MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
SUB-INSTITUTE OF HYDROMETEOROLOGY AND ENVIRONMENT OF SOUTH VIETNAM

Vietnam-Netherlands Mekong Delta Masterplan project

FINAL DRAFT

CLIMATE CHANGE IN THE MEKONG DELTA

Climate scenario's, sea level rise, other effects

HO CHI MINH CITY, 2010

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CLIMATE CHANGE IN THE MEKONG DELTA

Climate scenario's, sea level rise, other effects

1. Inventory of available data

- Meteorology and Hydrology

Due to historical reasons, meteorological data in Vietnam is not continuously recorded. Some stations have data of the first years of 20th century but these were discontinued in the period from 1930 to 1960. In the Vietnamese Mekong Delta (VMD, Mekong Delta) case, meteorological data from 1978 to now is fairly complete.

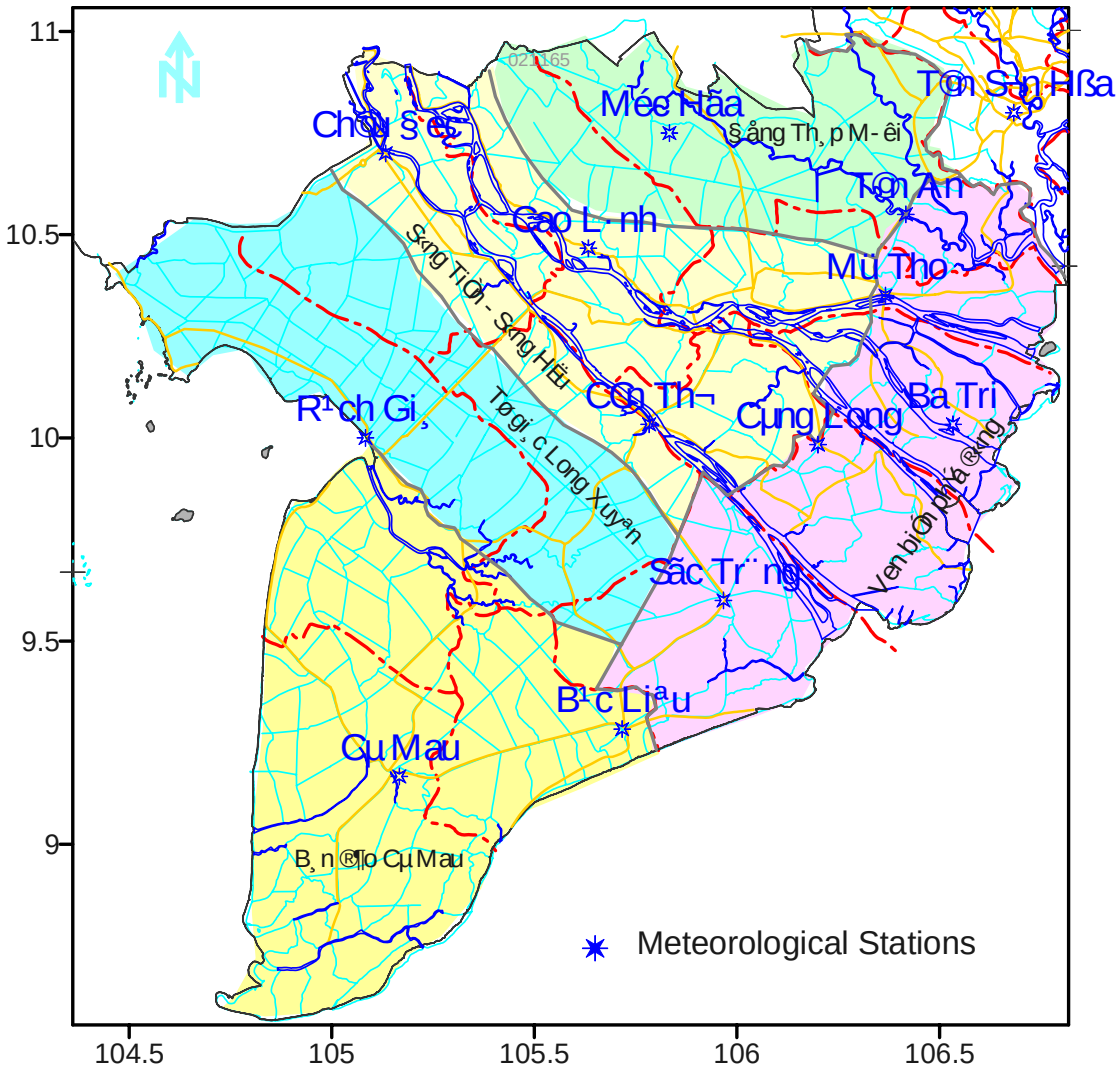

Figure 1. Mekong Delta's meteorological stations

In Mekong Delta, there are 13 meteorological stations. The list of these stations is presented in Table 1. Rainfall and evaporation monitoring data are available at these stations; rainfall data through gauge readings and PICHE instruments are used to measure evaporation.

Table 1. Meteorology stations in Mekong Delta

No	Nam of station	ID	Longitude (^{0}E)	Latitude (^{0}N)	No	Name of station	ID	Longitude (^{0}E)	Latitude (^{0}N)
1	Tân Sơn Hòa	*003*	*106.68*	*10.8*	8	Cao Lãnh	*701*	*105.63*	*10.47*
2	Tân An	*502*	*106.42*	*10.55*	9	Châu Đốc	*752*	*105.13*	*10.7*
3	Mộc Hóa	*503*	*105.83*	*10.75*	10	Ba Tri	*806*	*106.53*	*10.03*
4	Mỹ Tho	*551*	*106.37*	*10.35*	11	Rạch Giá	*851*	*105.08*	*10.00*
5	Càng Long	*603*	*106.20*	*9.98*	12	Cà Mau	*904*	*105.17*	*9.17*
6	Cần Thơ	*651*	*105.78*	*10.03*	13	Bạc Liêu	*905*	*105.72*	*9.28*
7	Sóc Trăng	*657*	*105.97*	*9.60*					

Data taken from non-automatic recording rain gauges is recorded as daily precipitation, whereas for automatic recording rain gauges rainfall intensity is recorded for 15', 30', 60', 90', 120' and 180' (minutes) intervals. Data obtained through PICHE is recorded as daily evaporation rate.

For the listed meteorological stations in Table 1, the available data is presented in Table 2. Data records are available for the period 1978 to 2009.

Table 2. List of available data

Data	Type of data		
	Daily average	Monthly average	Yearly average
Temperature	x	x	x
Rainfall	x	x	x
Evaporation	x	x	x
Relative humidity	x	x	x
Sun hour	x	x	x
Wind	x	x	x
Pressure	x	x	x

Note: "x" means available

There are 43 water level gauging stations in Mekong Delta. The list of these stations is presented in Appendix 1, and location of the stations are presented in Figure 2. Data is mainly available from 1984 up to now. Hourly water level and daily maximum and minimum water level are recorded.

There are more than 40 salinity gauging stations in the coastal areas of Mekong Delta. Only a few of these stations have data from 1980 onwards, the majority of them has data from 1994 up to now. Names and locations of these stations are presented in the Appendix 2. Salinity is mainly recorded during dry season and high tide period.

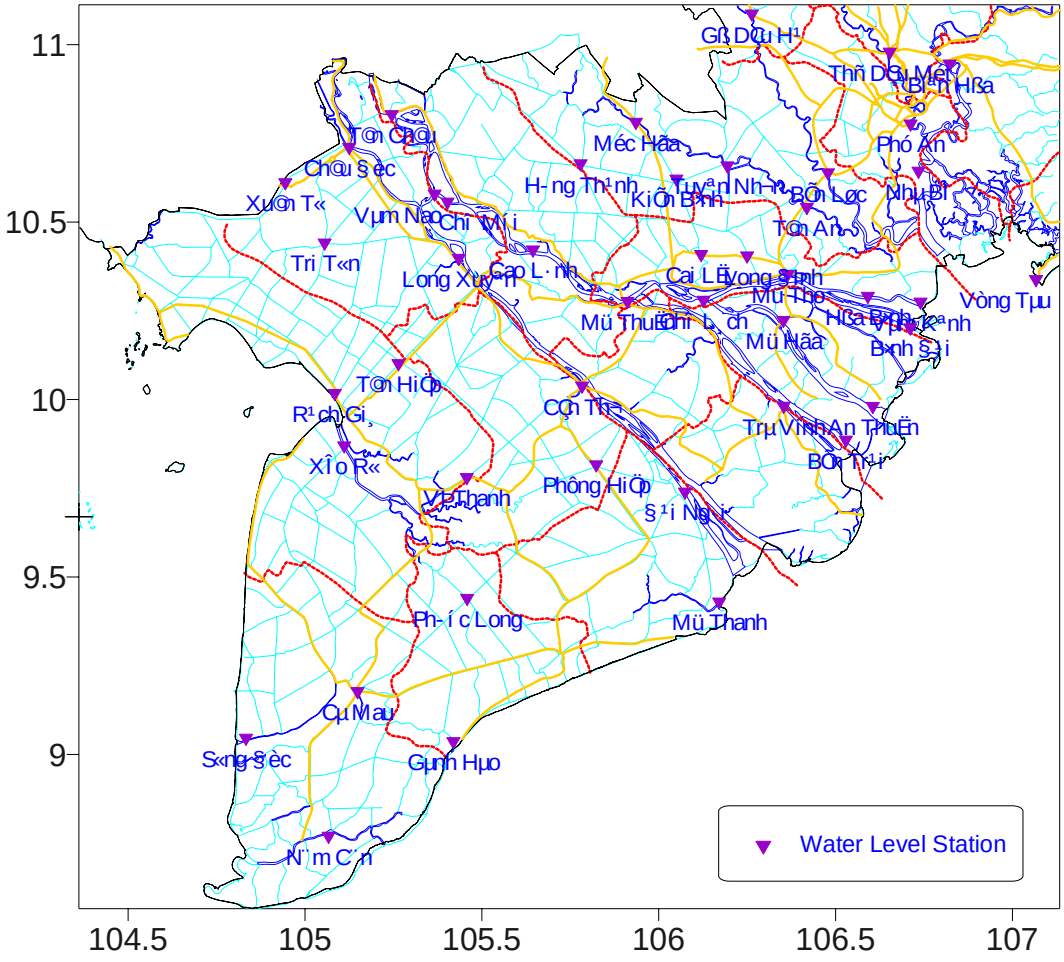

Figure 2. Location of water level stations in the Mekong Delta

Meteorological and hydrological data was recorded on paper, and partly digital in Excel or text format.

The tasks of the National Hydro-Meteorological Service (NHMS) are to carry out basic meteorological, hydrological and water environmental observations. Moreover to provide weather, hydrological forecasts and specialized services in support of natural disaster prevention and preparedness, national security and defense of the country.

- Geography

In 2004, the Ministry of Natural Resources and Environment has completed the establishment of the national geodetic control network regarding cadastral surveying and topographic maps at scale of 1:50,000 for the whole of Vietnam. Maps were published by Department of Survey and Mapping under

management of Ministry of Resources and Environment. Maps of Mekong Delta are in paper and digitized format. Map Layers include elevation, land use, river network, roads etc.

In 2008, the Ministry of Natural Resources and Environment completed the project of "Establishing database of basic hydro - topographic information system for flood control and socio - economic development in Cuu Long river delta". This was one of the priority projects applying advanced technologies in many fields such as surveying, mapping, data management of a hydrological information system as well as a geographical information system.

The National Target Program to respond to climate change, period 2010-2015, involves a project of "Building digital elevation model with height accuracy in coastal Vietnam for warning and rescue, and responses to climate change".

2. Current system overview and analysis

2.1 Current rainfall and evapotranspiration pattern in time and space

- Rainfall

The yearly average rainfall in the Mekong Delta is 1733mm and concentrates mainly in the rainy season (from May to November). The highest average rainfall (2200-2500 mm) occurs in Ca Mau and Kien Giang provinces. Provinces with the lowest rainfall, ranging from 1300-1500 mm, are Dong Thap, Tien Giang and Ben Tre. The difference between highest and lowest annual rainfall amounts up to 1200mm.

Table 3. Average rainfall in Mekong Delta (mm) [19]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
9	5	15	58	187	233	235	246	264	295	143	43	1733

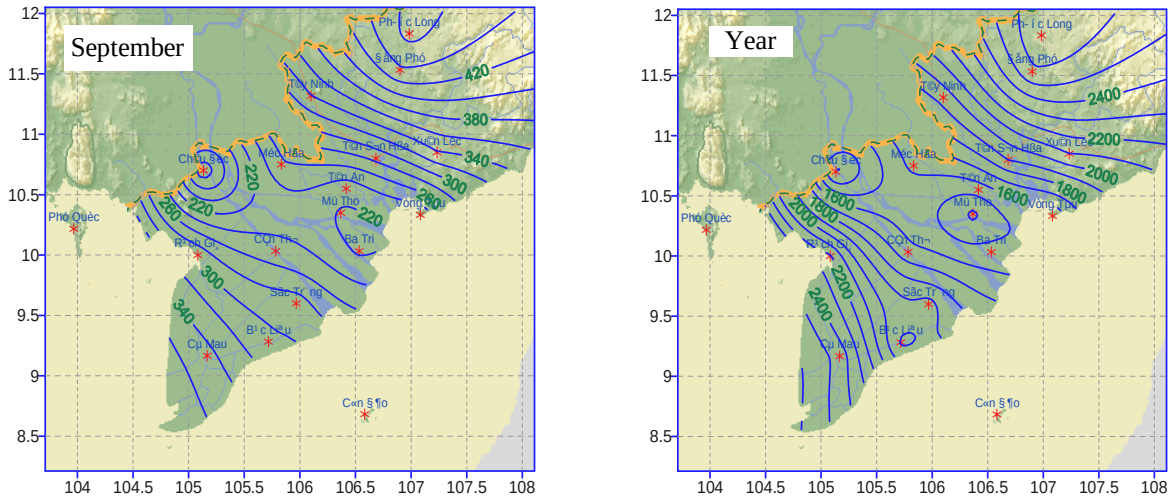

Figure 3. Average rainfall of September and year (mm)

October, which has the highest rainfall, is the period of flood peaks in the Mekong Delta and also of water level rise due to Chuong wind. From January to March, average rainfall in this area is very low. Sea water level rises due to wind surges during this dry period can lead to drought spells and salt intrusion that may severely affect agriculture. The combination of heavy rainfall, drought and water level rise due to wind and the occurrence of flood peaks are important issues which need special consideration in climate change coping and adaption strategies for the Mekong Delta.

Statistical results of average rainfall in the Mekong Delta are presented in Table 4. The standard deviation shows that in this area the rainfall variation is fairly stable.

Table 4. Variation of rainfall in the Mekong Delta [19]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Min	*0*	*0*	*0*	*20*	*129*	*172*	*178*	*198*	*194*	*214*	*47*	*2*	*1680*
Max	*45*	*33*	*83*	*306*	*289*	*349*	*395*	*389*	*498*	*431*	*252*	*112*	*2405*
Max-Min	*45*	*33*	*83*	*286*	*160*	*178*	*217*	*191*	*304*	*217*	*205*	*110*	*705*
StDev	*10*	*9*	*23*	*61*	*47*	*45*	*57*	*50*	*66*	*47*	*58*	*27*	*174*

The variation of rainfall in this area is strongly related to the meteorological El Niño and La Niña phenomenon (ENSO). Studies of the impacts of ENSO on the Mekong Delta climate [19] show that the average rainfall in years with occurrence of El Niño is lower (anomaly value is –117mm); the number of days with rainfall is lower, and the rainy season starts later, becomes shorter and drought increases. In the period of La Niña, the situation is reversed: higher annual rainfall (anomaly value is +339mm); increase of the number of days with rainfall; and the rainy season starts earlier and lasts longer. However, the conditions are not always like this in years with El Niño or La Niña, it also depends on the intensity of ENSO and many other factors.

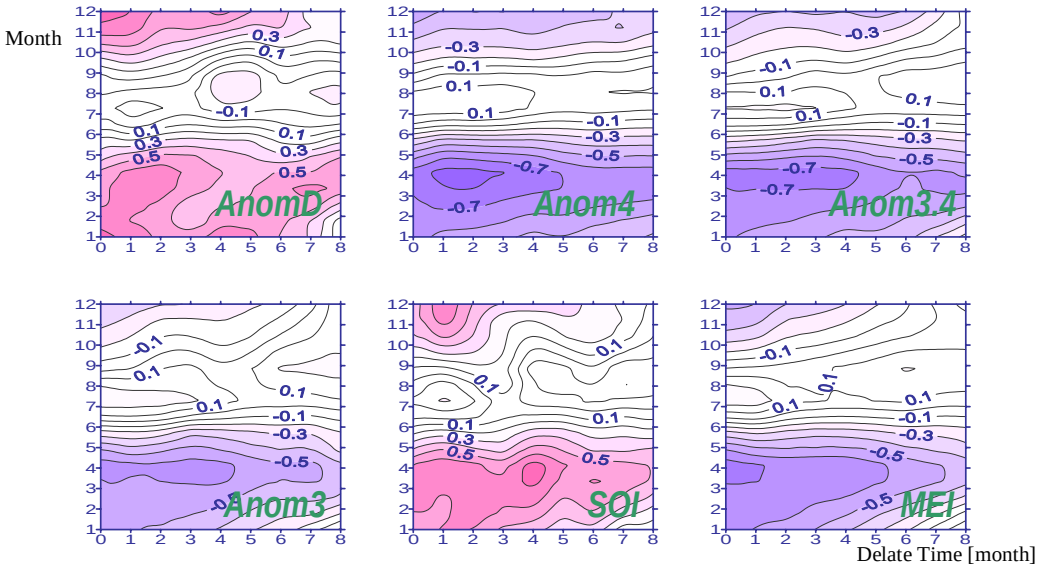

Figure 4. Correlation coefficient between rainfall and ENSO factors [19]

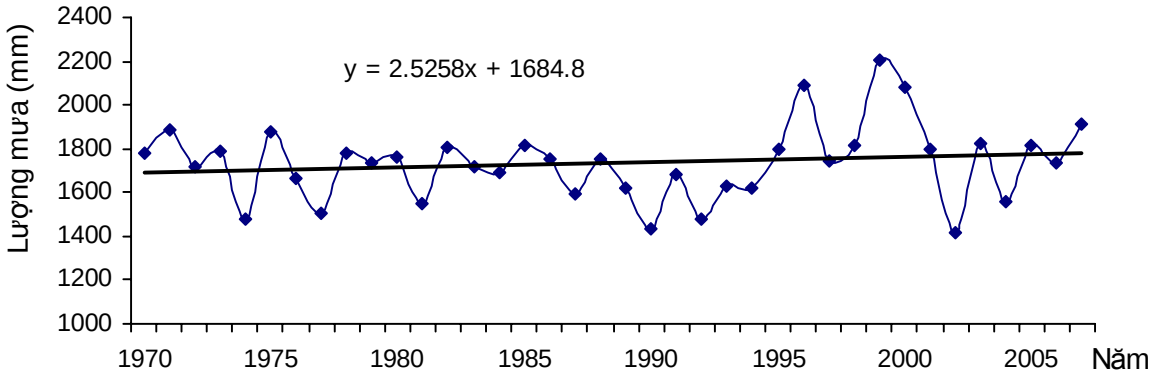

Figure 5. Average rainfall trend in Mekong Delta

The average starting and ending day of the rainy season in Mekong Delta is the 118th (April 28th) and the 317th (November 13th) day respectively. So the average duration of the rainy season is 199 days. Trend analysis of the starting and ending days of rainy season shows that the rainy season has been elongated by 6 days over the period 1970 – 2007; starting overall 3 days earlier and lasting 3 days longer [19].

Table 5. Average starting and ending days of rainy season

Character	ID of stations													VMD
	3	*502*	*503*	*551*	*603*	*651*	*657*	*701*	*752*	*806*	*851*	*904*	*905*	
Starting day	121	121	114	123	120	122	119	125	117	123	115	110	122	118
Ending day	319	315	320	309	313	318	315	320	316	310	322	324	320	317

Note: days in order of day in year

In the period 1970 – 2007, rainfall tended to increase in the whole Mekong Delta by an average increase of rainfall of 95 mm per year. The actual annual increase is related to the geography of the Mekong Delta, with Ca Mau peninsula as the area with the lowest increase, and Dong Thap Muoi as the area with the highest rise in annual rainfall with a value of +144mm.

So, along with the lengthening of rainy season, the average rainfall in Mekong Delta increased considerably. With average annual rainfall of about approximately 1700mm in Mekong Delta, the rate of rainfall increase over this 37 year period is 5.5%.

- ***Evaporation***

In the period 1970 – 2007, total evaporation in Mekong Delta measured by PICHE instrument is 1095mm/year. Months with highest evaporation are from February to April, which are also the months with low humidity and high

temperature. During the months of the rainy season, due to high air humidity and lower temperature, the evaporation is low with values ranging from 2.2 to 2.6 mm.day^{-1}.

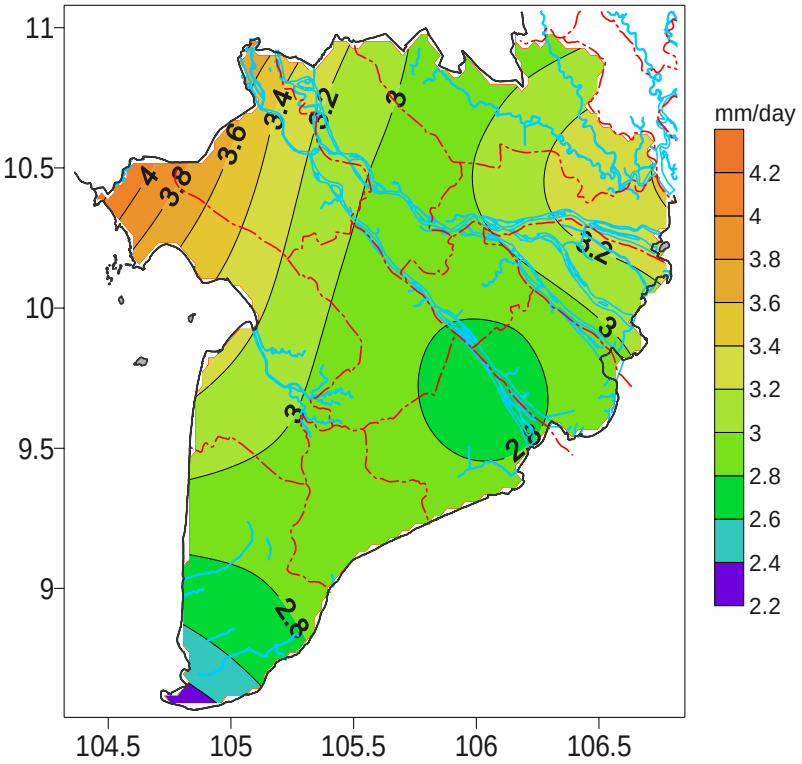

Figure 6.Average evaporation in Mekong Delta (mm.day^{-1}) [19]

Table 6. Average evaporation (mm.day^{-1}) [19]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
3.4	3.8	4.1	4.0	3.0	2.7	2.6	2.6	2.3	2.2	2.7	3.0	3.0

Spatially, Kien Giang and Dong Thap provinces have the highest evaporation with average values ranging from 3 to 4 mm.day^{-1}. The East-coast provinces including Ca Mau, Soc Trang, Bac Lieu and Tra Vinh have the lowest evaporation with value from 2.6 to 3 mm.day^{-1}.

Table 7. Variation of evaporation in Mekong Delta (mm.day^{-1}) [19]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Min	*2.6*	*3.0*	*3.3*	*2.8*	*2.2*	*2.1*	*2.0*	*2.1*	*1.8*	*1.8*	*2.0*	*2.3*	*2.5*
Max	*4.4*	*5.2*	*5.3*	*5.1*	*4.0*	*3.2*	*3.2*	*3.1*	*2.8*	*3.0*	*3.3*	*3.8*	*3.6*
Max-Min	*1.8*	*2.3*	*2.0*	*2.3*	*1.8*	*1.2*	*1.2*	*1.0*	*1.0*	*1.2*	*1.3*	*1.5*	*1.0*
StDev	*0.38*	*0.48*	*0.45*	*0.51*	*0.42*	*0.27*	*0.31*	*0.27*	*0.24*	*0.31*	*0.35*	*0.32*	*0.24*

Statistical results of evaporation variation in Mekong Delta are presented in Table 7. This table shows that from February to April, the standard deviation or variation is highest. Similar to rainfall, this variation is also connected to the El Niño and La Niña phenomena. Studies of ENSO impacts on Mekong Delta's

climate.[19] show that evaporation tends to increase in years with El Niño compared to years without. The situation is the reverse when La Niña occurs.

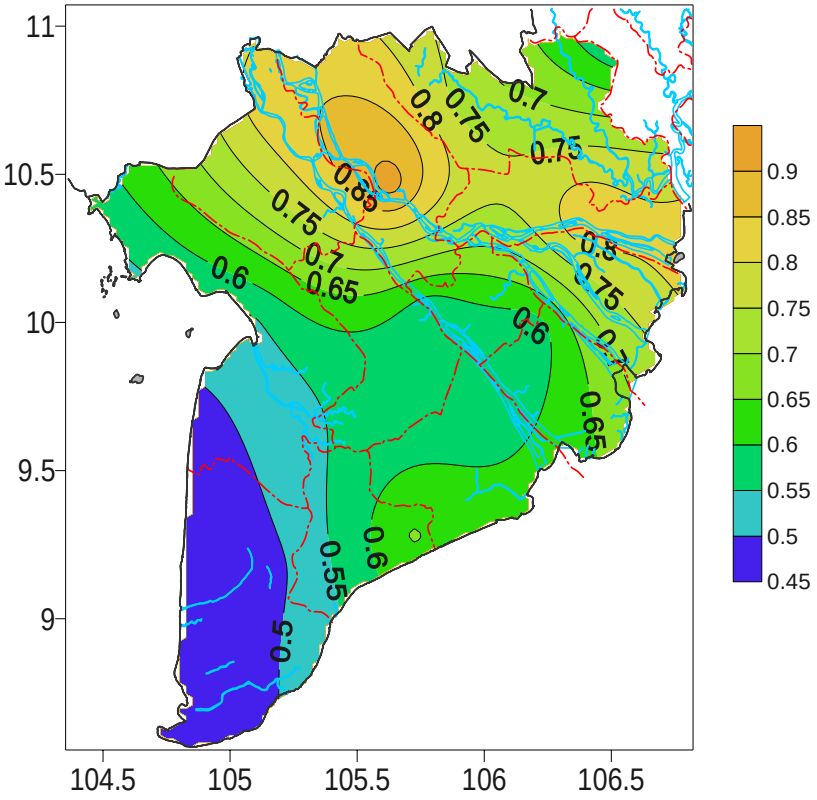

Figure 7. Drought index in Mekong Delta [19]

The drought index for the Mekong Delta is presented in Figure 7. This index is calculated as the ratio of evaporation over rainfall. Yearly average value of drought index for Vietnam ranges from 0.15 to 1.2 and varies with every province. The yearly average drought index in the Mekong Delta ranges from 0.5 to 0.9, indicating a water surplus. Compared to the drought index for the whole country, this area has an average value. The distribution of drought index indicates that Dong Thap, Tien Giang and Ben Tre provinces are most prone to drought. On the other hand, Ca Mau, Bac Lieu, Soc Trang and Hau Giang provinces are rather wet.

2.2. Predicted changes in rainfall and evapotranspiration pattern both in time and space

The prediction of climate change in Vietnam was carried out by Vietnam National Institute of Meteorology, Hydrology and Environment (IMHEN). The first official report was presented in 2009. Three climate change scenarios for Vietnam were built: Low emission (B1), Average (B2) and High emission (A2).

The model used for building the climate change scenarios was MAGICC/SCENGEN. MAGICC/SCENGEN is the integration of MAGICC

model (for assessing climate change – caused by greenhouse gases) and SCENGEN (for building zonal climate scenarios).

These scenarios and reports were elaborated for 5 areas of Vietnam including North West, North East, North Delta, North Central, South Central, Central Highlands and the South. The time frame used in the climate change report and scenarios are 2020, 2030, 2040, …, 2100.

The outcomes of the Ministry of Resources and Environment assessment on rainfall change in each scenario from low to high emission is presented in Table 8.

Table 8. Rainfall change (%) in South Vietnam relative to the period of 1980-1999

Scenario	Monthly Period	Decades in the 21th Century								
		2020	2030	2040	2050	2060	2070	2080	2090	2100
B1	Dec - Feb	-2.7	-4.4	-6.2	-7.7	-7.7	-9.4	-9.1	-10.1	-10.1
	Mar - May	-2.6	-3.6	-5.8	-7.2	-8.1	-8.7	-9.2	-9.4	-9.4
	Jun - Aug	0.3	0.5	0.6	0.8	0.9	1.0	1.1	1.1	1.1
	Sep - Nov	2.6	3.8	5.0	6.3	7.3	8.1	8.3	8.5	8.5
B2	Dec - Feb	-3.0	-4.4	-6.2	-8.1	-8.7	-11.4	-12.8	-14.2	-15.8
	Mar - May	-2.8	-4.1	-5.8	-7.5	-9.1	-10.6	-12.0	-13.2	-14.3
	Jun - Aug	0.3	0.5	0.6	0.9	1.1	1.2	1.4	1.5	1.6
	Sep - Nov	2.6	3.8	5.3	6.8	8.3	9.6	10.9	11.9	13.0
A2	Dec - Feb	-3.3	-4.5	-5.9	-7.4	-9.7	-12.0	-14.4	-16.9	-19.6
	Mar - May	-3.0	-4.2	-5.5	-7.2	-9.0	-11.1	-13.3	-15.7	-18.2
	Jun - Aug	0.4	0.5	0.6	0.8	1.0	1.3	1.5	1.8	2.1
	Sep - Nov	2.8	3.8	5.0	6.5	8.2	9.3	12.1	14.3	16.5

The reported values are 3-month averages: December to February, March to May, June to August and September to November. Included in the climate change report are data on temperature, rainfall and sea level rise.

2.3. Current and predicted changes in temperature variation

2.3.1 Current changes of temperature

Statistical results of mean temperature change in the studied areas are presented in Table 9 [19]. Similar to rainfall, statistical results include mean, max, min and standard deviation. Two periods were analyzed: 1970-1988 and 1989-2007.

The statistical results indicate that mean temperature in Mekong Delta in the later period has increased by 0.22^0C compared to the earlier period. Moreover a

majority of stations has recorded temperature increase and only few of them have recorded changes in standard deviation. In the later period, the maximum and minimum yearly mean temperature values are higher than those of the preceding period -- for the Mekong Delta these amount to $+0.3^0$C and $+0.4^0$C for minimum and maximum temperature respectively.

Table 9. Yearly mean temperature characteristics (^{0}C)

Period	Values	Station's ID													VMD
		3	*502*	*503*	*551*	*603*	*651*	*657*	*701*	*752*	*806*	*851*	*904*	*905*	
1970-1988	Min	26.8	26.1	26.5	26.1	25.9	25.6	26.4	26.2	26.0	26.6	26.9	26.4	26.2	26.3
	Max	27.7	27.5	27.5	27.0	27.0	26.8	27.1	27.4	27.4	27.3	27.8	27.2	27.1	27.3
	Mean	27.3	26.8	27.1	26.6	26.6	26.3	26.7	26.9	26.8	27.0	27.4	26.8	26.6	26.8
	Stdev	0.22	0.39	0.33	0.23	0.29	0.33	0.23	0.33	0.43	0.22	0.25	0.21	0.26	0.29
1989-2007	Min	27.3	25.9	27.0	26.5	26.6	26.5	26.5	26.7	26.5	26.5	27.1	26.6	26.4	26.6
	Max	28.5	27.4	27.9	27.4	27.5	27.4	27.5	27.5	27.8	27.4	28.0	27.9	27.4	27.7
	Mean	27.8	26.6	27.4	26.9	26.8	26.9	26.7	27.1	27.3	26.9	27.5	27.2	26.8	27.1
	Stdev	0.36	0.43	0.25	0.21	0.23	0.23	0.23	0.23	0.42	0.22	0.24	0.37	0.29	0.28

The temperature trend for the period 1970 – 2007 of Mekong Delta is presented in Table 10 and Figure 8. In Mekong Delta, temperature shows an increasing trend in both dry and rainy seasons.

Table 10. Mean Temperature change for the period 1970 - 2007

Areas \ Factors	Yearly mean temperature change (^{0}C)	Mean temperature change in dry season (^{0}C)	Mean temperature change in rainy season (^{0}C)
Mekong Delta	0.61	0.72	0.49
Long Xuyen quadrangular	0.65	0.75	0.53
Ca Mau peninsula	0.59	0.70	0.46
Dong Thap Muoi	0.66	0.77	0.55
Tien – Hau rivers	0.65	0.76	0.52
East coastal zones	0.52	0.62	0.41

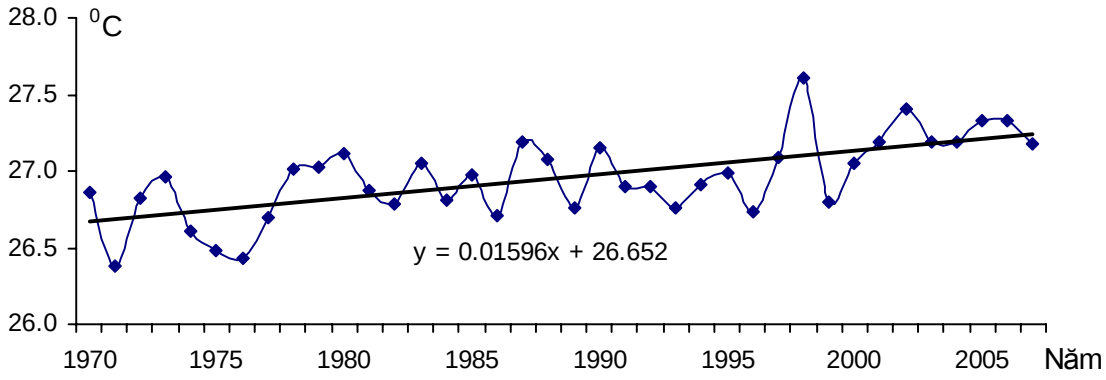

Figure 8. Mean temperature trend in Mekong Delta [19]

For the whole year, mean temperature change of the Mekong Delta in the period 1970-2007 is 0.6^{0}C. Looking at subareas, the East coastal zone has the lowest temperature change with 0.5^{0}C (approximately 0.1^{0}C lower than the Mekong Delta average) and areas with the highest changes are the Long Xuyen quadrangular, Tien-Hau rivers and Dong Thap Muoi with average temperature increases in the range from 0.65^{0}C to 0.66^{0}C.

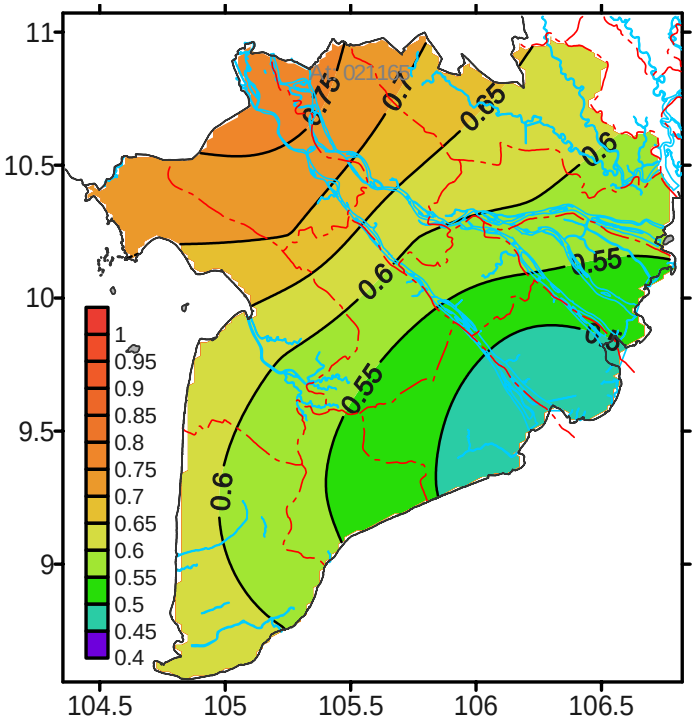

Figure 9. Trend of mean annual temperature change (^{0}C) in the period 1970 – 2007 [19]

Seasonally, temperature change in the dry season is higher than for the rainy season, with dry season temperature increases of 0.21^{0}C to 0.24^{0}C higher than those for the rainy season. This is mainly the effect of increased rainfall during the rainy season which has a temperate effect on temperature.

2.3.2 Forecast of temperature change

The report of Ministry of Resources and Environment on temperature change in each scenario, from low to high emission is presented in Table 11. In this table the South comprises of Mekong Delta and the South East. According to statistical data on climate change for the period 1970 – 2007, there is no significant difference in the value of temperature increase between Mekong Delta and the South East.

According to these scenarios, temperature rise in the rainy season will be higher than in the dry season for all periods. This conclusion is radically different compared to the increasing trend recorded in the period 1970 – 2007. In 2100, the temperature increase compared to the period 1980 – 1999 in scenario A2 in rainy season is 2.9^0C. This value is two times higher than that of scenario B1.

Table 11. Temperature change in South Vietnam relative to the period of 1980-1999

Scenario	Monthly Period	Decades in the 21th Century								
		2020	2030	2040	2050	2060	2070	2080	2090	2100
B1	Dec - Feb	0.3	0.5	0.6	0.8	0.9	1.1	1.1	1.1	1.1
	Mar - May	0.4	0.6	0.8	0.9	1.0	1.2	1.2	1.3	1.3
	Jun - Aug	0.5	0.7	0.9	1.1	1.3	1.4	1.5	1.5	1.5
	Sep - Nov	05	0.6	0.9	1.2	1.2	1.4	1.5	1.5	1.5
B2	Dec - Feb	0.3	0.5	0.6	0.8	1.0	1.3	1.5	1.5	1.7
	Mar - May	0.4	0.6	0.8	0.9	1.2	1.4	1.7	1.8	1.9
	Jun - Aug	0.5	0.7	0.9	1.2	1.5	1.8	2.0	2.1	2.1
	Sep - Nov	0.5	0.6	0.9	1.2	1.4	1.8	1.9	2.1	2.3
A2	Dec - Feb	0.3	0.5	0.7	0.8	1.0	1.3	1.5	1.8	2.1
	Mar - May	0.4	0.6	0.8	0.9	1.2	1.5	1.9	2.1	2.7
	Jun - Aug	0.6	0.7	0.9	1.2	1.5	1.8	2.2	2.6	2.9
	Sep - Nov	0.5	0.7	1.0	1.2	1.5	1.8	2.1	2.5	2.9

2.4. Predicted sea level rise due to climate change

2.4.1 Recent change of sea level

Monitoring data from marine stations along the coast of Vietnam indicate that the speed of mean sea level rise in Vietnam is currently approximately 3mm/year (period 1993 – 2008), which is nearly equal to the average sea level rise worldwide. In the past 50 years, sea level in Hon Dau station has risen about 20 cm [2].

In the period 1980 – 2007, data at Vung Tau station shows that the highest, average and the lowest sea level increases are 14 cm, 13 cm and 12 cm respectively. Stations on the river belonging to Sai Gon – Dong Nai river system and stations at estuaries in Cuu Long river system also have recorded mean sea level rise of 9 – 13 cm during this period [21].

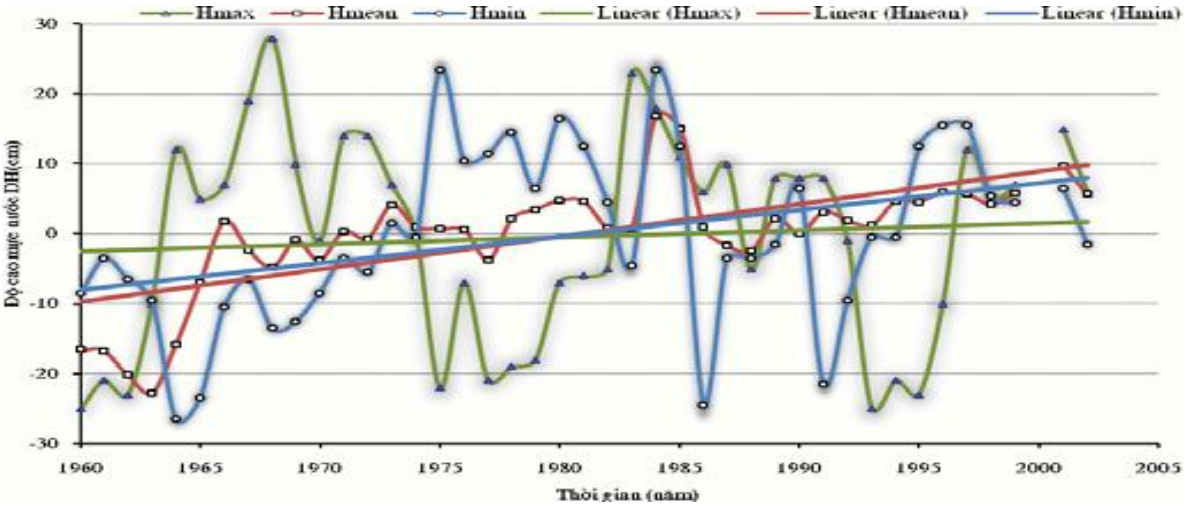

Figure 10. Sea level trend at Hon Dau station [2]

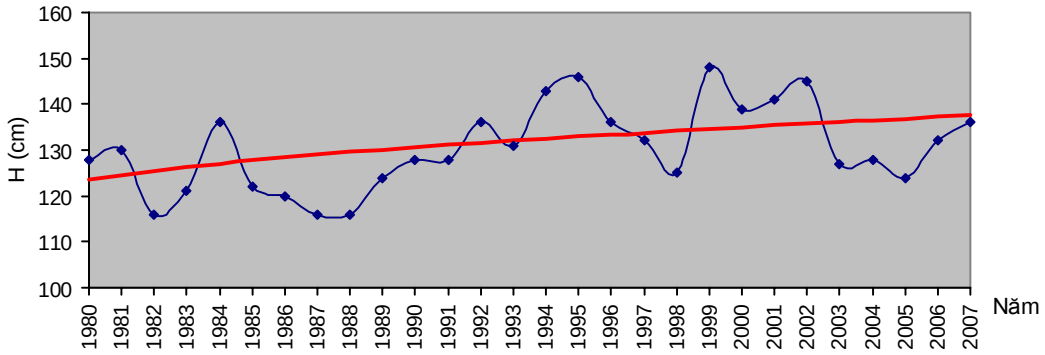

Figure 11. Trend of highest water level in the period 1980 – 2007 at Vung Tau station [21]

2.4.2 Forecasting of sea level trend

In the report of the Ministry of Resources and Environment on sea level change the following 3 scenarios of sea level rise in Vietnam were included: low emission (B1), average emission (B2) and highest emission (A1FI). The results are presented in the following table:

Table 12. Sea level rise (cm) relative to the period of 1980-1999 [3]

Scenario	Decades in the 21th Century								
	2020	2030	2040	2050	2060	2070	2080	2090	2100
Low (B1)	11	17	23	**28**	35	42	50	57	**65**
Average (B2)	12	17	23	**30**	37	46	54	64	**75**
Highest (A1FI)	12	17	24	**33**	44	57	71	86	**100**

Results from these scenarios show that in 2100, sea level will have risen 65 cm to 100 cm compared to the period 1980 – 1999.

2.5. Effects of sea level rise on flooding and drainage status of lowlands in the Mekong Delta

The impacts of sea level rise on inundation and drainage of the Mekong Delta low lands are becoming more and more clear. In recent years (2008, 2009), due to impact of sea level rise combined with high tide, Kien Giang, Bac Lieu and Can Tho have been heavily inundated. Even high lands such as urban, residential areas and roads in some places have been also inundated.

Depending on yearly rainfall distribution, flood in Cuu Long river system, tidal water level and surging water due to wind, inundation usually occurs at the end of the wet season. In this area, heavy rainfall occurs in October, which is also the time of peak flood appearance, start of Chuong wind and high tide so that inundation is common.

Statistical analysis of water level data of estuaries in the Mekong Delta indicate that the highest recorded water levels have occured in recent years. The increase of rainfall and sea level rise due to climate change impacts makes inundation more extreme and more difficult to effectively drain.

The impacts of sea level rise on inundation and drainage of agricultural areas are the most pronounced. In addition, due to increased urbanization of low lying areas that are heavily affected by tide, impacts of sea level rise on urban areas are considerably high. Currently, drainage system in these urban areas is facing many difficulties. The combined impacts of sea level rise and the increase of rainfall intensity due to urban heat island effect (UHI) will pose difficulties for urban drainage.

In the low elevation Mekong Delta, the estimated sea level rise can result in large areas of inundated coastal plains. Predictions of inundations as presented by the climate change models for each emission scenario of MONRE in the Mekong Delta are shown in and Figure 12:12 [3].

Table 13. Inundated area of Mekong Delta to 2100 for each emission scenario

Scenario	Inundated area (km^2)	Percent of inundated (%)
Low (B1)	5133	12.8
Medium (B2)	7580	19.0
Highest (A1FI)	15116	37.8

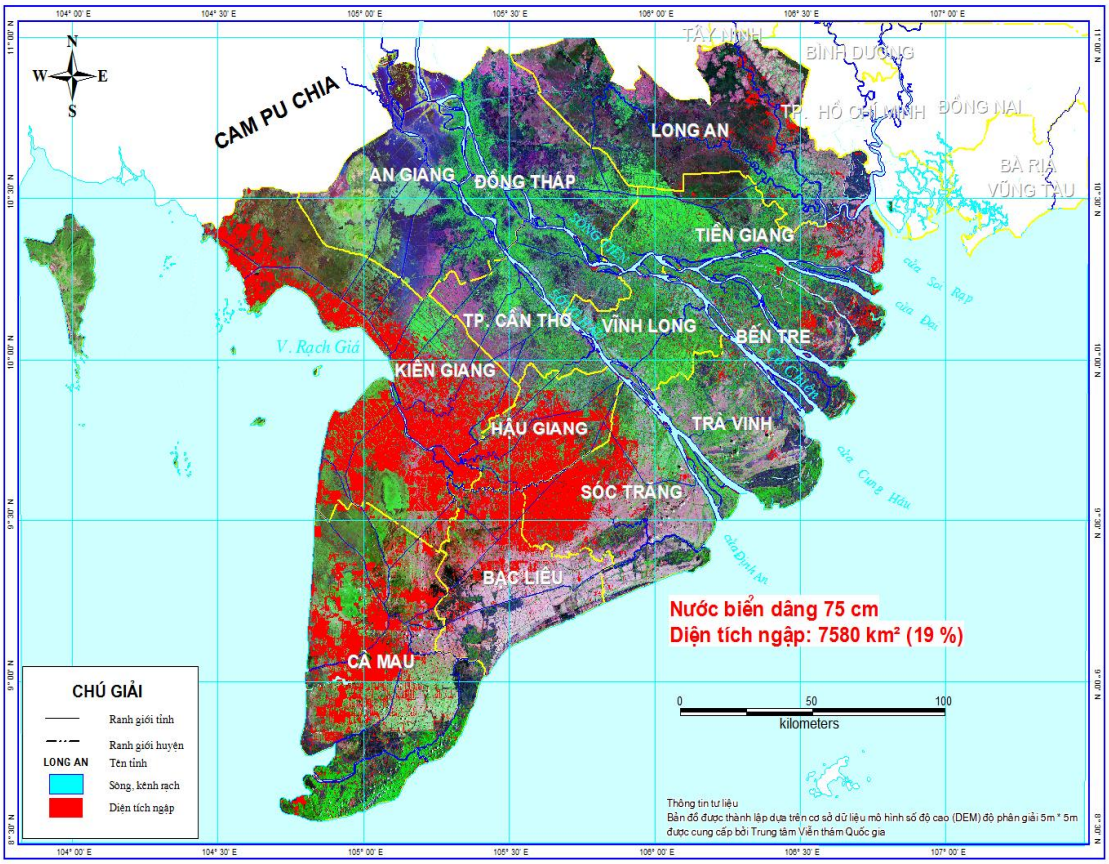

Figure 12:12 Scenarios of sea level rise impacts on inundation and drainage in the Mekong Delta are presented in many reports. Report [13] includes modeling results of inundation in the Mekong Delta from July to November for sea level rise of 20cm and 45cm. The outputs show that the contour lines of water levels will be shifted up to 25 km and 50 km inland due to higher sea levels. At the onset of the flood season (August), the average increment in water levels in the Delta is 14.1 cm and 32.2 cm, respectively. At the peak of the flood season (October), high river discharge from upstream increases the increment in water level, resulting in further average water level rise of 11.9 cm and 27.4 cm respectively, aggravation the flooding problems in the Mekong Delta. GIS techniques were used to delineate areas with different levels of vulnerability: i.e. area with high (2.3 mil. ha = 60% of the Mekong Delta), low (0.6 mil. ha = 15%) and medium (1 mil. ha = 25%) vulnerability due to sea level rise. Rice production will be affected through excessive flooding in the tidally inundated

areas and longer flooding periods in the central part of the Mekong Delta. These adverse impacts could affect all three cropping seasons, Mua (main rainfed crop), Dong Xuan (Winter–Spring) and He Thu (Summer–Autumn) in the Mekong Delta unless preventive measures are taken.

Table 14. Depth and area of inundation in Mekong Delta [18]

Depth (m)	Area (1000 ha)		
	2004	Sea level rises 0.69 m	Sea level rises 1 m
0.5< H ≤ 1.0	1063	604	496
1.0< H ≤ 1.5	724	1007	421
1.5< H ≤ 2.0	459	1270	1880
2.0< H ≤ 2.5	288	414	592
2.5< H ≤ 3.0	212	281	323
H>3	66	84	102
Total	2813	3660	3815

According to report [18], for sea level rise of 0.69m to 1m, depth of inundation will increase considerably. Compared to 2004, sea level rise of 0.69m and 1m, will increase the area with an inundation depth of more than 0.5m with 847,000ha and 1,002,000ha, respectively.

In order to assess the actual risk of sea level rise, it is necessary to take into account the impacts of tide and water level rise by other reasons such as heavy rainfall, flood, hurricane, Monsoon wind, high wave etc … The Mekong Delta is heavily affected by tide with tidal magnitude at some places of 4 m. Besides, Chuong wind, high waves and hurricanes can raise the water level much. Therefore, inundation by sea level rise due to climate change will be significantly higher during condition of extreme weather, which have not been accounted for yet in these scenarios.

2.6. Effects of sea level rise on salt water intrusion

The Mekong Delta has dense canal systems, draining into the sea, and large rivers such as Tien river, Hau river flowing through the plain into the sea through 9 exits with width ranging from hundreds of meters to several kilometers (e.g. Vam Co Dong river and Vam Co Tay river flowing through Dong Thap Muoi). Such topographical and geographical conditions create favorable conditions for salinity intrusion deep into the land. Apart from

topographical and geographical conditions, Chuong wind (occurring from November to April, and strongest in February/March), West South Moonsoon wind, rainfall, Mekong river discharge and even human activities can contribute to the increase of salinity intrusion.

According to report [18], 1,637,000 ha of the Mekong Delta will be prone to a salt intrusion of $4^0/_{00}$ in the dry season, if the sea level rises with 1m (corresponding to sea level rise scenario in 2100 of MONRE). This will result in an increase of 334,000ha in relation to the benchmark year of 2004.

Table 15. The Mekong Delta area affected by salinity of more than $4^0/_{00}$ in dry season [18]

2004	Sea level rise of 0.69 m	Sea level rise of 1 m
1,303,000 ha	1,493,000 ha	1,637,000 ha

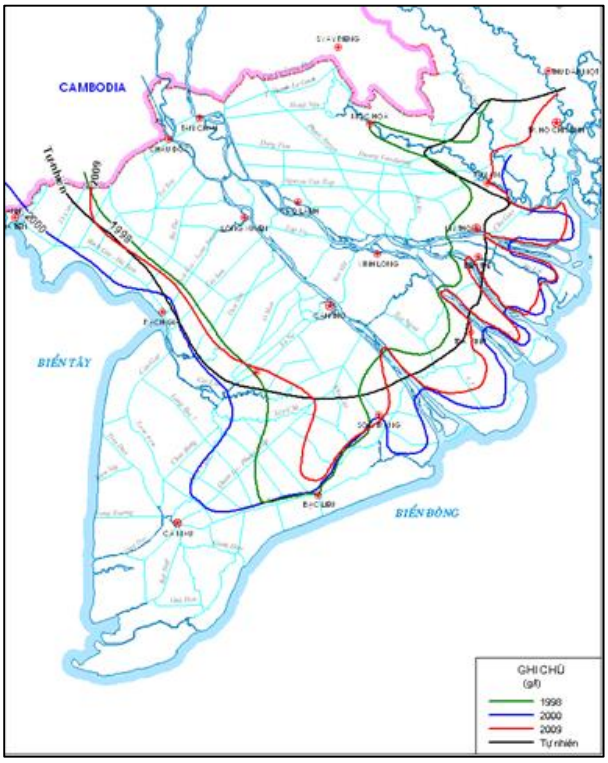

Figure 13. Salinity boundary $4^0/_{00}$ in 1998, 2000 and 2008

Sea level rise, impacts of high tide and low discharge in dry season contribute to deeper salinity intrusion. In 2005, deep intrusion (and more early than normal), high salinity and long-lasting salinization occurred frequently in Mekong Delta provinces. In Tien river, Ham Luong river and Co Chien river, salt intrusion is 60 – 80 km deep into the land. In Hau river, salt intrusion also went 60 – 70 km deep into the land. In main streams such as Vam Co Tay, Vam Co Dong, salinity intrudes up to 120 – 140 km. In Long An, the total

salinity ensued economic loss mounted to 16 billions VND. The province's 14,693 ha of sugar cane production decreased by 5- 10%; 1,093 ha of rice in Duc Hoa district was all destroyed due to salt intrusion. Total losses for Soc Trang were assessed at 46 billions VND, with 16,500 ha affected by drought and salinity. The salt affected area of Hau Giang is 9,000 ha, with a total economic loss of 11.4 billions VND. In Can Duoc and Can Giuoc districts was severe shortage of freshwater and in Tien Giang and Ca Mau provinces thousands of houses lacked water

In Ca Mau, in March 2008, salt water severely intruded into the freshwater area of U Minh district. At some locations in this area, people broke dams to let salt water in for shrimp hatching, which made the situation worse. Apart from Ca Mau, saline water has been threatening other areas in the Mekong Delta. In Rach Gia city, salt water intruded deep into the land, pushing freshwater in Cai San river and Rach Gia – Ha Tien canal further inland. Crops are facing water shortages and premature harvesting.

During the dry season of 2010, many provinces of the Mekong Delta have been affected by salt water intrusion, causing losses to agriculture. Many areas are lacking freshwater to serve domestic uses and industrial production.

When sea level rises, the salinity boundary will move inland. Due to distinctions between West sea and East sea's tide, this boundary change is different among areas. Impacts of salinity intrusion due to sea level rise on this area are:

- Salinization of Soil
- Lack of freshwater for domestic use and production
- Decreasing crop and livestock productivity
- Impacts on biodiversity
- Rising costs of production

2.8. Inventory of existing initiatives for downscaling global and regional climate models

Besides the MAGICC/SCENGEN model used to build climate change scenarios, the PRECIS model (Providing Regional Climate for Impacts Studies) of Global Climate Center Hadley is also being applied in Vietnam.

Currently, in Vietnam, there does not yet exist a specific priority list to downscale the global and regional climate models. The following points need to be considered in downscaling climate change:

- Give priority for both statistical and dynamic downscaling
- Maximize resolution of the modeling results
- Select parameterized scheme (cloud parameterized micro – physics, convection, radiation, aerosol, etc …), the modeling domain is suitable for the area studied.
- Choose a variety of input data from climate models
- Enhance assessment to standardize modeling results
- Regularly update climate change scenarios

The above points should be implemented in international cooperation projects with nations with high potential of climate change research and facing similar climate change conditions as in Vietnam.

In order to downscale climate models effectively, another priority needs to be taken into account: exclusion of local factors, especially the impacts of land use change to monitoring data and modeling results.

3. Stakeholder analysis

3.1 Governmental roles and responsibilities; relevant policies in place/being developed

3.1.1 Responsibilities of the government

Climate change has great impacts on the whole society. Therefore, it is the responsibility of government from central to local to implement programs of climate change, especially activities related to adaptation to climate change.

The government guides all related activities including integrating climate change into policies, plans, and national fund development.

The Ministry of Natural Resources and Environment (MONRE) is the focal point for climate change related activities. Groups of technical experts from different sectors/fields, including one for vulnerability and adaptation to climate change, have been established to assist in the implementation of climate change projects.

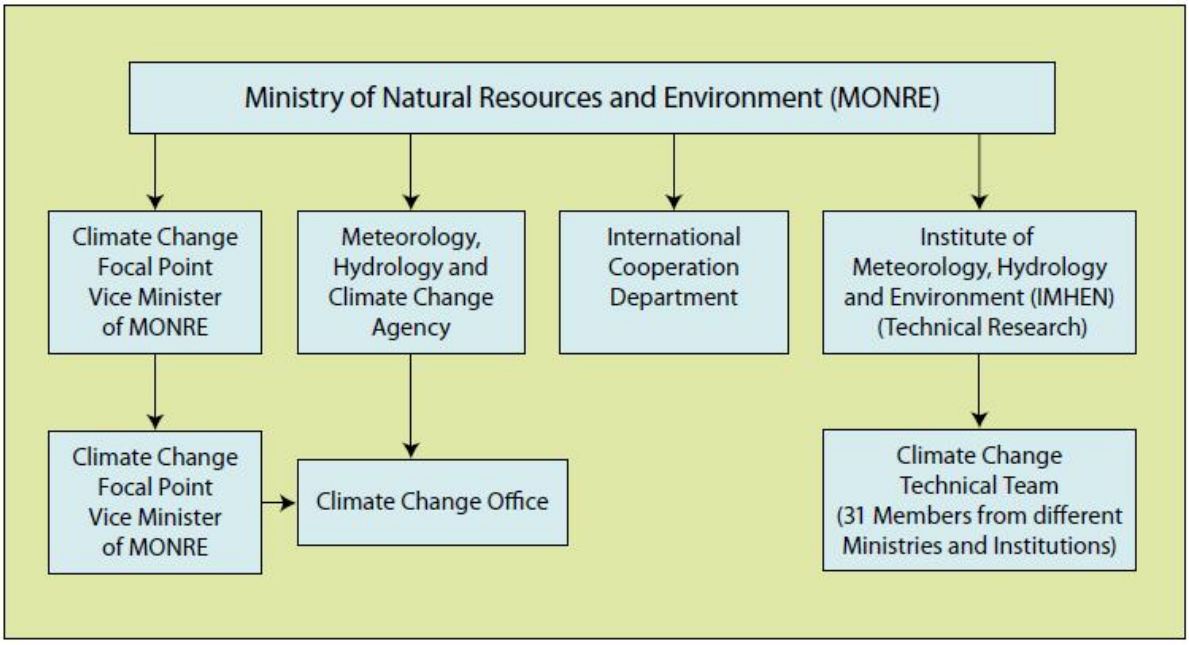

Figure 14. Institutional arrangements for climate change at ministerial level

MONRE works with other departments and with local authorities to carry out the climate change programs, with the primary focus on:

- Hosting and cooperating with different branches and levels of government in the formulation and implementation of policies, and supervise the implementation of the programs;
- Defining goals and responsibilities, calculating costs and proposing solutions. Basing on the accepted responsibilities and total cost, work with Ministry of Planning and Investment and Ministry of Finance to prepare the specific list of costs and propose the equal budget distribution for departments, branches and provinces for the government to approve. Submitting to Director Panel to integrate into 5 – year plan and handing in to Government every year.
- Guiding and supporting departments, branches and provinces in building and implementing their actions to cope with climate change;
- Hosting and working with Ministry of Planning and Investment, develop supervising and assessing mechanism to the implementation of programs approved by Government;
- Regulating activities on information, education, and communication related to climate change;
- Guiding, supervising and assessing the implementation of climate change programs;
- In charge of building and implementing the Department's Action plan.

Ministry of Planning and Investment is in charge of:

- Hosting and working with other Ministries, branches, and local authorities to check and correct strategies, planning and national socio- economy development plans taking into account climate change;
- Leading and guiding departments, branches and local authorities in integrating climate change into strategies, projects and national social economy development plan; together with Ministry of Finance, responsible for distributing funds, regulating common costs and sponsorship including yearly government fund for programs and plans related to climate change;
- Building and implementing the action plan of the ministry.

Ministry of Finance is in charged of:

- Together with Ministry of Planning and Investment, distributing funds, regulating common costs and sources of sponsorship including the yearly national fund for programs and plans related to climate change;
- Building and implementing the Action plan of the Ministry.
- Ministries, organizations at ministry level and other organizations directed by the government:
- Responsible for building and carrying out the Action Plan to cope with climate change for their Ministries and branches;
- Implementing their tasks of the Program;
- Actively taking part in cooperation under the guidance of National steering committee

People's Committee is in charged of

- Building and implementing the Action plan to cope with climate change;
- Organizing activities related to climate change;
- Actively mobilizing sources and integrating related activities of other programs to meet the goals of the Program;
- Preparing periodic reports on the working progress of implementing goals, responsibilities in the city's territory following current regulations.

For the Mekong Delta, the long term responsibility of government is to contribute to the mitigation of the area's vulnerability by impacts of climate change through regulating governmental and non – governmental organizations, developing policies and enhancing coping and adapting ability to

climate change to ensure the sustainability of the environment, the economy and social equality.

3.1.2 Related policies being implemented

The Government of Vietnam ratified the United Nations Frame Convention (UNFCCC) in 1994 and the Kyoto Protocol in 2002 and subsequently stipulated a number of policy documents to enable the implementation of national commitments to address climate change issues. The first communication to UNFCC was submitted in 2003 (MONRE, 2003). Many ministries, branches, and local authorities have deployed research programs on the progress and impacts of climate change on the resources, environment and social – economic development, and proposed and implemented coping plan at the first stage. Documents of related policies on climate change being implemented of Vietnam government include:

- Document No. 1357/CP-QHQT on 11 – 13 – 1998 of the Government to assign Department of Hydro – Meteorology (now is Ministry of Resources and Environment) the leading organizations in carrying out Frame convention of the United Nations on climate change and Kyoto Protocol;
- Frame Convention of the United Nations on Climate Change was signed by Vietnamese government on 11 – 16 – 1994; Kyoto Protocol was signed on 9 – 25 – 2002. From 2/1995, Vietnam has been officially a member not belonging to Appendix I of the Frame Convention of The United Nations on Climate Change;
- Law of Environmental Protection in 2005 clearly states: Vietnamese government is willing to commit to the international duty of environmental protection that was signed for;
- Document No 35/2005/CT-TTg on 10/17/2005 of the Prime Minister on implementing Kyoto Protocol – a part of Frame Convention of United Nations on Climate Change in Vietnam;
- Decision No. 47/2007/QĐ-TTg on 4 – 0 – 2007 of the Prime Minister to have Ministry of Resources and Environment and other ministries, branches and local authorities implementing Kyoto Protocol and Clean Production;
- Resolution No. 60/2007/NQ-CP on 12 – 3 – 2007 of the Government to Ministry of Resources and Environment, in charge of hosting and working with other Ministries and branches in order to build The Vietnamese National Target Program to Respond to Climate Change (NTP)
- Establishing NTP in 2008, implementing Resolution No.60/2007/NQ-CP on 12-3-2007 of the Government.

The NTP aims to communicate priority activities addressing the urgent and immediate needs and concerns of the country, relating to adaptation to the impacts of climate change. The NTP is proposed to be integrated into future national, sectoral and local socio-economic development strategies and international commitments. The strategic objectives of the NTP are to assess climate change impacts on sectors and regions, to develop feasible sector action plans to effectively respond to climate change to ensure the sustainable development of Vietnam, to take opportunities to develop towards a low-carbon economy, and to join the international community's efforts in mitigating climate change and protecting the climatic system. The specific objectives of the NTP are:

- To identify the extent of climate change in Vietnam due to global climate change and assess climate change impacts on every sector, area and locality;
- To identify measures to respond to climate change;
- To promote scientific and technological activities to establish the scientific and practical basis for climate change response measures;
- To consolidate and enhance the organisational structure, institutional capacity and the development and implementation of policies to respond to climate change;
- To enhance public awareness, responsibility and participation; and develop human resources to respond to climate change;
- To promote international cooperation to obtain external support in response to climate change;
- To mainstream climate change issues into socioeconomic, sectoral and local development strategies, plans and planning;
- To develop and implement action plans of all ministries, sectors and localities to respond to climate change; to implement projects, and first of all pilot projects to respond to climate change.

The NTP is divided into three phases: (i) First Phase (2009 – 2010): Start up; (ii) Second Phase (2011 – 2015): Implementation; and (iii) Third Phase (after 2015): Development. The key tasks that need to be implemented over the period of 2008 – 2010 are to assess climate variability and impacts of climate change on different fields, sectors and regions, and develop climate change scenarios. Activities suggested for implementation under the NTP are:

- Assessment of climate change extent and impacts in Vietnam;
- Identification of measures to respond to climate change;

- Development of a science and technology programme on climate change;
- Strengthening the capacities of organization, institutions and policy on climate change;
- Awareness raising and human resources development;
- Enhancement of international cooperation;
- Mainstreaming climate change issues into socioeconomic, sectoral and local development strategies, plans and planning.
- Development of Action Plans of Ministries, sectors and localities to respond to climate change;
- Develop and implement projects of the programme.

Under the National Target Program to Respond to Climate Change, which serves as a national climate change strategy framework, responsibility for climate change and adaptation activities in Vietnam will be expanded to involve not only the MONRE specific structures but all ministries and sectors, provinces and local governments. In 2008, the Prime Minister established the Steering Committee and Executive Board for the NTP. The Steering Committee is a high level organisation comprising the Prime Minister and other Ministers of relevant line agencies and the Executive Board comprises ministers and vice-ministers of relevant line agencies. Both MONRE and the Ministry of Planning and Investment (MPI) have key roles to play in the implementation of the NTP.

Vietnam's policy framework for disaster management is set out in the National Strategy for Disaster Prevention, Response, and Mitigation 2020. This strategy prioritises increased awareness raising and participation, minimizing loss of life and assets, and stresses the importance of coexistence with floods. Other key initiatives of the Second National Strategy include: establishment of disaster forecast centres in the north, centre and south of the country; construction of flood corridors and flood retention areas in southern Vietnam; the use of advanced information and communication technology; strengthening the role of schools and the media in awareness raising; maintaining and upgrading equipment for local Flood and Storm Control Committees; and a proposal for a national disaster fund for projects on disaster mitigation and preparedness, and setting up a disaster insurance company. The Second National Strategy is still, however, designed principally to address short-term climate extremes rather than to respond to future climate change.

3.2 Availability of technical expertise and institutional capabilities

To cope and adapt to climate change, in recent years, many universities in Vietnam have incorporated climate change into their teaching program. At many institutes, specialty offices have been formed with the function to develop climate change research. Many national and international training sessions have been implemented. About experience, Vietnam has many programs and projects related to climate change set up in recent decades. Some typical research programs on climate change that present Vietnam's ability are:

- The project "Study the greenhouse gas reducing strategy with the least cost for Asia" (ALGAS) – Cooperation between Institute of Hydro – Meteorology, UNDP and ADB;
- "Vietnam's First National Report on Climate Change for UNFCCC" – Cooperation between Institute of Hydro – Meteorology and UNEP;
- Research of Institute of Hydro – Meteorology and UNEP – RISO on cost of reducing greenhouse gas;
- The project "National Strategy Research on Clean Production", cooperation between Institute of Hydro – Meteorology, AusAID and World Bank.
- "Study of climate change in South East Asia and assessing impacts, losses and adapting solution for rice cultivation and water resource " – Cooperation between Institute of Hydro - Meteorology and Environment and SEA START RC;
- "Study of the impacts of climate change in Huong river watershed and adapting policy in Phu Vang district,Thua Thien Hue province" in Holland Program to support climate change research (NCAP);
- "Benefit of climate change adaptation from medium to small – sized hydro electric plant, matching with rural development" in Lao Cai territory sponsored by DANIDA Denmark;
- Take part in "The Second National Report of Vietnam for Frame Convention of United Nations on Climate Change".
- In June/2009, Ministry of Resources and Environment released "Scenario of Climate Change and Sea Level Rise", the next mission of the Ministry is "In the end of 2010, finish updating climate change scenarios and to 2015, continue to update climate change scenarios, especially sea level rise for periods to 2100". This is the result of the cooperation of Institute of Hydro – Meteorology and Environment, START in the South East and Meteorological Center Hadley – United Kingdom.

In the Mekong Delta, there are many organizations and agencies acting in climate change sector. Recently, in Can Tho (11/20/2008), Institute of Climate Change Research – Can Tho University (DRAGON – Mekong – CTU in short) was established. The ability and specialty of the institute can be described as follows:

- Studying and building programs on climate change.
- Integrating analysis of social economic information, vulnerability and adaptation to climate change.
- Proposing coping and adapting solutions for adverse impacts of global climate change and sea level rise in the Mekong Delta. Integrating vulnerable factors and possible adaptation strategies into development programs.
- Training the people in the provinces of the Mekong Delta how to cope and adapt to climate change.

3.3 Private sector roles and responsibilities

Climate change is an environmental as well as sustainable development issue. Coping with climate change is a task for the whole society. Policy making and program development is not only the task of the government but also of the private sector. This includes the following activities:

- Promoting, educating and raising the awareness of the public on climate change problem, protecting natural resources and the environment for sustainable development.
- Estimating the vulnerablity due to the current climate oscillation and extreme climate phenomena at places prone to climate change;
- Participating in planning, relying on the community to specify adapting solutions mainly in local practical conditions and setting priorities;
- Choosing adapting priority activities to propose into Action Plans to cope with climate change;
- Establishing and carrying out pilot projects at community level to deal with urgent and timely adaption requirements in the local areas. Participating or carrying out projects in the framework of the Program and Action Plan of the Ministry, branches and the local offices; receiving and applying environmental friendly technologies;
- Participating in financial market and insurance mechanisms regarding climate change under the regulation of the government.

- Develop 'best cases' and implement them at broad scale

3.4 Climate change and society

3.4.1 Effects of climate change

Given the sensitivity of the Mekong Delta region in Vietnam to the effects of climate change, the potential impacts in this region are summarised below in terms of effects on water resources, crop production, forest and aquatic ecosystems, public health and infrastructure/energy/industry.

A rise in sea level will further increase the salt water intrusion in the coastal zones, which is already a problem in some areas due to fresh water extraction for irrigation and drinking water and the construction of canals in the delta. The Mekong River Delta will be the most affected region. Inundation and the resulting loss of land, and saline water intrusion will be the main problems. The rice sector in the Mekong Delta will be the most affected by these effects, and may affect rice exports (Vietnam is the second largest exporter of rice in the world) and possibly national food security.

IPCC (2007), through analysis and forecasting of climate change impacts, agreed that the Mekong Delta, Ganges – Brahmaputra (Bangladesh) and Nile (Egypt) are in the group of the most vulnerable areas . UNDP (2007) stated: "when sea level rises 1 meter, Vietnam will lose 5% of land, 11% of population will lose their settlement, agriculture yield will decrease 7% (approximately 5 million tons of rice and 10% of domestic income) and 2 million hectares of the Mekong Delta will be inundated."

Besides inundation, more frequent flooding, saline water intrusion, drought, typhoons and rising temperatures will affect agriculture and natural ecosystems. This may induce changes in growing periods, crop calendars and crop distribution, and increases pests and viruses. Some species too may become extinct as a result of changing climatic conditions.

Rice production is predicted to decrease by 9%. Food crops, fruits and freshwater aquaculture will also be affected. The present role of the Mekong Delta as the national main rice provider, a main contributor to the export and national financial and food security will be seriously challenged.

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3.4.2 Raising awareness and perception regarding climate change

The awareness about climate change of the communitive and administrative organizations is still limited. In order to deal with this limitation, one of the

main goals of the NTP (The Vietnamese National Target Program to Respond to Climate Change) is "Enhancing the awareness, responsibility of the community and developing the human resources" to cope with and adapt to climate change. This goal is being targeted with the following activities:

- Intensify information and education to improve awareness and responsibilities on climate change issues for the whole society;
- Improve the co-operation between departments and branches in planning and management;
- encourage the participation of enterprises and communities in implementing response activities;
- Intensify human resources education, especially high-quality experts to meet the Program's requirements in every period.

3.4.3 NGO activities

Along with relentless effort of the Government, recently, non – governmental organizations in Vietnam also made great efforts in mitigating the impacts of climate change and protecting the environment.

The network of non – governmental organizations in Vietnam and climate change (VNGO&CC) was established on 09/11/2008. It was first set up by 4 significant non – governmental organizations on climate change in Vietnam (Center for Sustainable Rural Development – SRD, Center of Marine Organisms Conservation and Community Development – MCD, Center for Environmental Research Education and Development – CERED and Institute of Social Science – ISS), the network has become an open forum for members to transfer information, cooperate and support each other in connection with the National Assembly and Governmental Organizations, social organizations and the sponsors. There are currently more than 100 organizations and individuals in the country or abroad participating in the network.

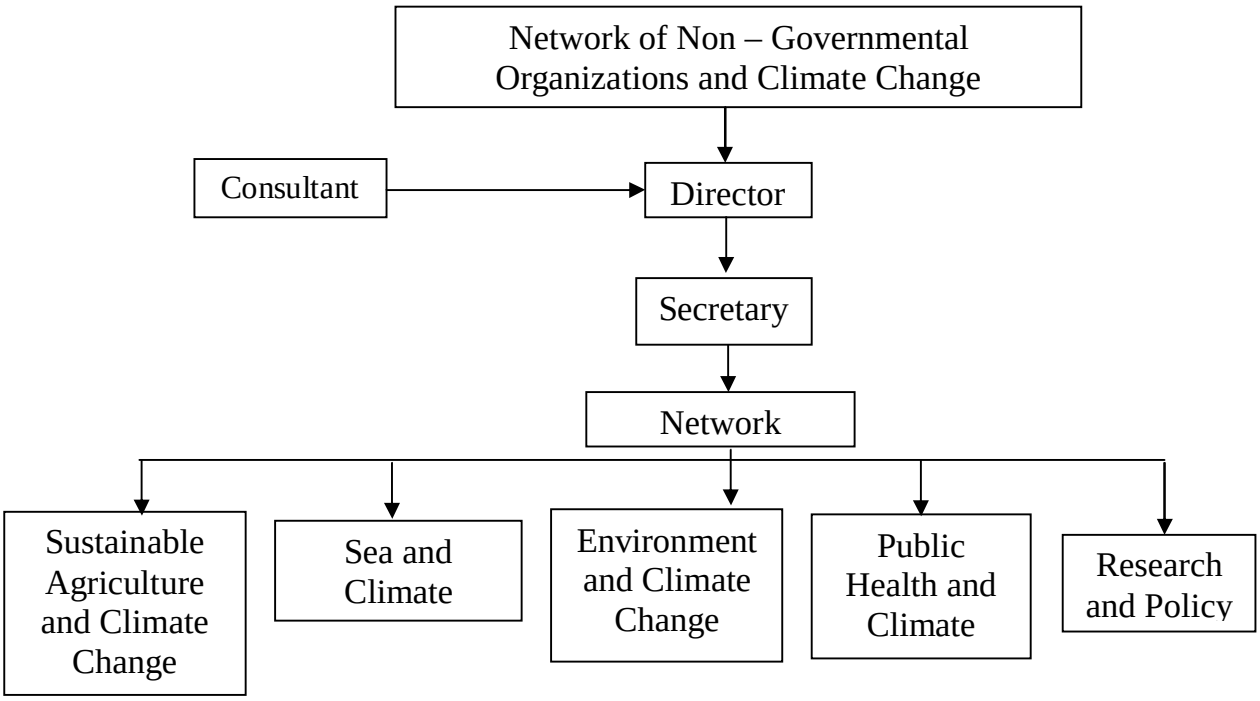

Figure 15. Chart of VNGO & CC's organization

Non – governmental organizations work mainly in:

- Establishing means to share information about climate change and related problems.
- Participating in policy planning, programs and plans to cope with climate change by playing a critical role.
- Improving the awareness of people on coping with climate change. Officers from NGOs, after taking part in training sessions on climate change, disseminate information to people and national agencies through specific activities to enhance the awareness about the climate change phenomenon that is currently happening and its impacts as well as harmful effects on the social economy and public health.
- Transfering information as well as results of climate change projects to the government.
- Developing and popularizing models as well as ways to success in dealing with climate change problems with support from the community, cooperating and supplementing to the Government's effort.
- Mobilizing funds from inside and outside the country, working with local authorities in adapting and mitigating climate change impacts.

Some related projects have been deployed:

- The project for building capacity on Climate Change for Civil Social Organizations, SRD and Knowlege Gate Thanh Giong in cooperation with VOV News organized online talk “Vietnam Coping with Climate Change” from 16h – 17h on 07/14/2010.
- “Study the impacts of climate change in Mekong Delta and Propose solutions”, by Institute of Meteorology and Environment (MONRE) as the main investor, the project is being implemented in Kien Giang and Ca Mau with total fund of 1.63 millions USD (ODA and ADB fund is 1.3 millions USD).
- The project ACCCRN (Asian Cities Climate Change Resilience Network) is being carried out in Can Tho funded by Rockefeller fund.
- The project “Adapting to climate change basing on community (CBA)” carried out in Ben Tre sponsored by Global Environmental Fund.

3.5 Vulnerable groups and sectors

3.5.1 Impacts on population

Data and analysis have shown that climate change has many potential impacts on different communities of Vietnam. Climate change raises the vulnerability and slows or reverses the development. The poorest people concentrating in rural areas, especially along the shore, are the ones most prone to climate change.

With a sea level rise of 1.0 meter, which is predicted to occur by 2100, approximately 10% of the population could be directly affected and economic losses could be equivalent to 10% of the GDP. The sea level rise in combination with increased rainfall in the rainy season could have serious impacts on low lying lands in the coastal zone. Approximately 40,000 km^2 of coastal delta area could be inundated, including 90% of the Mekong Delta. This region is the most densely populated in the country, with over 18 million inhabitants, or 22% of the national population and this population is growing by about 300,000 people per year. A high proportion of poor households, which are more susceptible to the impacts of climate change, are located in this area. Twelve provinces with an area of 12,376 km^2 and a population of about 5 million people are predicted to be affected (Table 16). More than 1,100 km^2 (7.65% of overall inundated area) will be inundated in the economically important southeastern economic region [26].

Table 16. Area inundated by 1.0 metre SLR in Mekong Delta, Viet Nam [26]

Province	Inundated area (km^2)	% of province area	No. of people affected	% of province population
An Giang	192.3	5.45	197,085	8.3
Bac Lieu	961.9	38.87	383,764	44.8
Ben Tre	1,131.4	50.14	759,174	54.6
Ca Mau	1,182.8	22.75	182,956	15.2
Can Tho	757.7	24.75	426,511	20.8
Dong Thap	389.4	11.53	222,289	13.4
Kien Giang	1,756.8	28.22	295,989	18.6
Long An	2,168.9	49.42	581,456	39.1
Soc Trang	1,424.6	43.71	457,821	35.0
Tien Giang	783.2	32.68	497,075	28.8
Tra Vinh	1,021.3	45.72	418,066	37.9
Vinh Long	606.4	39.69	364,414	31.6
Total	12,376.7	31.0	4,786,600	26.7

Loss of houses and means of living are some of the major factors in assessing impacts of climate change, especially for the Mekong Delta which has low elevation. To ensure people lives, building new places to live is necessary. This is, however, difficult due to the limitation of high land area and the increasing population. The majority of people living in the Mekong Delta are working in the agricultural sector and their lives heavily depend on the nature. Climate change will cause changes in the landuse, environment, soil erosion, water availability , environment deterioration etc … which make some areas no longer suitable for production. This raise many concerns on people's means of living related to the impacts of climate change.

People living in coastal areas of Ben Tre, Vinh Long, Tra Vinh, Ca Mau and Kien Giang provinces are the population most vulnerable to climate change impacts.

Climate change is also expected to affect people's health as increasing temperatures facilitate the growth and development of various viruses and disease carriers, resulting in higher incidence of infectious diseases such as malaria and dengue. Moreover, extreme weather and increased frequency and/or intensity of natural disasters, such as typhoons and floods, will threaten people's lives and may lead to more fatalities. The death toll by natural disaster will increase along with poverty due to loss of income and houses. The most vulnerable group includes farmers, ethnic minority, children, women and the elderly.

Impacts of climate change on public health are diverse and complex. There are many types of different impacts of climate change on public health. Hot climate, high radiation, weather changes are direct factors causing harm to human health, such as:

- Illness and body problems increase in severe climatic conditions
- Loss of water balance and salt which leads to problems usually occuring in areas with hot weather, especially in low area.
- Increased risk of illness for the old and people with cardiovascular diseases due to hot and moist weather.
- Indirect impacts on human health through worse living conditions by infection, spreading of infectious diseases etc …
- Impacts through growth and development of pathogenic bacteria, insects and hosts.

Climate change reduces human strength and increases risk of illness, requiring long term strategies for public health care.

Indirect impacts of climate change on health can be seen in many different issues. The living environment will be considerably affected by global climate change. Public health also has close connection with food supply and industrial production, typically energy. Because climate change has impacts on those issues at different levels, it also has impacts on public health. Climate change also increases the adverse effects of pollution and diseases.

Besides, food production in many areas will become difficult, affecting the food prices which in turns causes bad impacts on the lives of farmers. Moving away from living areas, job loss and income decrease will have considerable impacts on people's living condition.

3.5.2 Impacts on economic sectors

3.5.2.1 Impacts on Agriculture and Forestry

Agriculture accounts for 50% of Mekong Delta economic structure with over 80% of labor. The Mekong Delta is the main rice supplier of Vietnam. The area of rice cultivation has continued to increase and met the peak in 2005. However after that, despite the diversifying policy on agriculture products and the increasing of aquatic cultivation area, rice productivity still kept increasing, which indicates that rice cultivation plays a very important role in the area's agricultural structure and national food security.

The abnormal change of the climate will have strong impacts on agricultural production. According to a World Bank study, when the sea level rises 0.2 to 0.6m and in the periods of floods, more than 90% of agricutural area of Mekong Delta will be inundated during 4-5 months and in dry season, about 70% will be impacted by salt intrusion with concentration above 4g/l.

Climate change leads to changes in living conditon of organisms which in turn, leads to the disapperance of some species and increases the risk of some harmful exotic species. In recent years, insects in Mekong Delta has progressed complicatedly, affecting intensive farming ability and decreasing crop yield. Changes of climate and weather factors can spark many new diseases to livestock which can turn to epidemic.

Climate change leads to food insecurity: climate change has great impacts on the growth and development of crops, affecting intensive farming, decreasing crop yield. Mekong Delta is the main rice supply of the whole country, it also has a large area of fruit trees, therefore, it can be severely affected by climate change. Climate change also increases the intensity and the variation as well as

severity of weather events such as flood, hurricane, drought etc .. which reduce the crop and livestock yield.

Climate change, sea level rise and salt intrusion make cultivated land salinated, the loss of cultivated land leads to decreasing in intensive farming in the Mekong Delta.

Climate change also affects forest ecosystems and sea level rise decreases mangrove areas. Biodiversity decreases due to the fact that species can not adapt to drought and inundation, on the other hand, species able to stand drought and inundation will increase. Furthermore, temperature increase and long – lasting drought increase the risk of forest fire.

3.5.2.2 Impacts on Aquaculture and Fishery

Climate change is expected to have a considerable impact on fishery and aquaculture sectors, which accounted for 4 percent of GDP. The numbers of tropical fish with a low commercial value (except for tuna) would increase and the numbers of sub-tropical fish with a higher commercial value would decrease. Coral reefs are expected to degenerate and fish living in these habitats are expected to disappear. Moreover, sharp decreases in plankton would lead to migration of fish and reductions in fish body mass. As a result, it is estimated that the economic sea production capacity of Viet Nam would be reduced by at least one third. Due to a rise in seawater level, aquaculture farms will have to be relocated and saline water intrusion and reduction of the mangrove area will create loss of habitat for fresh water creatures. However, increased rainfall intensity might temporarily reduce the salt concentration of seawater, affecting some species, such as dual crust molluscs, living in coastal areas.

Fishery and aquaculture will be affected by drought, sea level rise, high tide, salt intrusion and soil degradation as well as other natural disasters.

Areas of freshwater aquaculture will shrink (Ben Tre, Tra Vinh, Soc Trang, Ca Mau, Kien Giang province) due to sea level rise and salt water intrusion. The coastal ecosystem will vary due to the change of mangrove (U Minh forest). The near – shore fishery will also vary in decreasing term.

Brackish and near - shore ecosystems especially two – shelled mollusc will die massively because of being unable to adapt to salinity and abrupt changes of temperature. The current biome will change in structure and species. Tropical fish will increase in number, on the other hand, sub – tropical fish species (with high economic value) will decrease in number or vanish. The fishery resources will be scattered.

3.5.2.3 Impacts on water resources

The Mekong Delta area involves the Me Kong river watershed with an area of 795.000 km^2 and discharge every year to the East sea of billions m^3. Due to climate change, streams of this watershed will change in negative way, especially Ben Tre province where there is huge volume of discharge. Rainfall pattern and streams change can cause severe floods in rainy season and droughts in dry season, making it difficult for water supply and sparking conflicts over water resources.

Future climate projection from regional climate model indicates that the Mekong River Delta tends to be warmer in the future with longer and drier summertime. An analysis of the impact of climate change scenarios on the flow of the Mekong [9] estimated increased maximum monthly flows of 16–19% in the delta (the lower value is for years 2010–2038 and the higher value for years 2070–2099, compared with 1961–1990 levels). Minimum monthly flows were estimated to decrease by 26–29% in the delta.

Climate change is likely to increase flooding. Due to the runoff increase, soil erosion is likely to increase and the water quality might be affected. Moreover there might be increased sediment loads in Mekong River. In addition, a change in the climate pattern in the upstream region of the Mekong River also affects the flow regime of the Mekong Delta in the rainy season, where the boundary of future floods could expand to wider coverage.

Temperature increases will affect the physical, chemical and biological properties of water, with predominantly adverse effects on individual freshwater species, community composition, and water quality. Warmer temperatures and changing precipitation patterns will likely reduce agricultural productivity. Rice farmers, shrimp farmers, salt farmers and small agricultural businessmen will be significantly impacted due to the lack of essential nutrient sources.

Sea level rise may exacerbate water resource constraints of the delta area due to increased salinisation of groundwater supplies. The livelihood conditions are sensitive and could be threatened by changing climate and hydrological cycle. Due to less rainfall in the dry season, the salinity intrusion situation in the Mekong River Delta becomes more serious.

Generally the groundwater resources of the Mekong Delta have not been investigated in detail. Very limited information about the groundwater resources amount, use, sustainability and quality is available from the literature. Only a few studies exist, focusing on some local areas within the Mekong Basin where an assessment is made of the resources, use and/or quality. Due to

increasing population, the pressures on the groundwater resources of the Mekong Basin are increasing. The impact of climate change on use of this resource is likely to be complex, and the response may vary across catchments of the basin. The projected increase in annual runoff in all catchments may reduce the reliance on groundwater for irrigation for areas where this increased surface water is accessible [24].

3.5.2.4 Impacts on other sectors

Impacts of climate change on transportation and traffic sector involve increased inundation of many main roads, the erosion of the roads' surfaces and bases, and the impacts on waterway transportation.

Impacts of climate change on the industry and construction sector involve increased possibility of inundation, (too) limited capacity of the drainage systems in big cities such as Can Tho, My Tho, Ca Mau, Rach Gia etc … and the treatment of contaminated water from industrial zones.

4. Restrictions

- Meteorological data

- Due to historical reasons, monitoring data before 1978 from meteorological stations in Mekong Delta is not continuous and comprehensive. Some stations have monitoring data from early years of 20th decade but these stations stopped working in the period from 1930 to 1950 and 1975 to 1976.
- Only a part of the monitoring data is stored in computers.

- Forecasting of climate change

- The report on climate change of Vietname only presents 3 scenarios: low emission (B1), medium (B2) and high emission (A2).
- The number of models being used is still limited.
- The scenarios are not very detailed (only for 5 zones of Vietnam). Factors estimated are not complete (only considering rainfall, temperature and sea level) .

- Assessment of temperature and sea level variation

- Assessment of temperature and sea level variation is not really detailed for zones and not comprehensive.
- Impacts of landuse change is not taken into consideration when assessing

temperature change trends.

- Impacts of tide, water surge due to wind and subsidence are still not eliminated when assessing water level change.

- Impacts of sea level rise on inundation, drainage, salt intrusion and marine environment

Assessing impacts of sea level rise on inundation, drainage, salt intrusion, and the marine environment is not detailed because:

- Lack of basic survey data
- Flow pattern change due to change of reservoirs built upstream
- This area is strongly affected by flood from upstream, tide and water rise due to wind.

- Related policies of government on climate change

- There are still not enough legal documents on climate change response. Some documents lack legal basis to regulate activities related to climate change.
- There is still not a specific mechanism for co-operation among departments, branches and local offices as well as a mechanism for participating and co-operating with the society and the communities in programs to respond to climate change.
- Therefore, this legal document system needs to be supplemented and completed as soon as possible to meet practical demand of society on sustainable development and climate change mitigation.

- The availability of organizations' capacity

Capacity of organizations doesn't really meet the requirements to cope and adapt to climate change. So, it is necessary to improve the capacity, equipment and co-operation between organizations.

- Responsibilities of private sector

Private sector has shown their responsibility on coping with climate change through many activities such as greenhouse gas emission surveillance, decreasing power consumption and developing clean energy. However, this contribution is still restricted and not specific. This may be due to administrative policies.

- Activities of NGOs

Before the establishing of the network of Vietnam NGOs and climate change, activities of those organizations were on small scale and scattered. Till now, financial support for those organizations is still from abroad. The connection between NGO&CC and many social organizations, therefore, is not really tight.

- Vulnerable groups and sectors

The study and assessment of vulnerable groups and sectors is necessary to propose solutions for climate change coping and adapting. However, current assessments are still not really detailed for every zone as well as for every group.

5. Conclusions and suggestions

The impacts of climate change in the Mekong Delta is obvious: from 1970 to 2007, average temperature and rainfall increase 0.6^0C and 94 mm respectively. In spite of the fact that Mekong Delta is not so large, there are distinctions in climate change impacts in every subarea. In the area near the South East, rainfall increases the most. The more inland, the more obvious the change in temperature is. Therefore, geographical locations and topography of the subareas also have impacts on climate change. Seasonally, there is considerable difference in temperature between dry and rainy season. In the period 1970 – 2007, average temperature in the dry season rose 0.72^0C, but in the rainy season the value is only 0.49^0C.

Together with the temperature increase, rainfall and water levels in the Mekong Delta also increase significantly. Besides, some weather events such as droughts and heavy rainfall also happen in complex patterns, causing a lot of problems in the Mekong Delta, especially regarding inundation, salinity intrusion, drought, etc.

Scenarios of climate change and sea level rise in Vietnam are not detailed but they present fundamental meteorological zones. In the long term, these scenarios will be updated to match real conditions.

Due to natural geographical properties and production as well as living pattern in the Mekong Delta, the impacts of climate change on this area is severe on social and economic term. To cope and mitigate the impacts of climate changes, it’s necessary to study in depth for each area, enhance forecasting capacity and improve the accuracy and detail of climate change scenarios.

Suggestions of Sihymete for next steps (from December 2010 to May 2011):

- Importing and processing meteorological data from 13 monitoring stations in

Mekong Delta. The collected data include: temperature, rainfall, evaporation, sun hours, wind speed and direction. Data type is daily. Collecting period is from 1978 to 2009.

- Importing and processing water level data from monitoring stations in Mekong Delta. Data collected is hourly data. Collecting period is from 1978 to 2009.
- Importing and processing salinity data at monitoring stations in Mekong Delta. Data to be collected is daily average. Collecting period is from 1978 to 2009.
- Assessing climate fluctuation in 5 sub – areas of Mekong Delta (Long Xuyen Rectangle, Ca Mau peninsula, Dong Thap Muoi, Tien – Hau river and the Eastern coastal zone)
- Assessing salt intrusion trends in seasons.
- Assessing water level trends in monitoring stations. Making maps of water level trends in the period 1978 – 2009.
- Building climate change scenarios for 5 subareas of the Mekong Delta to 2100.
- Analyzing and assessing impacts on Mekong Delta in climate change scenarios.
- Researching in detail impacts of climate change on inundation, salt intrusion, water resources and agricultural production to propose coping solutions.

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Appendices

1. List of water level gauging stations

No	Name	Longitude	Latitude	River name	Province
1	Phú An	106°42'43.6"	10°46'17.6"	Sài Gòn	TP.HCM
2	Nhà Bè	106°44'4.3"	10°38'19.6"	Đồng Điền	TP.HCM
3	Thủ Dầu Một	106°39'11.5"	10°58'27.2"	Sài Gòn	Bình Dương
4	Gò Dầu Hạ	106°15'47.7"	11°4'53.9"	Vàm Cỏ Đông	Tây Ninh
5	Kiến Bình	106°3'	10°37"'	Kênh 12	Long An
6	Tân An	106°25'7.4"	10°32'11.6"	Vàm Cỏ Tây	Long An
7	Mộc Hóa	105°56'7.1"	10°46'35.6"	Vàm Cỏ Tây	Long An
8	Tuyên Nhơn	106°11'38.7"	10°39'12.9"	Vàm Cỏ Tây	Long An
9	Bến Lức	106°28'42.8"	10°38'2.8"	Vàm Cỏ Đông	Long An
10	Mỹ Tho	106°21'52.9"	10°20'51.1"	Tiền	Tiền Giang
11	Hòa Bình	106°35'28.5"	10°17'10.1"	Cửa Tiểu	Tiền Giang
12	Vàm Kênh	106°44'24.7"	10°16'11.6"	Cửa Tiểu	Tiền Giang
13	Long Định	106°15'	10°24"'	Kênh Xáng	Tiền Giang
14	Cai Lậy	106°7'11.9"	10°24'14.3"	Rạch Bà Rài	Tiền Giang
15	Mỹ Thuận	105°54'42.2"	10°16'18.3"	Tiền	Vĩnh Long
16	Trà Vinh	106°21'11.9"	9°58'36.2"	Cổ Chiên	Trà Vinh
17	Cần Thơ	105°47"'	10°2"'	Hậu	Cần Thơ
18	Vị Thanh	105°27'26.9"	9°46'31.9"	Kênh Xà No	Cần Thơ
19	Phụng Hiệp	105°49'23.9"	9°48'40.4"	Cái Côn	Cần Thơ
20	Đại Ngãi	106°4'27.3"	9°44'4.4"	Hậu	Sóc Trăng
21	Mỹ Thanh	106°10'15.3"	9°25'29.2"	Mỹ Thanh	Sóc Trăng
22	Cao Lãnh	105°38'40"	10°25'0.2"	Tiền	Đồng Tháp
23	Hưng Thạnh	105°46'44.9"	10°39'34"	K.Phước Xuyên	Đồng Tháp
24	Tân Châu	105°14'42.9"	10°47'52.7"	Tiền	An Giang
25	Châu Đốc	105°7'29.9"	10°42'20.4"	Hậu	An Giang
26	Long Xuyên	105°26'5.2"	10°23'35.2"	Hậu	An Giang
27	Chợ Mới	105°24'10.4"	10°33'5.9"	R. Ông Chưởng	An Giang
28	Vàm Nao	105°21'59.1"	10°34'27.4"	Vàm Nao	An Giang
29	Xuân Tô	104°56'39.8"	10°36'22.6"	Kênh Vĩnh Tế	An Giang
30	Tri Tôn	105°3'20"	10°26'11"	K.Tri Tôn	An Giang
31	Chợ Lách	106°7'36.2"	10°16'30.4"	Hàm Luông	Bến Tre
32	Bình Đại	106°42'40.4"	10°11'49.3"	Cửa Đại	Bến Tre

No	Name	Longitude	Latitude	River name	Province
28	Vàm Nao	105°21'59.1"	10°34'27.4"	Vàm Nao	An Giang
29	Xuân Tô	104°56'39.8"	10°36'22.6"	Kênh Vĩnh Tế	An Giang
30	Tri Tôn	105°3'20"	10°26'11"	K.Tri Tôn	An Giang
31	Chợ Lách	106°7'36.2"	10°16'30.4"	Hàm Luông	Bến Tre
32	Bình Đại	106°42'40.4"	10°11'49.3"	Cửa Đại	Bến Tre
33	Bến Trại	106°31'44.4"	9°52'51.2"	Cổ Chiên	Bến Tre
34	Mỹ Hóa	106°21'8.2"	10°13'5.5"	Hàm Luông	Bến Tre
35	An Thuận	106°36'18.8"	9°58'33"	Hàm Luông	Bến Tre
36	Rạch Gía	105°5'2.7"	10°0'44.3"	Kiên	Kiên Giang
37	Tân Hiệp	105°15'51.3"	10°5'47"	K.Cái Sắn	Kiên Giang
38	Xẻo Rô	105°6'39.1"	9°51'53.1"	Cái Lớn	Kiên Giang
39	Phước Long	105°27'30.4"	9°26'6.6"	Phụng Hiệp	Bạc Liêu
40	Gành Hào	105°25'10.2"	9°1'53.2"	Gành Hào	Bạc Liêu
41	Năm Căn	105°4'0"	8°45'53.8"	Cửa Lớn	Cà Mau
42	Cà Mau	105°8'55.3"	9°10'20.9"	Gành Hào	Cà Mau
43	Sông Đốc	104°49'59.4"	9°2'28.3"	Sông Đốc	Cà Mau

2. List of salinity gauging stations

No	ID	Name	Longitude	Latitude	River name	Province
1	002	Nhà Bè	106 ° 44 '	10 ° 40 '	Nhà Bè	Hồ Chí Minh
2	024	Thủ Thiêm(PA)	106 ° 42 '	10 ° 46 '	Sài Gòn	
3	068	Lái Thiêu	106 ° 41 '	10 ° 53 '	Sài Gòn	
4	005	Ngã 3 Cát Lái	106 ° 47 '	10 ° 45 '	Đồng Nai	
5	032	Long Đại	106 ° 51 '	10 ° 50 '	Đồng Nai	
6	502	Tân An	106 ° 25 '	10 ° 31 '	Vàm Cỏ Tây	Long An
7	504	Tuyên Nhơn	106 ° 11 '	10 ° 38 '	Vàm Cỏ Tây	
8	505	Bến Lức	106 ° 26 '	10 ° 38 '	Vàm Cỏ Đông	
9	531	Cầu Nổi	106 ° 35 '	10 ° 28 '	Vàm Cỏ	
10	535	Xuân Khánh	106 ° 21 '	10 ° 51 '	Vàm Cỏ Đông	
11	551	Mỹ Tho	106 ° 23 '	10 ° 21 '	Tiền	Tiền Giang
12	552	Hòa Bình	106 ° 35 '	10 ° 17 '	Cửa Tiểu	
13	553	Vàm Kênh	106 ° 44 '	10 ° 16 '	Cửa Tiểu	
14	570	An Định	106 ° 26 '	10 ° 18 '	Mỹ Tho	
15	573	Đồng Tâm	106 ° 20 '	10 ° 20 '	Tiền	

No	ID	Name	Longitude	Latitude	River name	Province
16	623	Vũng Liêm	106 o 13 '	10 o 6 '	Cổ Chiên	Vĩnh Long
17	624	Tích Thiện	105 o 59 '	10 o 58 '	Hậu	
18	602	Trà Vinh	106 o 20 '	9 o 58 '	Cổ Chiên	Trà Vinh
19	614	Hưng Mỹ	106 o 26 '	9 o 52 '	Cổ Chiên	
20	615	Trà Kha	106 o 15 '	9 o 38 '	Hậu	
21	616	Cầu Quan	106 o 7 '	9 o 45 '	Hậu	
22	650	Thạnh Phú	105 o 54 '	9 o 30 '	K.Như Gia	Sóc Trăng
23	652	Đại Ngãi	106 o 0 '	9 o 47 '	Hậu	
24	655	Mỹ Thanh	106 o 10 '	9 o 25 '	Mỹ Thanh	
25	657	Sóc Trăng	105 o 58 '	9 o 36 '	K.Maspero	
26	672	Long Phú	106 o 8 '	9 o 36 '	Hậu	
27	687	An Lạc Tây	106 o 0 '	9 o 50 '	Hậu	
28	802	Bình Đại	106 o 42 '	10 o 10 '	Bình Đại	Bến Tre
29	803	Bến Trại	106 o 31 '	9 o 53 '	Cổ Chiên	
30	805	An Thuận	106 o 36 '	9 o 58 '	Hàm Luông	
31	808	Mỹ Hóa	106 o 20 '	10 o 13 '	Hàm Luông	
32	809	Hương Mỹ	106 o 23 '	9 o 59 '	Cổ Chiên	
33	817	Sơn Đốc	106 o 30 '	10 o 02 '	Hàm Luông	
34	818	Lộc Thuận	106 o 36 '	10 o 12'	Cửa Đại	
35	851	Rạch Giá	105 o 5 '	9 o 59 '	Sông Kiên	Kiên Giang
36	853	Xẻo Rô	105 o 5 '	9 o 53 '	Cái Lớn	
37	856	Gò Quao	105 o 21 '	9 o 44'	Cái Lớn	
38	863	An Ninh	104 o 57 '	9 o 38 '	Cái Bé	
39	881	Luỳnh Quỳnh	104 o 49 '	10 o 10 '	K.Luỳnh Quỳnh	
40	902	Phước Long	105 o 27 '	9 o 26 '	K.Phụng Hiệp	BạcLiêu
41	903	Gành Hào	105 o 25 '	9 o 00 '	Gành Hào	
42	904	Cà Mau	105 o 8 '	9 o 10 '	Gành Hào	Cà Mau
43	916	Sông Đốc	104 o 50 '	9 o 03 '	Sông Đốc	

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