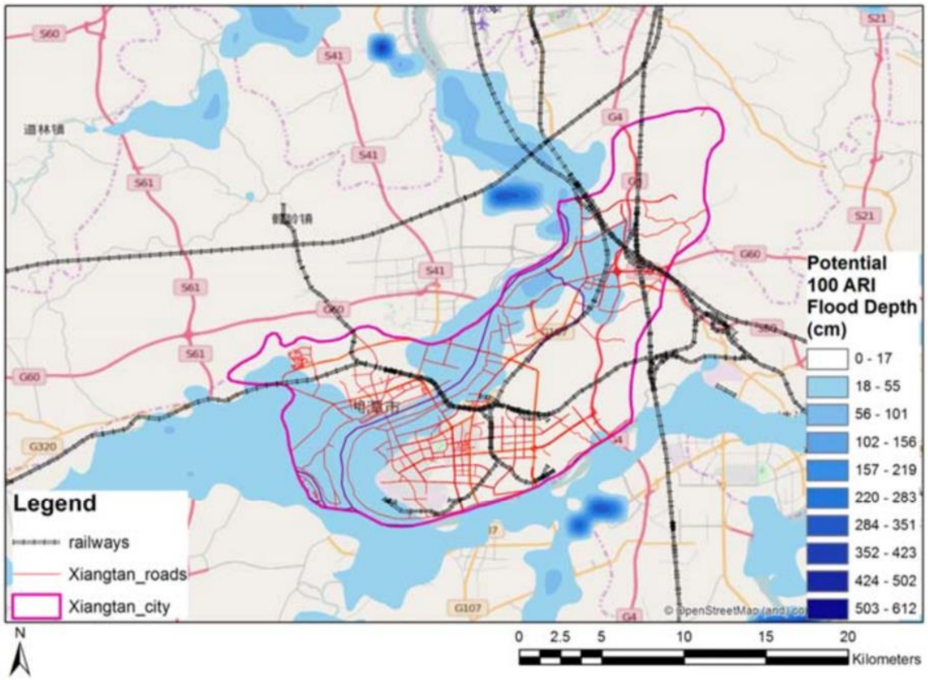
	Extreme Wet	Severe Wet	Moderate Wet	Mild Wet	Mild Dry	Moderate Dry	Severe Dry	Extreme Dry
Baseline	1.97	4.43	9.75	34.70	34.62	8.74	3.66	2.13
2030 RCP8.5 change (%)	2.40	5.25	9.70	35.66	32.76	8.50	3.55	2.19
2050 RCP8.5 change (%)	2.79	5.98	9.45	35.74	31.53	8.42	3.63	2.46

RCP = representative concentration pathway

G. Flooding

25. Since the issue of urban flooding is complicated with urban land use change and modification of the river and drainage system, the accurate simulation of future flood risk requires more detailed data collection and modelling works. As screening flood risks, the following map was generated using Global Assessment Report (GAR) 2015 flood data, which is only used as an indicative map.

Figure 13: Historical 100 year return flood depth in Xiangtan based on GAR 2015 data



26. Xiangtan experienced eight major flood events during the period 1906 to 1954, the largest of which was recorded in 1926 with a maximum discharge of 21,900 m^3/s. Since the establishment of Xiangtan Hydrological Station, the largest flood is recorded as one in 1994 with a maximum discharge of 20,800 m^3/s and a 41.95m flood height. Hunan Hydro and Power Design Institute estimated that a 1 in 100 year flood at Xiangtan Hydrological Station would be approx. 24,600 m^3/s, resulting in the submerged urban area for a 1 in 100-year flood is 9.5 km^2, with an inundation depth of up to 5.0 m and an affected population of ~0.36 million, 2007).

H. Vulnerability to Existing Energy Infrastructure

27. Electricity is primarily supplied to Xiangtan by two thermal power plants located in urban area, which are (i) Xiangtan Datang power plant and (ii) Datang Huayin power plant. Other power sources are (i) small hydropower plants located in Xiangxiang City and Xiangtan County, which are rural parts of Xiangtan. A combined installed capacity of clean energy source likes hydropower, photovoltaic, biogas are around 105,000 kilowatts. And natural gas is becoming an increasingly important source of energy within the city and round 90% of households are connected to the natural gas supply that are used mainly for cooking. Within two urban districts of Xiangtan, three industry-owned power plants exist: (i) 486.5 megawatts (MW) power plant by Xiangtan Iron & Steel Co., Ltd. Of Hunan Valin; (ii) 9 MW thermal power plant by Sinoma Cement Co., Ltd.; and (iii) 7.5 MW thermal power plant by Xiangtan Electrochemical Scientific Co., Ltd.

28. There are ongoing works to replace overhead transmission and distribution power lines with underground ones, which is aligned with the draft Xiangtan City Environmental Health Management Regulations that prohibits overhead lines on main streets and public spaces. Yet, still main part of urban areas occupied with overhead power cables. Power substations, voltage transformers, gas storage and distribution stations are on the ground and may expose to climate

risks. The following table provides vulnerability risk matrix taking into energy infrastructure in Xiangtan.

Table 7: Climate risks and vulnerability matrix in Xiangtan energy infrastructure

Climate Variables		Infrastructure at Risk									
Variables	**Specific Risk**	**Power Generation based on fossilfuels (coal, oil, Gas and nuclear)**	**Power Generation based on renewable (hydro, wind and solar)**	**Power Transmission & distribution (Sub-stations)**	**Power Transmission & distribution (powerlines)**	**Supply of fuels**	**Demand**	**steam underground concreteducts**	**Distict heating concreteducts**	**Distic heating pre insulated pipes**	**Underground Pump stations**
Precipitation	Extreme Precipitation	Red	Red	Red	Red	Amber	Red	Grey	Grey	Grey	Grey
	Changes in Mean Rainfall	Amber	Amber	Amber	Amber	Amber	Amber	Grey	Grey	Grey	Grey
	Drought	Green	Green	Green	Green	Green	Green	Grey	Grey	Grey	Grey
Temperature	Extreme Temperatures	Red	Red	Red	Red	Amber	Red	Grey	Grey	Grey	Grey
	Increased Mean Temperature	Amber	Amber	Green	Green	Green	Amber	Grey	Grey	Grey	Grey
Wind and Storms	Lightening & Extreme Storm Events	Amber	Amber	Red	Red	Green	Amber	Grey	Grey	Grey	Grey
	Strong Wind & High Wind Speeds	Amber	Amber	Red	Red	Amber	Amber	Grey	Grey	Grey	Grey
	Humidity	Amber	Green	Amber	Amber	Green	Green	Grey	Grey	Grey	Grey
	Bushfires	Green	Green	Green	Green	Green	Green	Grey	Grey	Grey	Grey
	Interdependencies	Red	Red	Red	Red	Red	Red	Grey	Grey	Grey	Grey

Red	Likely high level risk. Needs consideration.
Amber	Potential risk. Needs investigation.
Green	Not a likely issue.
Grey	Non existent.

I. Vulnerability to Existing Transport Infrastructure

29. As a part of Changsha-Zhuzhou-Xiangtan (CZT) cluster city, Xiangtan transport network contains urban and regional roads, highways, high-speed urban and inter-city railways. The target for public transport coverage in the master plan is 22–24% of the total urban area, but currently there is limited utilization of the public transport network, which only makes up 4.5% of all means of transport. Road lengths are: (i) 266 km of expressways; (ii) 294 km of primary (truck) roads; (iii) 382km of tertiary roads; and (iv) 232 other minor roads indicated under the Xiangtan Planning Scope Area.

30. The transport network is particularly susceptible to inundation – under a 1-in-100 year flood event, it is reported that the national highway 320 and three main railway lines will be flooded, with major disruption to the transport network. According to the city authority, current road design standards account for earthquakes and 1-in-100 year flood levels (current). Table below presents overview of vulnerability risk matrix taking into Xiangtan transport infrastructure.

Table 8: Climate risks and vulnerability matrix in Xiangtan transport infrastructure

Climate Variables		Infrastructure at Risk		
Variables	**Specific Risk**	**Rail/Metro/Cable Car**	**Roads (incl. bridges)**	**Underground infrastructure (tunnels, stations, etc.)**
Precipitation	P1 Extreme Rainfall	red	red	red
	P2 Changes in Mean Rainfall	yellow	yellow	yellow
	P3 Drought	yellow	yellow	yellow
Temperature	T1 Extreme Temperatures	red	red	yellow
	T2 Mean Temperatures Changes	yellow	yellow	green
	L1 Lightning and Storms	red	red	yellow
	L2 Wind Speed	red	red	green
Humidity	W1 Humidity	yellow	yellow	yellow
Other	W2 Wildfires	green	green	green
	V1 Interdependencies	yellow	yellow	yellow

red	Likely high level risk. Needs consideration.
yellow	Potential risk. Needs investigation.
green	Not a likely issue.
grey	Non existent.

J. Vulnerability to Existing Water Infrastructure

31. Main water source for Xiangtan is surface water from Xiangjian River. The east and west river areas only have one water supply point, indicating a high susceptibility to system failures. Abstraction of groundwater is no longer permitted by the Government, yet it is noted the possible use in case of emergency. Water consumption is roughly divided as 70% for domestic use and 15% each for commercial and industrial uses in Xiangtan. According to the information, the water supply network in Xiangtan is rather aging and leakage seems high, resulting in low water pressure and high workload and cost for maintenance.

32. Water quality monitoring indicates the quality of supply from the Xiang River is good. However, in discussion with stakeholders, the river can be polluted by heavy metals from upstream production facilities, particularly during flood events. More advanced treatment methods have become necessary to ensure good quality drinking throughout the year. Heavy rainfall increases the sediment load in the river, requiring increased filtration capacity. Pollution is also exacerbated during drought conditions, when water intakes are close to the bottom of river, where pollution is heavy. Both of these situations will increase with climate change.

33. The existing wastewater management system is separated in some areas and combined in others. The system is old and experiences a high level of infiltration. The Xiangtan Statistical Communiques note that the sewage treatment rate increased from 87.8% in 2013 to 92.5% in 2015, although the discussion with stakeholders indicated that there is still a large discharge of untreated wastewater to the river systems and only some of the sewers are connected to wastewater treatment plants.

34. The design basis for stormwater drainage for pluvial flood protection is a return period of 1 in 100 years for Xiangtan with a capacity to drain a 1 in 10-year rainstorm within 24 hours. Stormwater management comprise three main elements: (i) Piped system, (ii) Drainage canals and natural ponds, and (iii) Sluice gates and pump stations. According to Xiangtan water bureau, existing stormwater drainage systems are insufficient. Drainage canals are severely silted and require cleaning – furthermore, the previous situation for draining of precipitation was limited to a 1 in 3 to 1 in 5-year event, resulting in frequent and severe flood events. Adaptation to climate changes requires a significant upgrading of the overall pluvial flood protection system.

35. Fluvial flood management is the responsibility of the Xiangtan water bureau, and flooding is managed through a series of dykes, drainage canals, pumping stations, and flood gates. 56.7km of dykes have been installed in the Xiangtan urban area in Hexi, Hedong and Yangtian Lake. There are plans also to increase surface water area (artificial lakes, storm water basins etc). Existing dykes and levees are designed for a 1 in 100 year flood event. The design criteria are based on a forecast model build on more than 50 years of hydro-meteorological measurements in Xiangtan. The applied design basis thus does not consider IPPC based climate changes. Table below presents overview of vulnerability risk matrix taking into Xiangtan water infrastructure.

Table 9: Climate risks and vulnerability matrix in Xiangtan water infrastructure

Climate Variables		Infrastructure at Risk								
Variables	Specific Risk	Reservoirs and water intake infrastructure	Water treatment infrastructure	Distribution networks	Collection systems	WWTP process infrastructure	WWTP supporting systems/infrastructure	Stormwater and drainage infrastructure	Communications	Power sources
Precipitation	Extreme Rainfall / Flooding	Red	Red	Yellow	Yellow	Red	Red	Red	Red	Red
	Changes in Mean Rainfall	Red	Yellow	Yellow	Yellow	Red	Red	Yellow	Green	Green
	Drought	Red	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Green	Green
Temperature	Extreme Temperatures	Red	Red	Red	Red	Red	Red	Red	Yellow	Yellow
	Mean Temperature Changes	Green	Yellow	Green	Green	Green	Yellow	Green	Green	Green
Cyclones / Storms	Lightning and Storms	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Red	Red
	Wind Speed	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow	Red	Red
Humidity	Humidity	Green	Green	Green	Green	Green	Green	Green	Green	Green
Other	Wildfires	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey
	Interdependencies	Red	Red	Red	Red	Red	Red	Red	Red	Red

Red	Likely high level risk. Needs consideration.
Yellow	Potential risk. Needs investigation.
Green	Not a likely issue.
Grey	Non existent.

K. Climate Risks and Vulnerability to Building Infrastructure

36. Residential areas make up approximately 61% and industrial land occupies 16.92% of urban land use within the urban districts of Xiangtan. In Xiangtan, a commitment to densification within the City is increasing the proportion of apartments. Furthermore, in Overall Planning of Xiangtan City (2010–2020), the City will expand to the east and north, closer to Changsha-Zhuzhou-Xiangtan City Cluster.

37. The Standard for Energy Efficiency Design of Public Buildings (GB50189-2015) explicitly promotes energy efficiency and the use of renewable energy within public buildings. The use of envelope insulation, shading, solar-passive design, appropriate orientation to winter sunshine and prevailing winds, and natural ventilation are specified to reduce the energy required for

heating, ventilation and air conditioning (HVAC) and address the urban heat island effects. Lighting should be either metal halide/ high pressure sodium lamps (large spaces and outdoor workplaces) or LED. The Standard further recommends the use of distributed energy as a heat source (cogeneration, waste heat, heat pump systems). Buildings over 150m high or with a gross floor area (GFA) of more than 200,000m^2, are also required to convene a team of experts to advise on energy-saving design.

38. Public buildings are seen to set an example for, and promote, energy-efficient building design for the City. Typically, new buildings in Xiangtan have centralized air conditioning, while old buildings have small chillers per apartment. At present the first district heating system in an residential blocks is in operation as pilot testing. Table below presents overview of vulnerability risk matrix taking into building infrastructure.

Table 10: Climate risks and vulnerability matrix for Xiangtan building sector

Climate Variables		Building Component/Function at Risk					
Variables	**Specific Risk**	**Foundations and building structures including roofs**	**Stormwater, drainage & sewer infrastructure/systems**	**Fascade, windows etc**	**Heating/cooling mechanisms**	**Landscaping and grounds**	**Access, egress and servicing**
Precipitation	Extreme Rainfall	Red	Red	Yellow	Yellow	Red	Red
	Mean Rainfall	Green	Yellow	Green	Green	Yellow	Green
	Drought	Yellow	Yellow	Yellow	Yellow	Yellow	Green
Temperature	Extreme Temperatures	Yellow	Yellow	Yellow	Yellow	Green	Green
	Mean Temperature Changes	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Cyclones / Storms	Lightning strikes & storms	Red	Green	Green	Yellow	Green	Green
	Cyclone & typhoons	Red	Red	Red	Red	Red	Red
	Wind Speed	Green	Red	Red	Yellow	Green	Green
Humidity	Humidity	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Other	Wildfires	Grey	Grey	Grey	Grey	Grey	Grey
	Interdependencies	Yellow	Yellow	Yellow	Green	Yellow	Green

- Red: Likely high level risk. Needs consideration.
- Yellow: Potential risk. Needs investigation.
- Green: Not a likely issue.
- Grey: Non existent.

L. Conclusion on climate risks and vulnerability

39. As indicated in previous climate risks analyses, Xiangtan would have the moderate impact of climate change on extreme events. Mean temperature would change very little from current levels by 2050. Precipitation amounts for each return period event increase but only by a small percentage by 2030 and 2050. Temperature extremes do increase and return periods shorten but extreme temperature already occur with a one in 50-year event becoming a one in five year event, which while more frequent is potentially not critically impactful for infrastructure unless it is already maladapted to current climate. There is evidence of roofs being lost in storms

however extreme cyclone wind speeds change very little through to 2050 and risk from wind events changes very little from current risk levels.

40. Clearly a critical issue for many sectors is flooding and inundation. As for precipitation and rainfall intensity, the impact is more significant on the intensity of heavy rainfall and storm events than on the total amount of annual precipitation. The increased rainfall intensity of individual storm events may result in higher flood peak flows and impose higher flooding risks to the project components. Therefore, the impact of climate change on extreme rainfall events should be factored into the project design.

II. ECOSYSTEM-BASED CLIMATE ADAPTATION AND RESILIENCE PLANNING SUPPOR TOOLBOX

A. Climate Risks and Pluvial Flood in Xiangtan

41. The climate risks and vulnerability assessment for Xiangtan identified flood as the most critical climate induced risks. It also found out that Xiangtan is currently less impacted by fluvial flooding due to an extensive dyke system around the rivers. Yet, some areas of Xiangtan are impacted by pluvial flooding as drainage capacity in these vulnerable areas and potentially others is exceeded. Based on these findings, a team of climate resilient experts was engaged to carry out further assessment on pluvial flooding in Xiangtan; to introduce and recommend a range of resilient measures; to develop an innovative tool and provide capacity building training on the tool to support decision making and adaptation planning for Xiangtan municipal government (XMG). This document summarizes the results of these activities, which also contributed to the project scoping and design of the proposed Xiangtan Low-Carbon Transformation Sector Development Program.

42. Systems analysis of the local conditions and vulnerabilities to pluvial flooding in Xiangtan involved the analysis of flood hazards, damage sensitivity, assessment of the required retention, detention, and/or storage capacity against floods, analysis of the applicability and feasibility of adaption measures; and stakeholder discussion to obtain feedbacks and preferences on those measures. The detailed assessment boundary was set for urban districts in Xiangtan: Yuetang and Yuhu districts, which are also the project areas of the proposed Xiangtan Low-Carbon Transformation Sector Development Program (SDP).

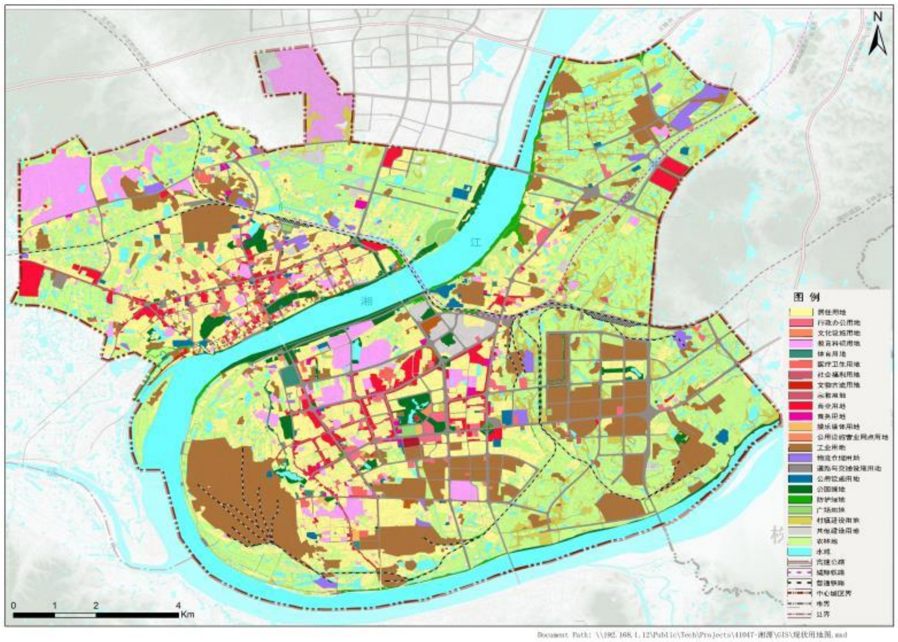
43. Data on many different aspects of the physical environment are needed to assess, which would further support on the decision on priority areas for resilience enhancement and also help in assessing effectiveness of proposed measures and relevant costs. Many different sources were used to collect this information from, ranging from public resources like google earth to local bureaus and informants. Data on land elevation was retrieved from Google Earth. Land use data was taken from the current land use map and 2030 land use maps in Xiangtan urban master plan (2017–2030). For water holding capacity, current and future land use, soil properties, rainfall intensities and evaporation data and information were used. A total of six years of daily rainfall data and 3 years of hourly data provided by Xiangtan water resources bureau and provincial meteorological bureau for detailed analysis. Table below summarizes data, information, and documents collected and used for the local conditions assessment.

Table 11: Sources for Local Conditions Assessment

Category	Data/Information Inputs	Resources
Climate Conditions	• Rainfall (daily data between 2007and 2017 and hourly data between 2016 and 2018) • Evaporation (2007–2013： daily)	• Water resource bureau and Meteorological bureau
Urban planning	• Xiangtan urban master plans up to 2030 • Xiangtan flood prevention and storm drainage plan (2015–2020) • Urban water conservancy planning of Xiangtan City • The sponge city special planning of Xiangtan • Xiangtan city black and odorous water treatment project conceptual design	• Planning bureau • Water resource bureau • Housing and urban rural construction bureau • Housing and urban rural construction bureau
Surface water & drainage system (relevant components)	• Flooding hot spots • Pumping stations • Stormwater system	• Housing and urban rural construction bureau • Water resource bureau • Urban master plan
Geographic Information System Mapping (GIS)	• Digital elevation model • Hill shade	• Google earth • Google earth
Soil	• Soil properties	• Xiangtan city assessment report (2017 and 2019) • Site visit

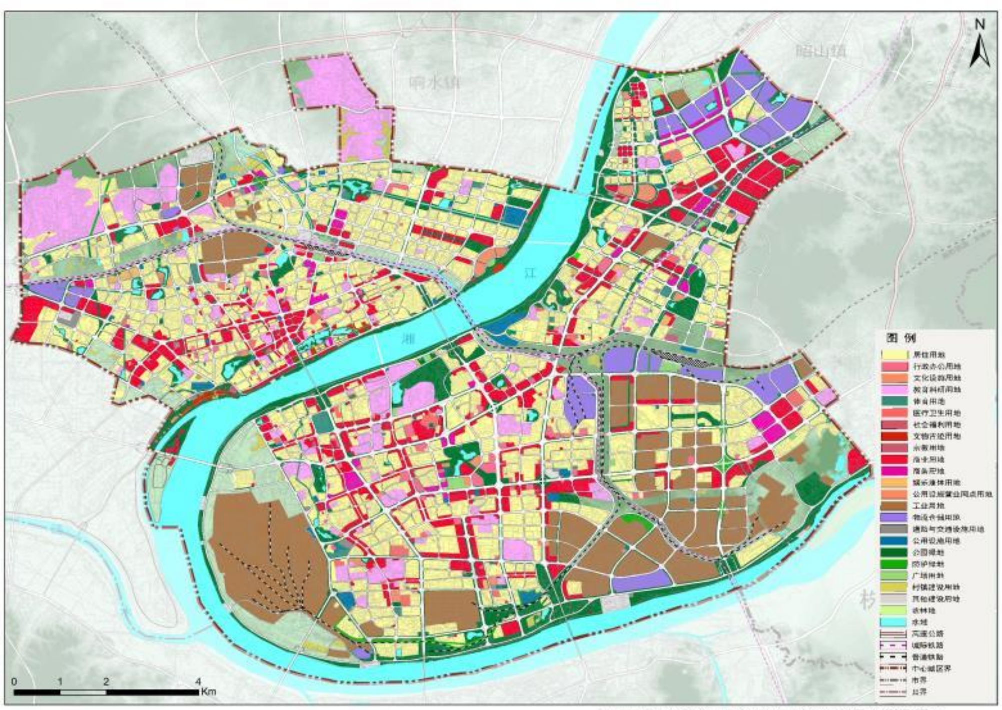
44. The wide ranges of data and various maps were integrated and the following maps are generated as below.

Figure 14: Current Land Use Map (2018) in Urban Xiangtan



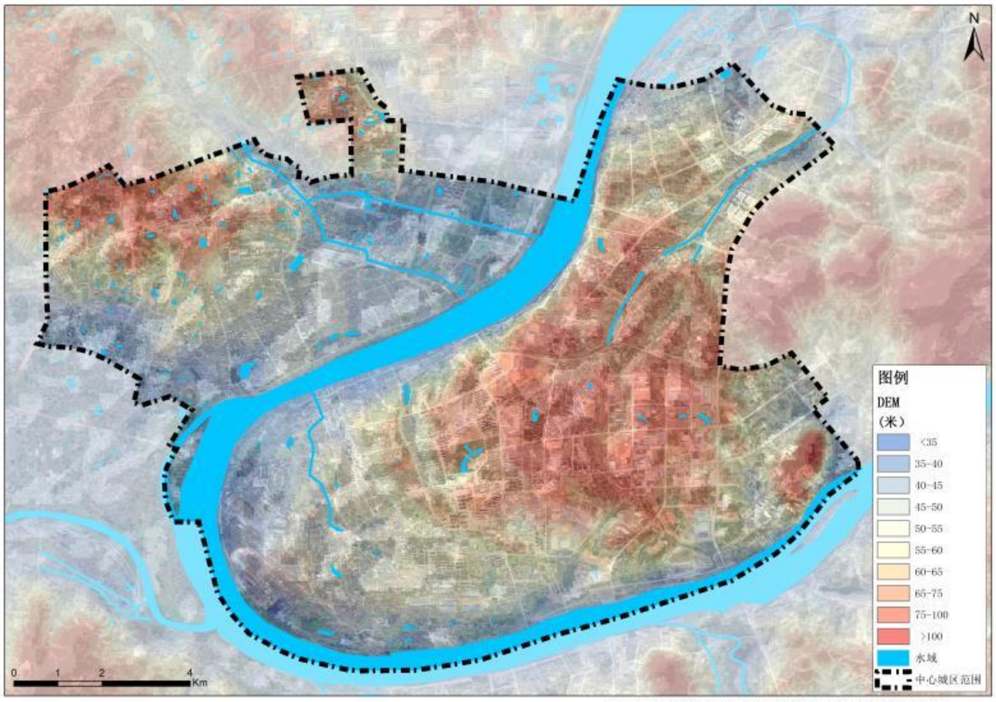
Source: ADB PPTA consultants

Figure 15: Future Land Use Map (2030) in Urban Xiangtan



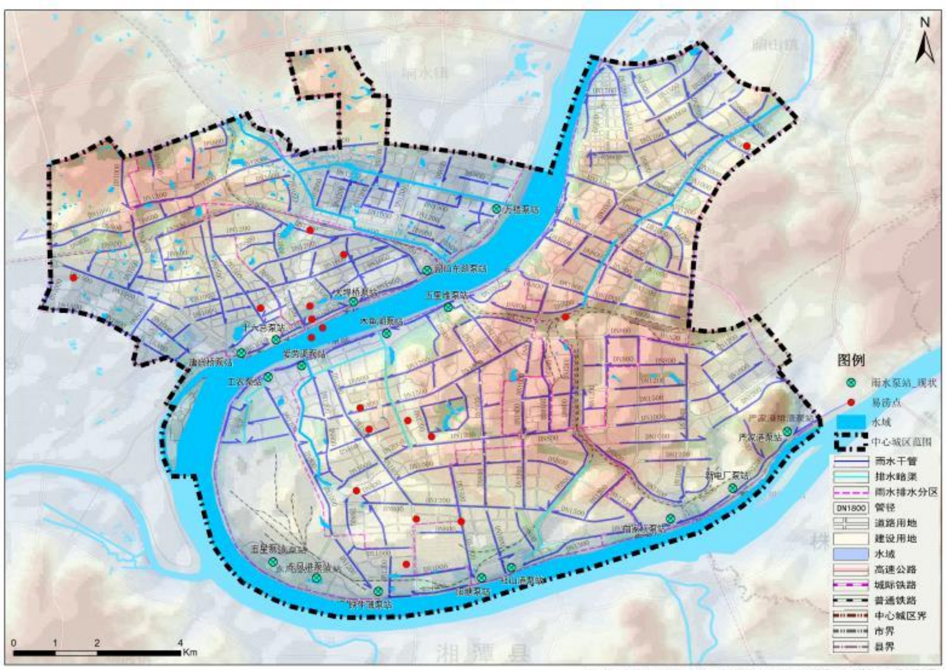
Source: ADB PPTA consultants

Figure 16: Topographic Elevation Map in Urban Xiangtan



Source: ADB PPTA consultants

Figure 17: Drainage Pipe Networks, Pumping Stations, Flood hotspots in Urban Xiangtan



Source: ADB PPTA consultants

B. Pluvial Flood Risks in Xiangtan

45. A hydraulic model relating to urban ecological baseline in Xiangtan was set up to conduct the pluvial flood hazard assessment. The model was run with various design events to identify vulnerable areas. As a result, the following pluvial flood hazards map is developed for a rainstorm with a 100-year return period as below. This map below is an overview map, which allows us to identify flood-prone zone and the most flood-vulnerable areas, both today and including the impact of the expansion of urbanization. This map can be further developed to show even neighborhood level flood hazards once more detailed data on land level, stormwater drainage system and design rainfall in any specific location.

46. Risks are defined as results of the probability of failure and the potential damage that would occur. Potential damage is defined by the damage sensitivity of people, objects and networks. Unfortunately, it proved to be impossible to find any data on flood damage sensitivity in the relevant existing urban areas. The only way to assess the flood risk is to combine the flood hazard map with the map of the projected future land use at this point.

47. To avoid flooding by extreme rainfall events a sufficient retention, detention, and/or storage capacity, and drainage capacity need to be installed. 'Sufficient', here, means that waterlogging and other forms of flooding should not occur more frequently than once every many years. The probability and volume of flooding depends on the rainfall intensities that occur, the land use, the drainage capacity and the available storage volume. The relationship between the required retention, detention, and/or storage capacity, and drainage capacity of this site, its land use, soil type and the acceptable return period of flooding is expressed in so-called Storage-Discharge-Frequency (SDF) curves.

Figure 18: Flood Hazard Map in Urban Xiangtan

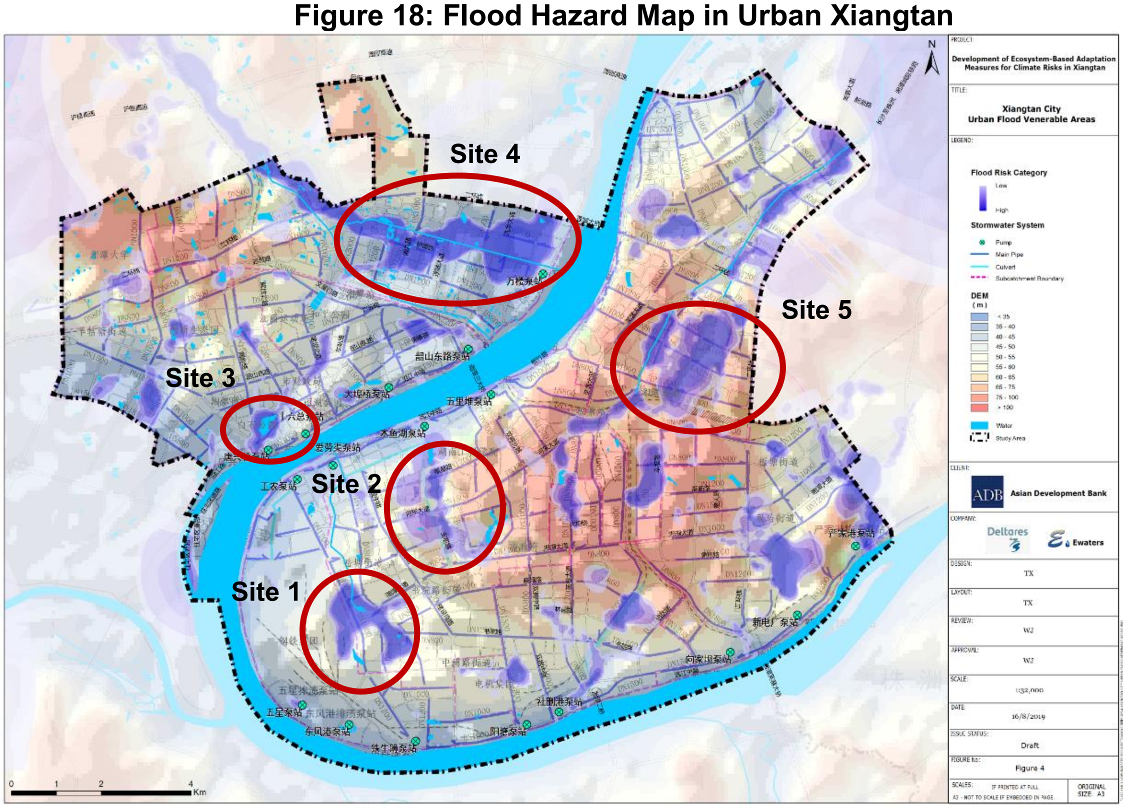
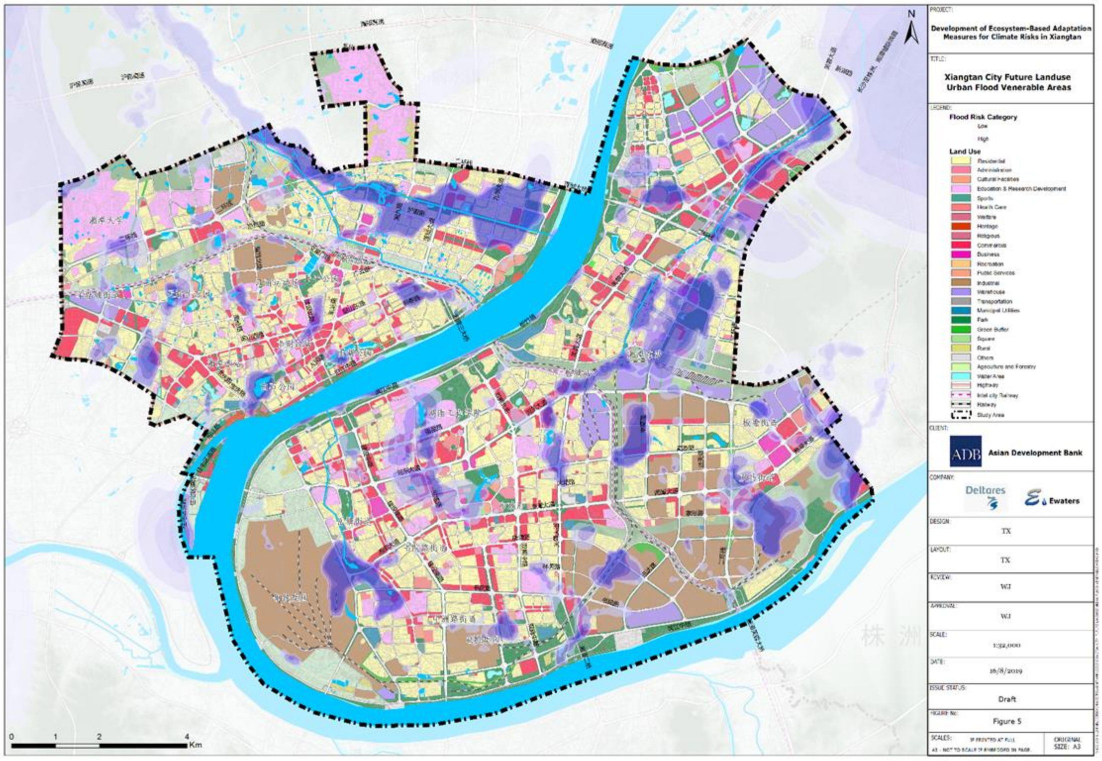


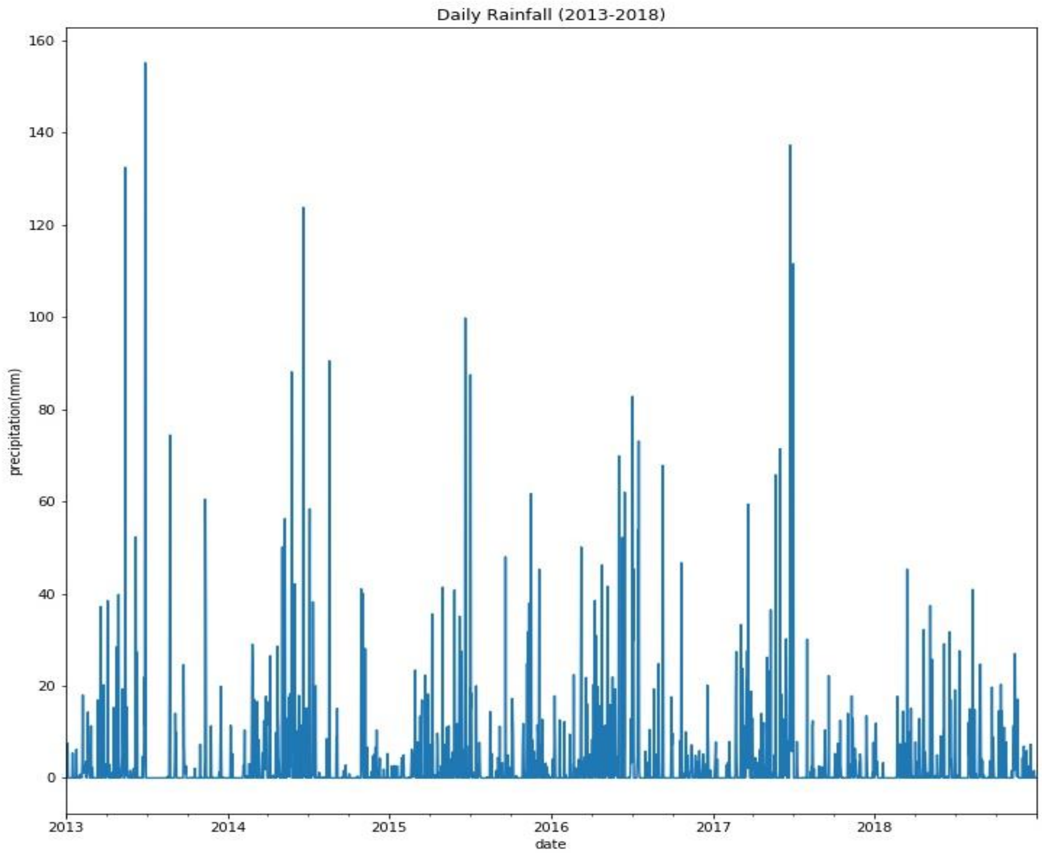
Figure 19: Flood hazard Map combined with Future (2030) Land Use



48. Local design standards for water logging hazard due to extreme rainfall require a safety of once per 5–10 years for normal roads and once per 30 years for critical infrastructure like a hospital. A fundamental principle of a good drainage system is that problems should not be shifted to the downstream neighborhood areas. That is why this discharge capacity should be minimized to a realistic level. Figure below shows many days with rainfall over 100 mm in 24 hours over the past six years between 2013 and 2018 in urban Xiangtan. In view of these rainfall volumes and predicted the SDF curves, a choice of a drainage discharge capacity of 40 – 50 millimeters per day (mm/day) seems reasonable. Lower capacities would result in a rapid increase in the required storage volume, while increasing the capacity over 50 mm/day has a more limited effect on the requires storage volume and will increase flood risks downstream.[2]

[2] More information on the Urban Water Balance model and the SDF assessment procedure can be found on https://publicwiki.deltares.nl/display/AST/Urban+Water+balance+model

Figure 20: Xiangtan Daily Rainfall Fluctuations between 2013 and 2018



Source: ADB PPTA consultants

49. Based on the results of pluvial flood hazard assessment, the team of experts carried out specific site visits for potential selection of project component for resilience improvement under the Xiangtan SDP.

50. Site 1: The Xiangtan Steel Company and the Baimu Lake Park(湘钢和百亩湖公园). Site one is located near the steel company and Baimu lake park area, where the ground elevation is very low and the stream along the road is extremely polluted by surround area. According to local residents' speaking, this area however rarely suffers from flooding since the reconstruction of the sewer system. The area however suffers from a polluted stream.

Xiangtan Avenue near the Xiangtan Steel Plant

The polluted drainage stream

51. Site 2: The Baota Road, Fuxing Middle Road, and Muyu Lake Park宝塔中路和木鱼湖公园.

52. Site two is the Baota Road, Fuxing Middle Road, and Muyu Lake Park, which is located in the northeast corner where Baota and Fuxing middle roads are crossing. The surrounding land use is basically residential and commercial area.

Baota Road

Muyu Park

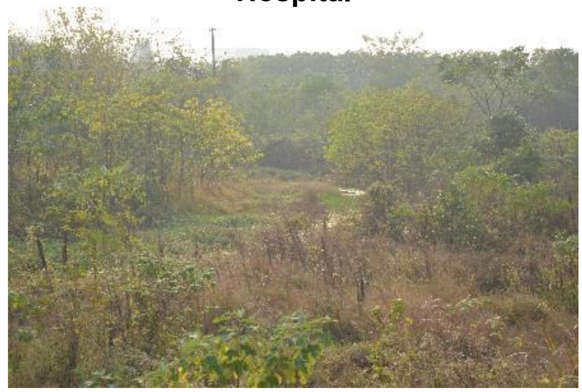
Intersection of Baota and Fuxing Middle Roads

Fuxing Middle Road

53. Site 3: The Baishi Park白石公园. The park is located at Baimahu Road, Yuhu District in Xiangtan and was built in memory of Qi Baishi. The park serves as a stormwater retention park to avoid surrounding area from being threatened by waterlogging.

Baishi Park

54. Site 4: Wanlou new development area万楼新城片区 and Biquan Lake Park碧泉湖公园. This site location is at North of Xiangtan city, which is a new development area. The Biquan Lake Park is a newly-built park located in the middle of this area, and some sponge city facilities have been applied. However, due to the large area of impervious pavements application and limited greening and trees, this park suffer heat stress a lot. South of this park is the area where the Wanlou new development area is located. Within these development blocks, the proposed Xiangtan No.1 hospital as a part of the Xiangtan SDP scope is located.

Biquan Lake Park	The proposed site of the proposed Xiangtan No.1 Traditional Medicine Hospital
	

55. Site 5: West of Furong Avenue芙蓉大道西侧. Site 5 is located in the west of Furong Avenue, which is a completely undeveloped at this moment (in 2019).

West of Furong Avenue 芙蓉大道西侧

56. Based on field visits and discussion with the Xiangtan Municipal Government, site 2 and site 4 are selected as a part of the Xiangtan SDP project scope to demonstrate climate resilience improvement.

C. Ecosystem-based Adaptation Measures

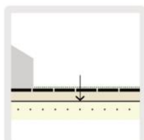
57. Recognizing growing demands to improve urban resilience, a wide range of adaptation measures has extended over the past decades. Earlier urban drainage systems and water sensitive urban design were main focus, nowadays a concept of green or blue-green infrastructure was introduced. Here, so-called ecosystem-based adaptation (EbA) measures that integrate the use of biodiversity and ecosystem services emerged as measures to advance climate resilience, at the same time to maximize co-benefits. Beside flood control purpose, EbA

measures can mitigate drought, reduce urban heat stress, provide aesthetic quality, recreational and restorative capacity and benefits health.

58. Benefis of EbA use are considered as the most effective measures to restore a city's capacity to absorb, infiltrate, store, purify, drain, and manage rainwater and also to regulate the water cycle as much as possible to mimic the natural hydrological cycle. Hierarchial steps to improve city's resilience is 'Retain-Store-Drain'. Thus, key principle of EbAs is to focus on (i) water storage in stead of drainage for flood and drought prevention; (ii) Infiltration instead of drainag for flood and drought prevention; (iii) handling stormwater locally instead of draining; (iv) vegetation evapotranspiration for heat-stress reduction. Figure below shows some examples of EbA measures.

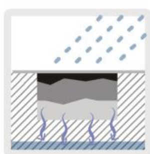
Figure 21: Examples of Ecosystem-based Adaptation Measures

Permeable pavement (infiltration & storage)



Permeable pavements consist of porous material that absorbs rainfall. Water can be stored either in the top layer (e.g. very open asphalt concrete) or in below the top layer in the foundation. Besides reducing runoff, permeable pavements can trap suspended solids and filter pollutants from the water.

Rain garden



These are sandy soil or aggregate filled depressions that treat stormwater runoff to improve water quality. Stormwater is captured and allowed to percolate through the soil/aggregate layer, where pollutants are removed, prior to being released through an underdrain located at the bottom of the depression.

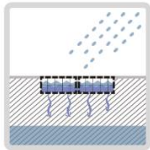
Bioretention cell

Bioretention cells are stormwater detention features that collect, detain, infiltrate, and filter stormwater runoff prior to releasing it to a storm sewer system via an overflow or discharge mechanism. These facilitie typically feature both surface level (freeboard) and subsurface stormwater detention. Starting from the surface, it is commonly composed by: planting (trees & native shrubs), mulch layer, bioretention soil, aggregate bridging course, aggregate subbase, pipe underdrain, and undisturbed native soil.

Infiltration trench

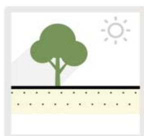
An infiltration trench, also known as a French drain, is a linear feature used to reduce stormwater runoff and improve water quality. These shallow excavated trenches are filled with aggregate or crushed stone that is designed to allow for stormwater to infiltrate the ground plane and ultimately percolate though permeable soils into the groundwater. Their linear shape can also serve to convey stormwater from one area to another, or away from built structures, and typically contain a perforated pipe underdrain.

Infiltration boxes



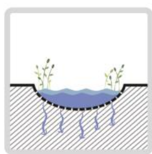
Infiltration boxes buffer rainwater underground and allow using a single area for two purposes. In general they offer more storage capacity than above-ground infiltration installations. More rainwater can be buffered temporarily and gradually released into the groundwater. The extra infiltration leads to less drought damage, subsidence and salinization.

Creating shade



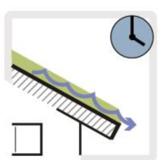
Creating shade is important to prevent surfaces from heating up and to cool the surroundings. This can be accomplished by using trees, pergolas, overhangs, awnings and such. Arcades and covered walkways are urban elements commonly used in warm countries to create shade.

Rainwater detention pond (wet pond)



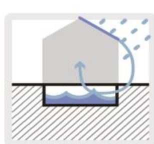
Buffer ponds temporarily capture precipitation and allow it to drain off slowly. During rainfall, the rainwater is captured in the pond and subsequently drained off to create room for the next precipitation. Buffer ponds can be designed to have a mostly stony or a mostly natural appearance.

Green roof with drainage delay



Green roofs with drainage delay are also called retention roofs. It is a green roof that can store extra water in a substrate layer under the green planted layer and is drained delayed with a pinched drain. A polder roof is a retention roof where the control system is linked to the weather forecast.

Systems for rainwater harvesting



Rainwater harvesting is the collection and storage of stormwater for reuse on site. This is most commonly be achieved by capturing runoff from the roof of a building, however, it can also include the collection of runoff from throughout the site or byproducts from systems such as air conditioning condensate. The collection structures can take on multiple forms and be installed either above ground or subsurface. Depending on its source and treatment, the harvested water can be reused on site for irrigation.

Source: Deltares-ADB PPTA consultants

D. Adaptation Planning Support Toolbox for Xiangtan

59. Urban planning contains a series of phases from conceptual, preliminary and final design up to implementation. Urban adaptation planning process ends with a final decision on an adaptation or (re)development plan. Many guidelines on climate resilient urban planning provide procedures for hazard, exposure and vulnerability analysis and an overview of potential solutions

and/or best practices. However, tools that have the ability to implement adaptation solutions in the actual urban planning and design practice seem to be missing.

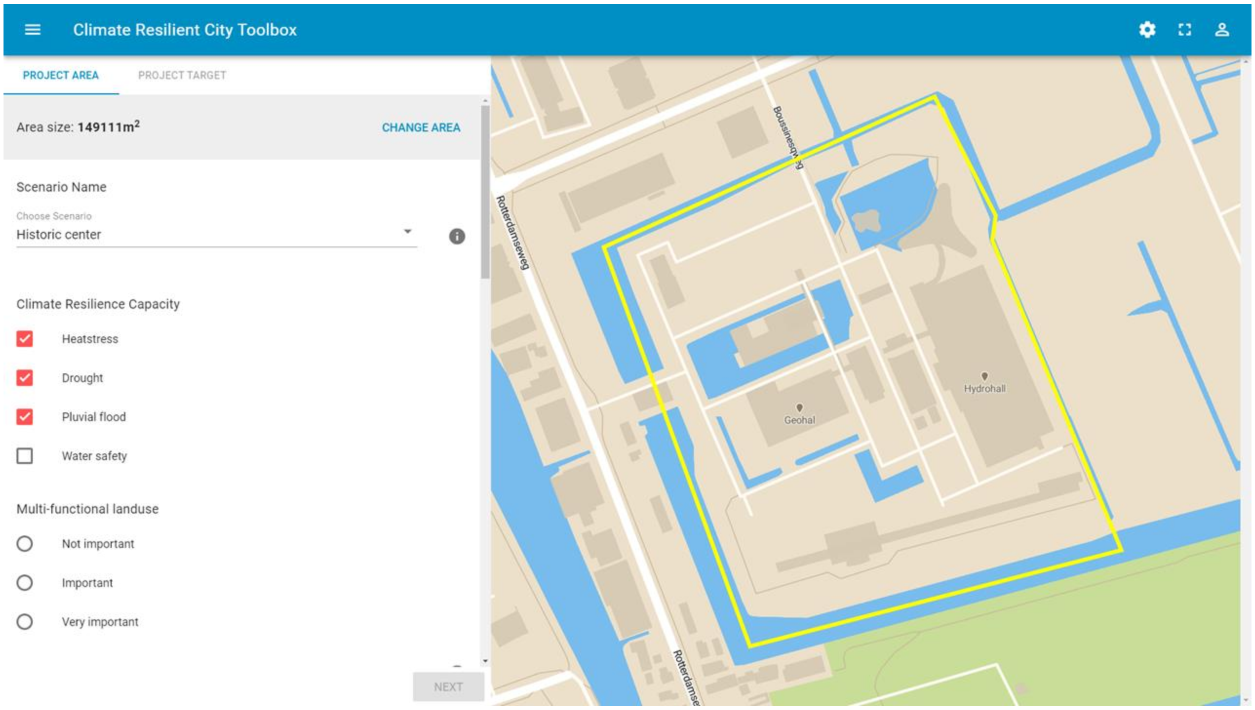
60. The Adaptation-planning Support Toolbox (AST) is created to fill this gap. The AST is a touch-table based platform that EbA design participants may use to select specific interventions, situate them in their determined project areas, and immediately see an estimated resilience capacity improvement as well of associated costs for implementation. This toolbox supports local policymakers, planners, designers and practitioners in defining the program of demands, in setting adaptation targets, in selecting blue, green and grey adaptation measures and with informed co-creation of conceptual adaptation plans. The AST provides quantitative, evidence-based performance information on (cost) effectiveness of adaptation measures regarding climate resilience and co-benefits. The AST can be used design workshops, to feed dialogues among stakeholders on where and how which ecosystem-based adaptation measures can be applied. Applications of the AST in various settings and context in cities on different continents have illustrated the added value of the toolbox in bringing policy and practice together with help of science.[3]

61. An AST (2.0 version) was developed with customization for Xiangtan. It is called 'Xiangtan's Climate Resilient City Toolbox' (XCRCT), which is available both in English (https://xiangtan.crctool.org/zh_en/), and Chinese (https://xiangtan.crctool.org/zh_cn/). The toolbox contains the 37 EbA solutions and information on their effectiveness and costs that are adjusted for local conditions. A step by step procedure to run AST2.0 is described at https://publicwiki.deltares.nl/display/AST/AST2.0+Using+the+tool.

62. Once opening the web-based built-in XCRCT, a specific location can be selected and named for a particular project name. Then, all the parameters for that particular project area shall be determined.

[3] More detailed and background information on the tool can also be found on https://publicwiki.deltares.nl/display/AST/AST2.0+Documentation .

Figure 22: Parameters for the project area



63. In the selected project area, adaptation measures need to be added. An overview and a detailed content of all available measures can be found in the toolbox. The list of measures is ranked according to their effectiveness based on the properties of the project area and the climate adaptation goal for the project area. The XCRCT provides a search field to look for a specific EbA measure.

Figure 23: List of EbA measures in the XCRCT (AST 2.0)

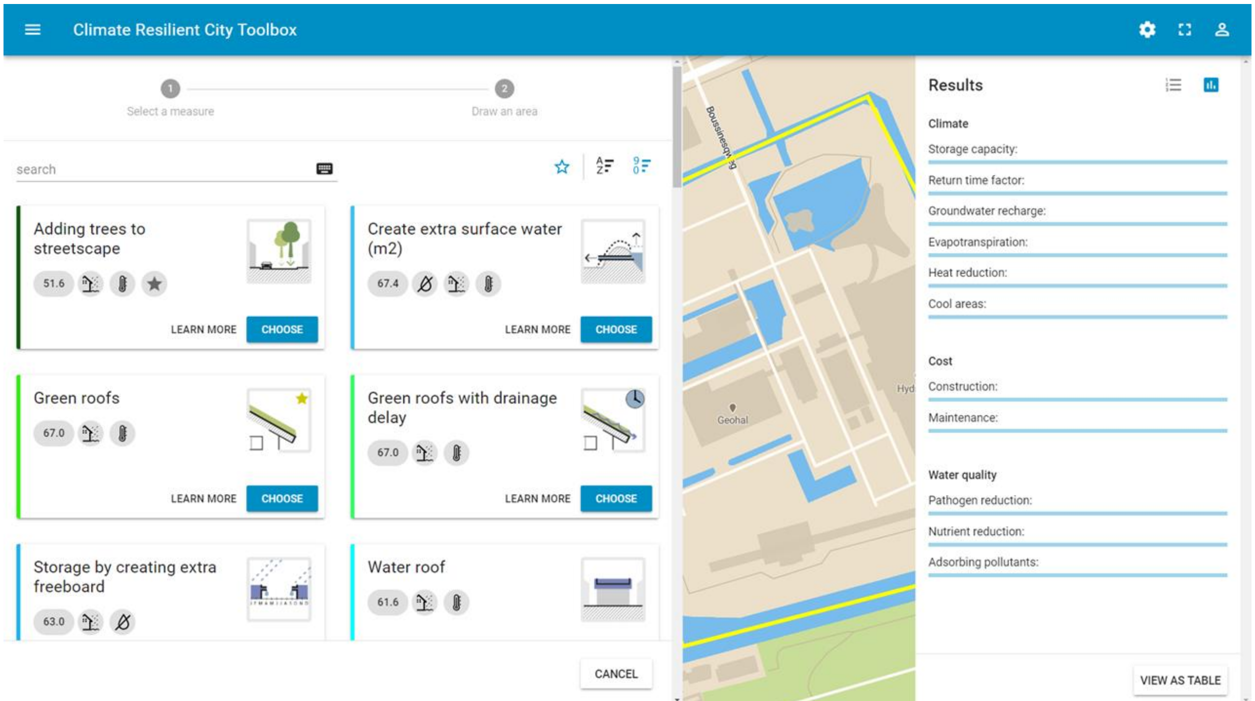
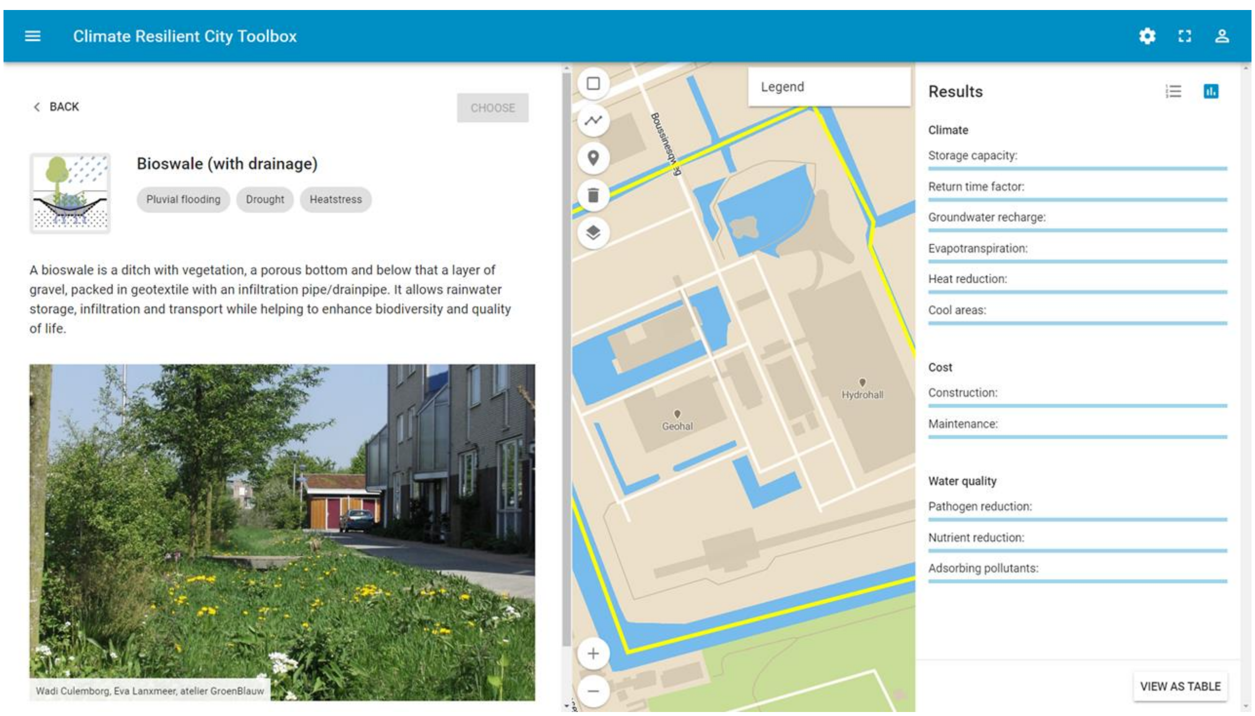
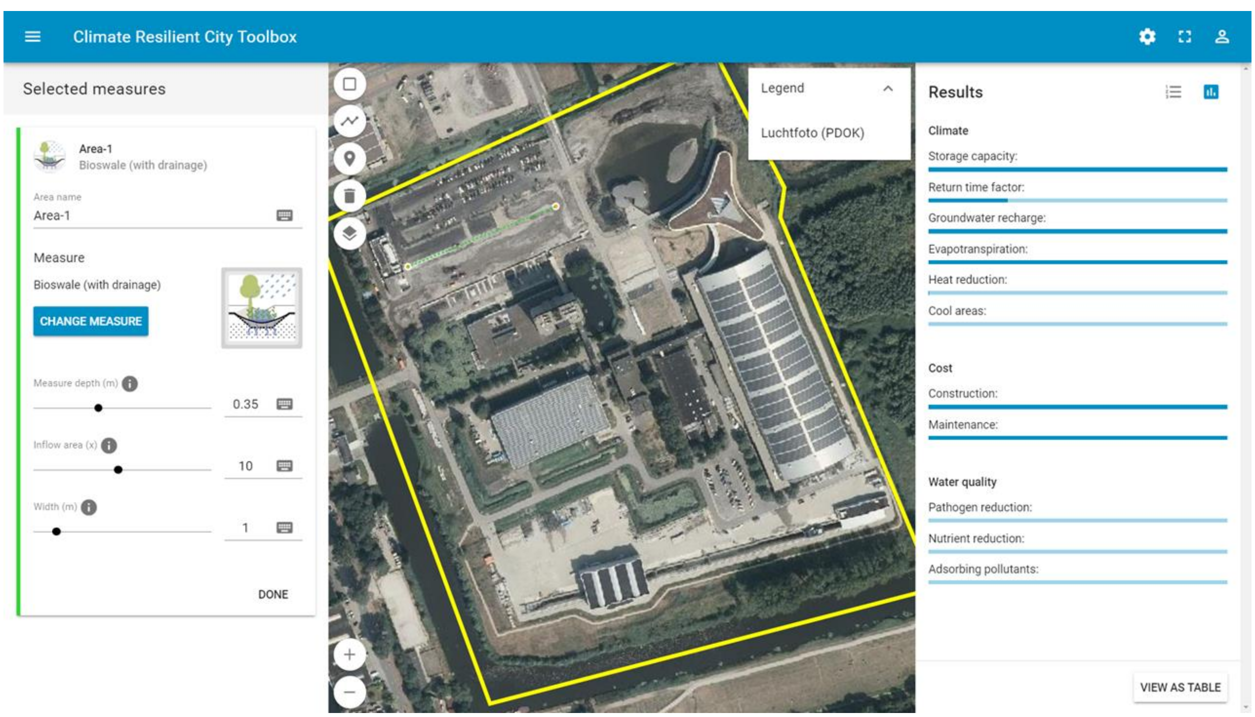


Figure 24: Example of the detailed content of a measure (general AST in English, and XCRCT in Chinese)



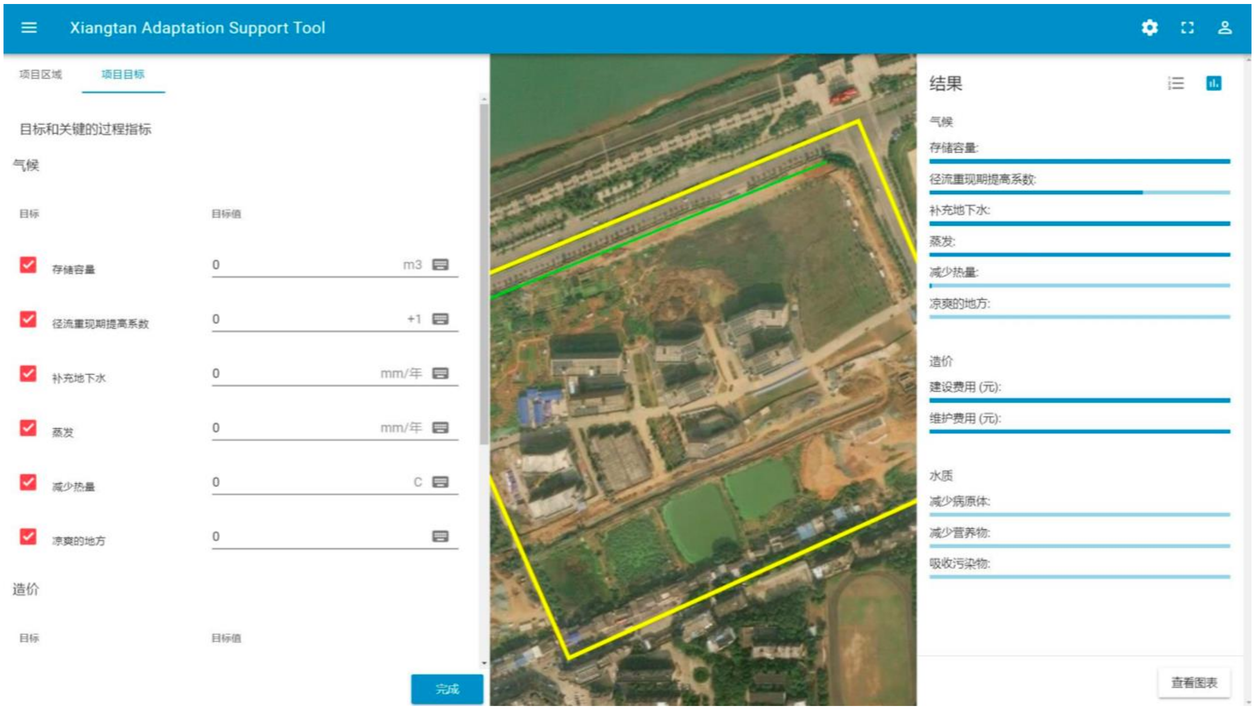
64. Once a measure is selected and added to the map, the measure settings panel would appear and the depth and inflow area data can be provided. An area or line can be drawn to add the corners of area or line.

Figure 25: Parameter ranges for a measure (general XCRCT in English and XCRCT in Chinese)



65. On the right side of the map, the results of applied measures are visualized. These are divided into results with regards to climate adaptation, costs and water quality. The results can be visualized both graphically as well as numerically.

Figure 26: Final screen of the XCRCT with results (general one in English and the XCRCT result in Chinese)

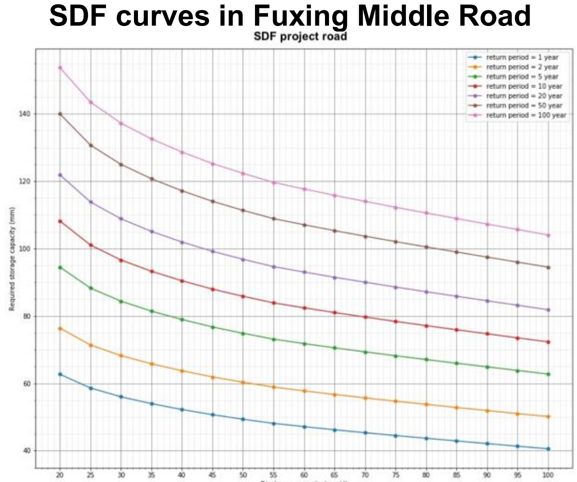


E. Detailed Assessment, Design Principles, the XCRCT Application, and Capacity Building in Xiangtan

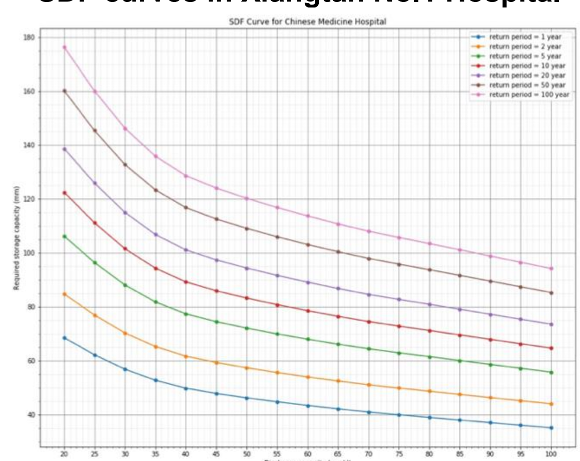
1. Detailed assessment in two project areas under the Xiangtan SDP

66. **Detailed:** The Storage-Discharge-Frequency (SDF) for selected project sites were first assessed further and then, the effect of the expected climate change on these curves was investigated. Referring that the annual precipitation tends to increase with a rate of 6.5 to 20.3 mm per 10 years , the future scenario is simply set by raising the values of existing rainfall data by 1.2% (3 year * 6 mm/10year/ (1500 mm/year); here called climate 1) and 4% (30 year * 20mm/10 year / (1500 mm/year); here called climate 2). The results are shown below.

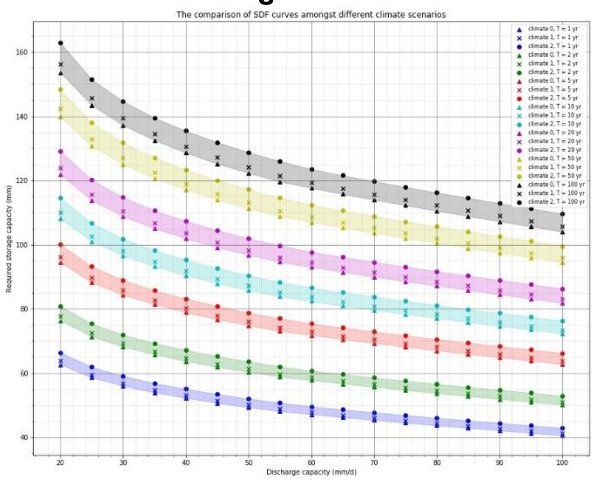
SDF curves in Fuxing Middle Road



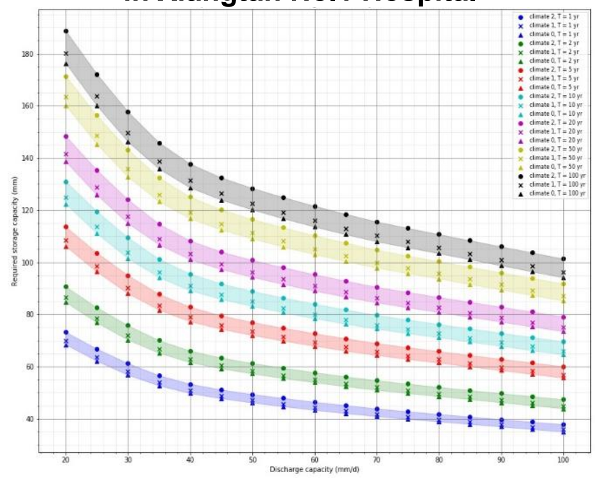
SDF curves in Xiangtan No.1 Hospital



SDF curves for different climate scenarios in Fuxing Middle Road



SDF curves for different climate scenarios in Xiangtan No.1 Hospital



67. In view of these rainfall volumes and the shape of the SDF curves, a choice of a drainage discharge capacity of 40 – 50 mm/day seems reasonable. Lower capacities would result in a rapid increase in the required storage volume, while increasing the capacity over 50 mm/day has a more limited effect on the requires storage volume and will increase flood risks downstream. For project road, this drainage capacity would result in a required retention/detention/storage capacity of approximately 90 mm (900 cubic meter per hectare [m3/ha]) while for the Chinese Medicine Hospital a retention/detention/storage capacity in the order of 110 mm (1100 m3/ha) is required.

2. Design Objectives and Approaches in two project areas under the Xiangtan SDP

68. **Fuxing middle road (2.9km):** The design objective for this road is to demonstration (i) how to utilize the possible space for various EbAs at cycling way and pedestrian walkways; (ii) how to treat the stormwater from the side roads to alleviate the drainage and runoff pollution to the downstream system; while improving the street amenity value. The design concept for the road needs to be developed in concerted action with the traffic and road safety engineers, so that limitations in space availability and land surface use can be considered in a comprehensive plan.

69. Works considered appropriate for EbA solutions may include:

- (i) Converting the existing trees to Tree pits, general, medium and high-quality types are considered to suit different locations
- (ii) Build new raingarden or swale, if gradient suits to treat stormwater from the side pathways. Different type of Raingardens or Swales with varying types of plants are to be considered
- (iii) Abandon/relocate/modify the existing catch pits to the new raingarden areas.
- (iv) Porous paving to be considered for the proposed cycle lane
- (v) Patchy porous paving to be considered for the pedestrian lane with the consideration of local conditions on landscaping
- (vi) Subsurface detention-/infiltration boxes to be considered for water storage under cycle lanes and footpaths

70. **Xiangtan No. 1 Traditional Medicine Hospital:** The hospital is located in the northern part of Wanlou new development area, which is between the Hutan West Road in the north and

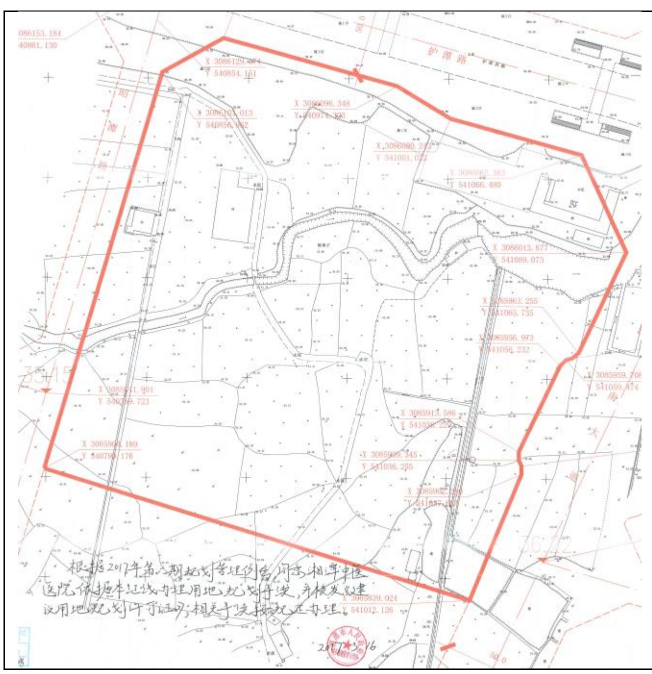
Guihua Road in the south, the Jiangnan Avenue to the east and Biquan Road to the west. The original conceptual design for the hospital itself and for the surrounding buildings are shown below. The original design for a landscaping areas of the hospital has approximately 740 m^3 of Volume Capture Ratio (VCR). Volume Capturing Ratio of annual rainfall (often abbreviated as VCR or VCRa) is used to quantify a retention capacity for stormwater runoff, to cover water demands in dry periods, not a detention capacity to avoid waterlogging and pluvial flooding during periods of extreme rainfall. The target value of the VCR is usually determined taking into consideration land use and ecological damage sensitivity of the area.

71. However, as the proposed hospital that is located in critical flood-prone zone, the hospital (5.53 hectare) requires 6,000 m^3 retention/detention/storage capacity for pluvial flood protection with a safety of once in 30 years. Thus, significant design change for flood protection is needed.

Original Concept Design of the Proposed Hospital

72. For concept design, further site analysis was carried out. The result shows that the total area of this project is relatively flat, the elevation of the site is between 34.1 and 35.5 meters, and the overall elevation difference is about one meter. However, one deep creek is draining through the existing area, towards Hutan River. The detailed site analysis, then, was incorporated in the XCRCT.

Elevation map of the hospital building site



Digital elevation model of the hospital building site

3. Conceptual Design with AST

73. **Fuxing middle road (2.9km):** First, conceptual designs were made with the XCRCT. This first draft is elaborated to a conceptual design in consultation with the Transport group of the project team. Figure below shows a top view of the design in principle of the improved blue/green road drainage system that can be used without hindering traffic or underground infrastructure. The design is not only capable of handling the runoff from the street but maximizes storage capacity and infiltration of stormwater in the subsurface, while greening the streetscape. Additional storage capacity can be created by installing a row of infiltration boxes below the root zone of the greenbelt on both sides of the street. This would allow us to capture not only stormwater runoff from the road (in the rain gardens and tree pits) but also part of the roof runoff from the buildings along the road.

74. Yet, at road crossings, the following design concept is applicable as a total of 1 m3/m1 is required. It seems feasible to store around 1.5 m3/m1 at the sidewalk and bike lane, depending on the subgrade depth and material used each side of the road. In order to achieve 2 m3 storage/m1 each side of road, infiltration boxes can be used under the side walk, in addition to the subgrade material. The availability of underground space for these boxes is however uncertain, due to the fact that this space is potentially taken by cables and mains for gas and water. This issue is to be resolved in the detailed design, when this information is to be available for design and construction activities.

Figure 27: Top View of Fuxing Middle Road-Concept Design with EbA measures

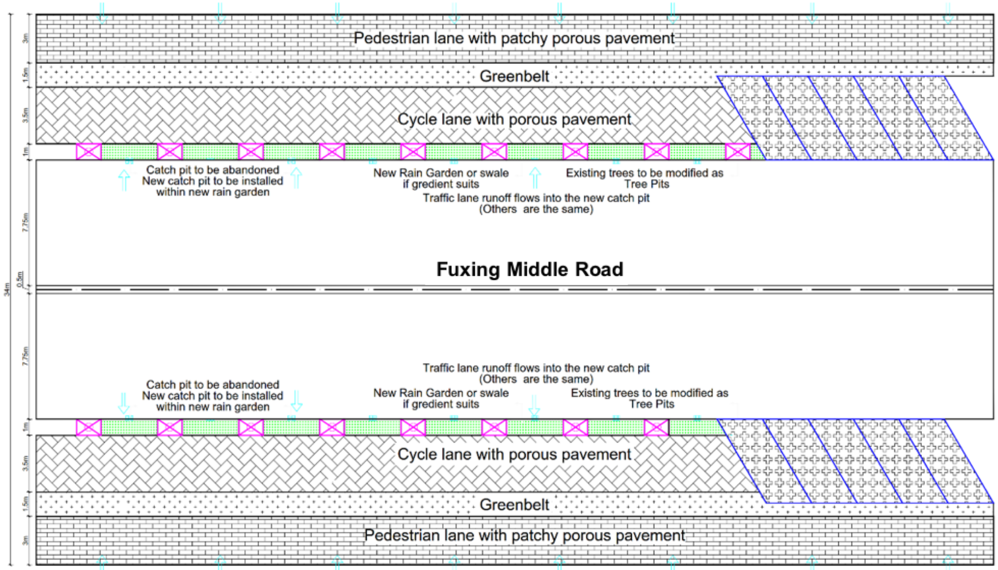
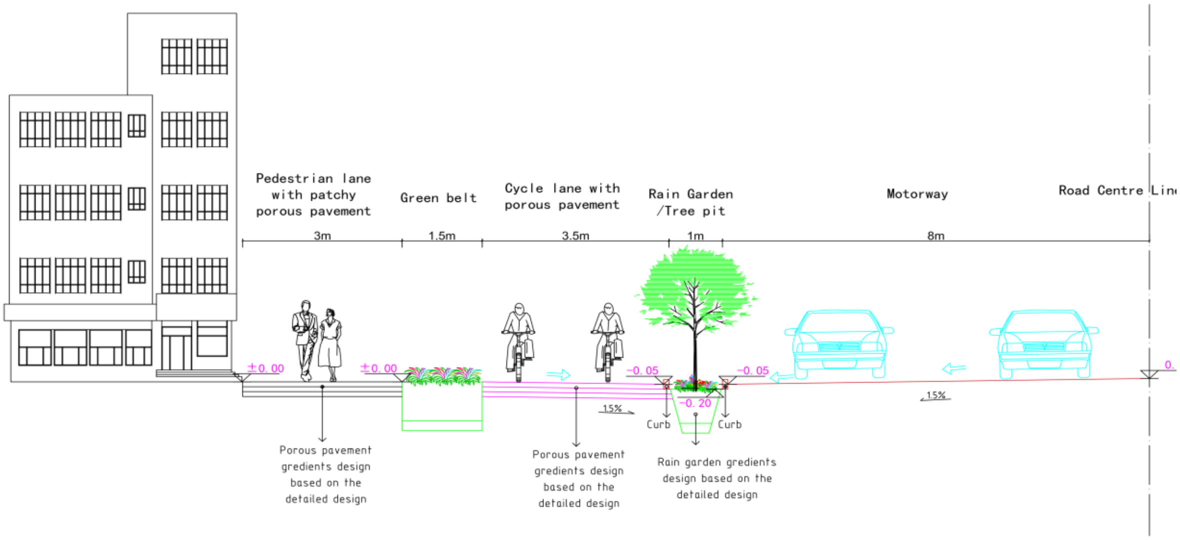


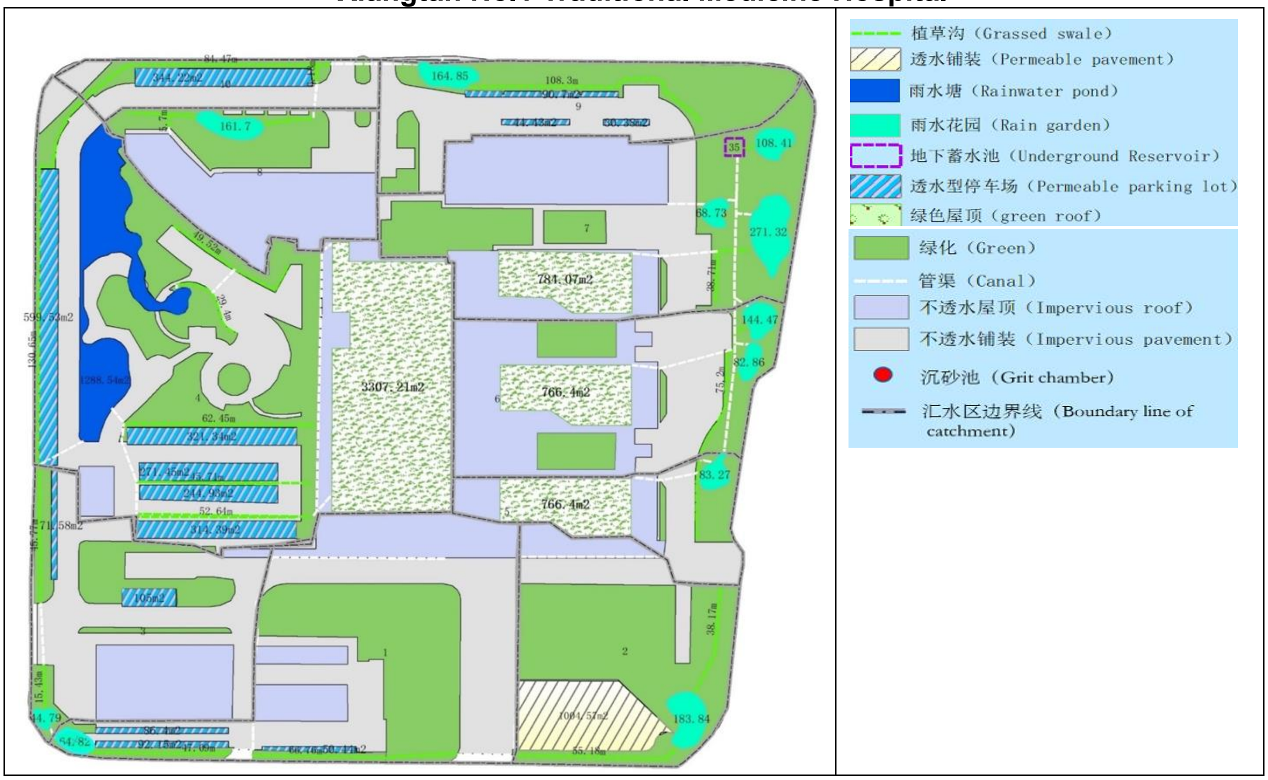
Figure 28: Conceptual cross section of the Road with EbA Measures



75. In addition to suspended sediments substantial concentrations of heavy metals, poly-aromatic hydrocarbons, mineral oil are to be expected due to traffic, while some pesticides might be used on the riparian vegetation. Most of these pollutants are particle-bound. Hence, filtering and settling are effective techniques to remove these pollutants from the runoff. The rain gardens and the catch pits play an important role in retaining pollutants. Filtration though a layer of soil aggregate and settling in special catch basins will achieve retentions of over 80–90 % of these pollutants.

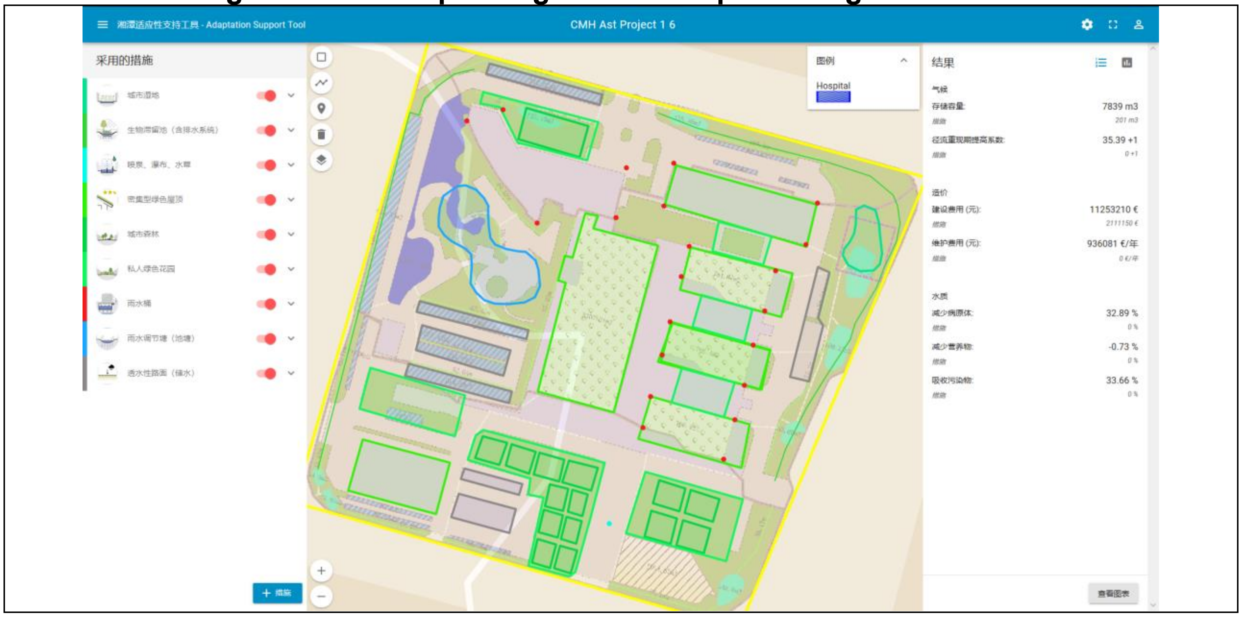
76. **Xiangtan No. 1 Traditional Medicine Hospital:** Based on design objective of the proposed hospital, a first draft design was prepared as below. The greening rate of the landscaping area is about 35% excluding the green roofs.

Figure 29: First conceptual design of blue-green, nature-based drainage system for Xiangtan No.1 Traditional Medicine Hospital



77. The first draft design above was used as input to the XCRCT. Then, using the toolbox, the following conceptual design, including landscape layout and resilient facility layout, is prepared with analysis on the underlying surface of each sub-catchment area. As shown in resilience effect using the XCRCT, the EbA enhanced concept design shows that the shape and site of the green infrastructure like rain gardens and ponds can be revised by detailed landscape design without loss of sponge capacity or other functionality.

Figure 30: Concept design of the hospital using then XCRCT



78. However, another concern remains as there is need for further detailed assessment of fluvial flood hazard from Hutan River, which is not currently available. Once this assessment is carried out, additional EbA measures shall be applied to the design of the building and its main access roads. For instance, these could include:

(i) elevating ('lifting') the level of the first floor (ground floor), the main access road and the land in the immediate surrounding of the building. This lifting of the construction could be in the order of 0.5–1.0 m without substantial extra construction costs;

(ii) bringing all critical infrastructure for the functioning of the hospital to the second floor or higher, so that the hospital can continue functioning despite flooding of the surrounding area;

(iii) including a 'flooding of the building' scenario into its emergency management plan, so that guidelines are available on how to act in times of flooding or flood threat.

F. XCRCT Capacity Building and Knowledge Transfer to Xiangtan Government and Stakeholder

79. In November 2019, two types of technical training and workshop were conducted. The first capacity building workshop aimed to introduce the importance of climate resilience improvement, and the benefits of EbA measures to Xiangtan Municipal Government and relevant local stakeholders. Another training workshop is designed to co-create the conceptual designs for the proposed project components. This dynamic workshops, participants used both the Toolbox and traditional ways – paper, maps, pens – to discuss what would be feasible and preferable adaptation measures for the two pilot areas, hence, what would be a realistic plan for a climate-resilient environment there.

Figure 31.AST Stakeholder Training Workshop in Xiangtan (November 2019)

G. Collaborative City Planning for Resilient Xiangtan

80. Ecosystem-based adaptation is a transdisciplinary concept involving multiple actors. Much of its planning, implementation and maintenance overlaps with the actions required for resilient city development. It is evident that implementation of ecosystem-based adaptation measures requires cooperation of many of these Bureaus and Departments, each with the need to adapt their policies, procedures, regulations and practices. Implementation of ecosystem-based adaptation will require learning from theory and practice. Based on the current institutional setting, the following table shows their potential roles of different Bureaus of Xiangtan Municipal Government in resilient city planning. At least 8 Xiangtan governmental departments are directly playing a role.

81. On strategical level, Xiangtan Bureau of Housing and Urban Rural Construction (XBHURC) takes a leading role in drafting regulations, policy and annual plans of climate resilient city and EbA, while Xiangtan City Administration and Comprehensive Law Enforcement Bureau (XCACLEB) makes relevant maintenance directives and Nature Resources and Planning Bureau of Xiangtan City (NRPBXC) fulfills Sponge City and EbA requirements in making relevant specified plans.

82. In terms of project implementation and maintenance phase, more bureaus shall be involved with specific roles and tasks. Ecology and Environment Department of Xiangtan (EEDX) could carry out environmental impact assessment. XBHURC could be actively engaged in project design assessment and supervise blue-green infra constructions and maintenance for

the whole city. Xiangtan Municipal Commission of Development and Reform could take part in project set-up assessment, feasibility study and preliminary design check-up; Xiangtan Water Conservation Bureau as being responsible for water conservation projects approval and should push to enhance EbA measures in water-related project construction. NRPBXC could direct land use management. XCACLEB could enhance and maintain large green land, parks and other large green infrastructures to enhance EbAs. Xiangtan Finance Bureau (XFB) could promote public–private partnership (PPP) projects and support funding allocation and distribution.

Table 12: Roles of XMG's Bureaus in Resilient City Planning

Xiangtan Municipal Commission of Development and Reform	Project setup assessment, feasiblitity study and preliminary design checkup
Xiangtan Water Conservancy Bureau	Responsible for water conservancy projects approval;
	Apply Sponge City concepts in water-related project construction;
	Urban blue line management;
Xiangtan Bureau of Housing and Urban Rural Construction	Leading role in making annual sponge city plans;
	Direct and supervise sponge city construction for the whole city;
	Organize experienced consultant teams to compile relevant directives and standards, and provide technical training sessions;
	Make Sponge City regulation, policy and backup measures;
	Make specified planning and get involved in project design assessment;
	Set assessment indicatprs during project review and apporval process.;
	Balance, direct and supervise the construction and maintenance of sponge city infrastructures in public buildings and neibourhoods
Xiangtan Meterological Bureau	Analize precipitation, help making specified plans and project desgin
Ecology and Environment Department of Xiangtan	Direct environmental impact assessment and monitor surface water quality
Xiangtan City Administration and Comprehensive Law Enforcement Bureau	Study plants used in blue-green facilities, maintain large green land, parks and other large green infrastructures and make relevant mainte
Nature Resources and Planning Bureau of Xingtan City	Direct landuse management, reflect Sponge City requirements in other specified plans
Xiangtan Finance Bureau	promote PPP project and distribute funding, lead the study of investment model in terms of Sponge City construction

83. When it comes to the field of research, XBHURC could organize experienced expert teams to compile relevant directives and standards, and provide technical training sessions. XCACLEB could further study the plants used in blue-green facilities, while XFB could lead the study of investment models for financing EbA measures. EEDX could further monitor surface water quality improvement in relations to EbA enhancement. Xiangtan Meteorological Bureau analyses temperature, precipitation and other meteorological data and helps making specified climate projections for project design.

84. In addition, other parties like upper-level government of Hunan Province, neighboring city Changsha and Zhuzhou, Committee of the City People's Congress, could participate in climate resilient planning and implementation process to maximize benefits. Figure below shows an overview of possible involvement of each of the stakeholders in the different phases of the resilient city design and implementation process. The need for a multi-actor approach to planning and implementation is evident from this overview.

85. As tested through this project, Xiangtan Climate Resilient City Toolbox provided an opportunity to practice collaborative city development planning. While putting efforts to institutionalize collaborative planning at XMG, this tool can be further used to explore adaptation options, more importantly to promote co-creating adaptation scenarios with representatives from

the various relevant Bureaus and organizations in Xiangtan. The next step could be to repeat the planning efforts that we did for future projects to improve climate resilience in Xiangtan.

Figure 32: Overview of Possible Institutional Arrangement for Resilient City of Xiangtan

Possible Roles and Tasks Play at a Project Level for Climate Resilience Improvement in Xiangtan