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Impacts of climate change on inundation and salinity intrusion of Cuu Long delta

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Abstract. Base on the results of the flow simulated by Mekong River Commission (MRC), combined with Sea Level Rise (SLR) and salinity scenarios by IMHEN, the paper presents impacts of CC on flooding and salinity intrusion in Cuu Long Delta. By 2050, the maximal flooded area which is more than 0.5 m depth can be up to 68.3% of the entire area of Cuu Long Delta. The maximum distance of salinity intrusion increases in the main rivers can reach by 10 km by the middle of the 21st century. The area affected by salinity intrusion at >4‰ occupies 41% area of all Cuu Long Delta and by salinity >1‰ is 59% of natural area.

Keywords: Inundation, salinity intrusion, Cuu Long, climate change.

1. Introduction

Cuu Long Delta is one of the major deltas in Vietnam. Located in the downstream of Mekong river basin, it covers 13 provinces with the total natural area of approximately 3.96 million ha, accounting for 79% of the total deltaic area and 5% of the area of Mekong river basin. Climate change has occurred, deeply affecting the socio-economic development in the Cuu Long Delta [1].

The water flowing into Cuu Long Delta mainly originates outside of Vietnamese territory. Therefore, to assess the impacts of climate change on Cuu Long Delta's flooding and salinity intrusion, it has to be carried out to assess the changes of water resources all over Mekong River Basin [2]. Thus, we inherit the research findings of MRC, especially which of the project MRC-CSIRO (Reducing vulnerability of water resources, people and the environment in the Mekong Basin to climate change impacts), the results of which were printed and reported in Technical Paper in 6/2010 [3].

The research of MRCS mainly assessed the flow into Vietnam; the combined impacts of sea level rise, flooding and salinity penetration were not considered. However, these impacts on Cuu Long Delta are very powerful, and therefore need to be fully analyzed and assessed. To assess the impacts of CC on flooding and salinity intrusion in Cuu Long Delta is an aggregated problem which should be considered from upstream to sea level rise

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along with rainfall and water demand in the inland area under the impacts of CC.

Base on the results of the flow calculation by MRCS, combined with SLR and salinity scenarios by IMHEN, further simulate and analyze the impacts on Cuu Long Delta.

Researching climate change impacts on flooding and salinity intrusion, the we inherit the entire hydrodynamic model ISIS, a component of the Decision Support Framework (DSF) developed by the Mekong River Commission. The model integrated river flow from upstream according to two scenarios calculated differently:

- Scenario S2: Water use in the river basin similar to the actual status in 2000 (BDP Baseline scenario) + meteorological data simulated by PRECIS in the period 1985-2000 adjusted to fit observed data.

- Scenario S4: Water use in the river basin similar to the actual status in 2000 (BDP Baseline scenario) + meteorological data in 2 scenarios A2 and B2 simulated by PRECIS in the period 2010-2050 and adjusted.

From S2, S4 scenarios, upstream boundary conditions which were taken from Kratie and the sub-basins around the Ton Le Sap Lake, water use in the area from Kratie downwards were considered as withdrawal water boundary.

Downstream boundary condition, tide and salinity, is simulated by ROMS model for the future tidal process through modeling hydrodynamic processes under some theories about the effects of global sea level rise (or local sea level rise if possible) [4].

The SLR along with the salinity at the estuaries was integrated into the model ISIS to simulate future flooding and saltwater intrusion in Cuu Long Delta.

2. Impacts on flooding

Every 10-year period, 2010-2019; 2020-2039; 2040-2049, a biggest flood was chosen and associated with SLR respectively 15, 23, 30 cm to simulate flooding [4]. In the scenario A2, floods in 2019, 2020, 2032, 2046; in scenario B2, floods 2019, 2021, 2039, 2047 corresponding to the period 2010-2019; 2020-2039; 2040-2049 were selected to simulate. Figure 1 shows selected flood hydrographs at Kratie as a upstream boundary condition [2].

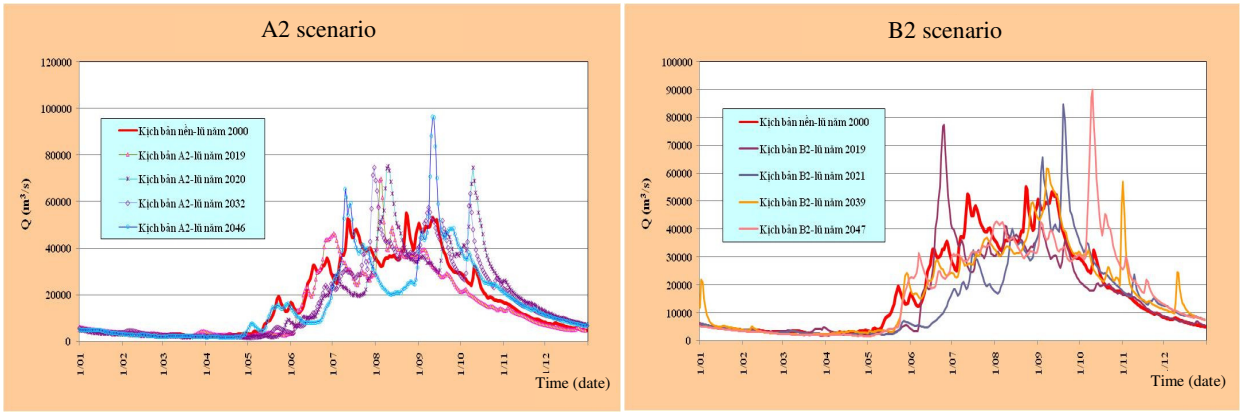


Figure 1. Selected flood hydrographs at Kratie.

The combination of the chosen floods and the sea levels in each period was integrated into ISIS model to simulate hydraulic regime for Delta. The flooding maps were develop based on the simulation results and topographic maps surveyd and made in 2009 by MONRE, with a resolution of 5x5 meters. Figure 2 show the flood maps for the scenario B2 of Mekong Delta.

For Cuu Long Delta, every year in flood season, the Mekong River flood inundates nearly 2 million hectares, lasting 3-5 months. In years with bigger floods, significant human and property losses occur. However, flooding also brings alluvial soils to fertilise the land, abundant aqua-product and good effects in sanitary for rice fields. Large floods in the mid 21st century combined with sea level rise of about 30 cm would increase the flooded area by 25% greater than that of the historical flood of 2000. The flooded area would occupy almost 90% of all natural area of Cuu Long Delta. The flooded area (>0.5m depth) would be 2,660,000 ha (accounting for 68.3% area of Cuu Long Delta), an increase of 1,160,000 ha (equivalent to 29.5% natural area) compared to the flood in 2000. The flooded area (>1.0m deep) would be approximately 1,500,000 ha (accounting for 40% area of Cuu Long Delta), an increases of 500,000 ha (equivalent to 14% natural area) compared to the flood in 2000.

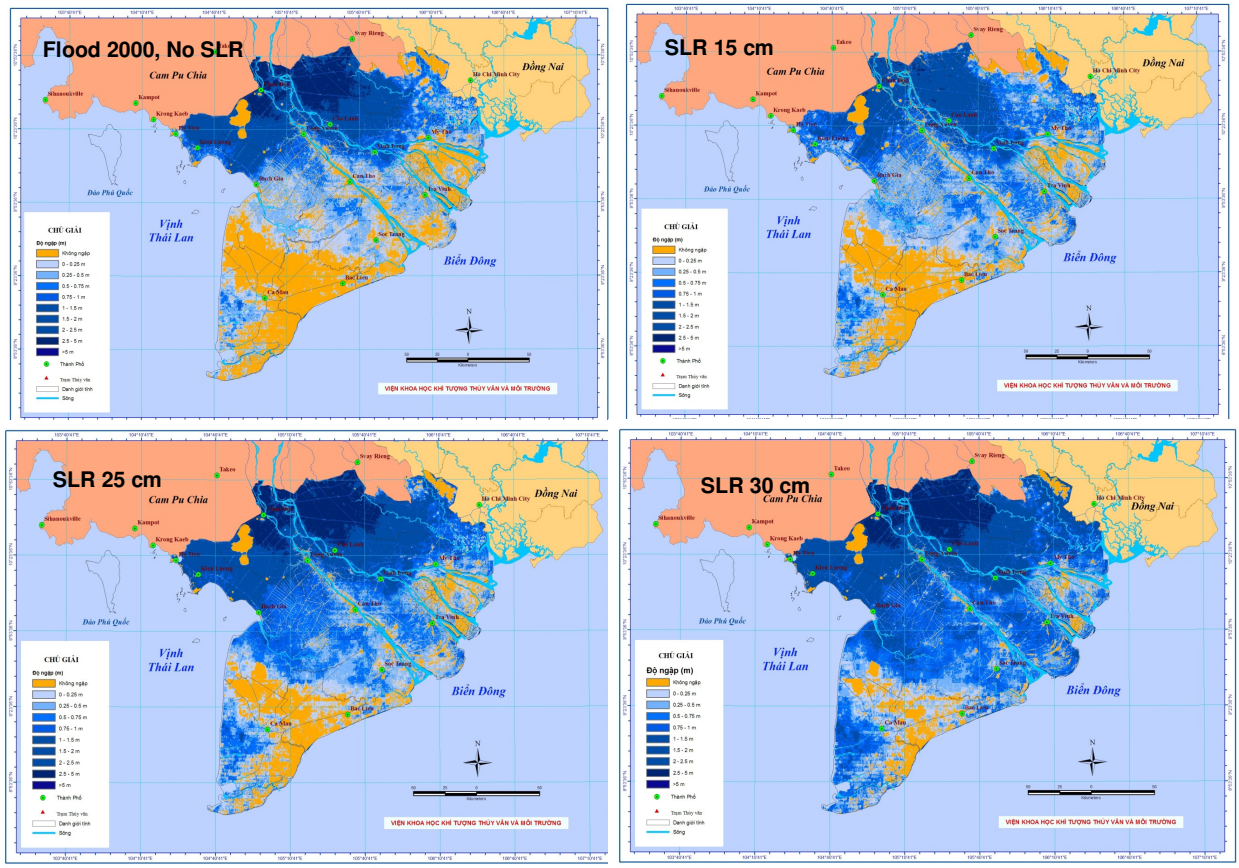


Figure 2. Flood map of Cuu Long Delta according to scenario B2 [5].

Floods would inundate the areas of Dong Thap Muoi and Long Xuyen quadrangle, with particularly serious flooding occurring in the area between the two rivers Tien and Hau. Apart from the cities and towns that are currently regularly flooded, such as Chau Doc, Long Xuyen and Cao Lanh, additional cities and towns would be flooded, including Sa Dec, Vinh Long, Tan An, My Tho, Can Tho, Vi Thanh, Soc Trang, Rach Gia and Ha Tien, which are inundated at more than 1.0 m. Among these towns, the most serious flooding occurs at Can Tho and Vinh Long. Sea level rise also makes the drainage in My Tho, Ben Tre, Tra Vinh, Bac Lieu and Ca Mau more difficult.

Increasing upstream flooding and rising sea levels will limit the drainage on MeKong River system and lead to more serious inundation. This leads to earlier flooding and late easing of floodwaters, which can make drainage difficult and make planting and harvesting of crops difficult. Assuming similar land uses in 2100 as in 2010, the biggest inundated area in agriculture could reach 2,100,000 ha, which is 53% of the natural area of Cuu Long Delta, while flooding in industry and residences could reach 500,000 ha (12.6% of land area) and flooding in aquaculture 250,000 ha (6.3%).

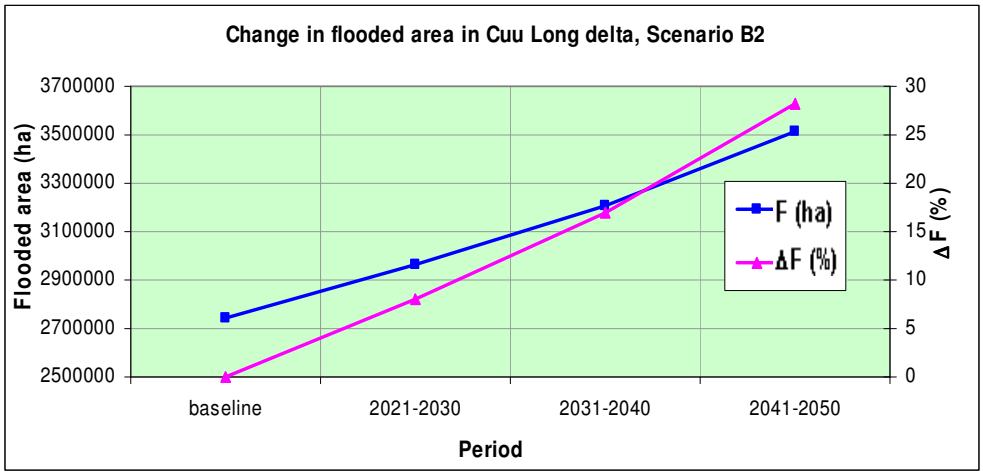
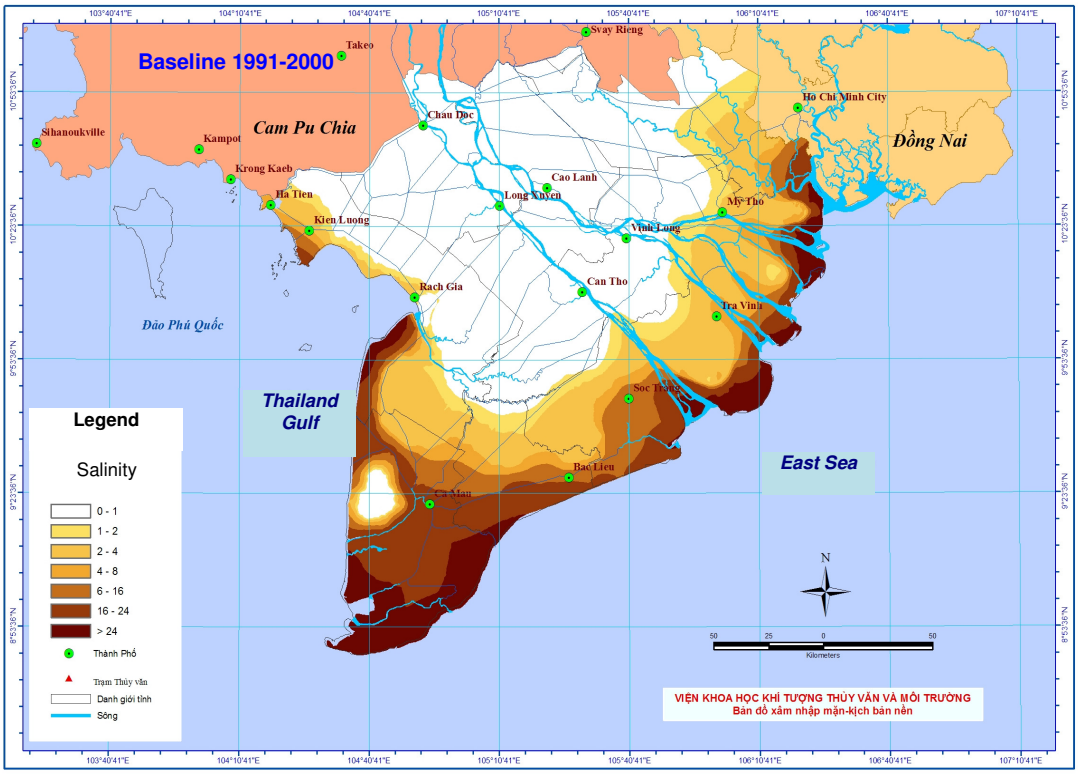
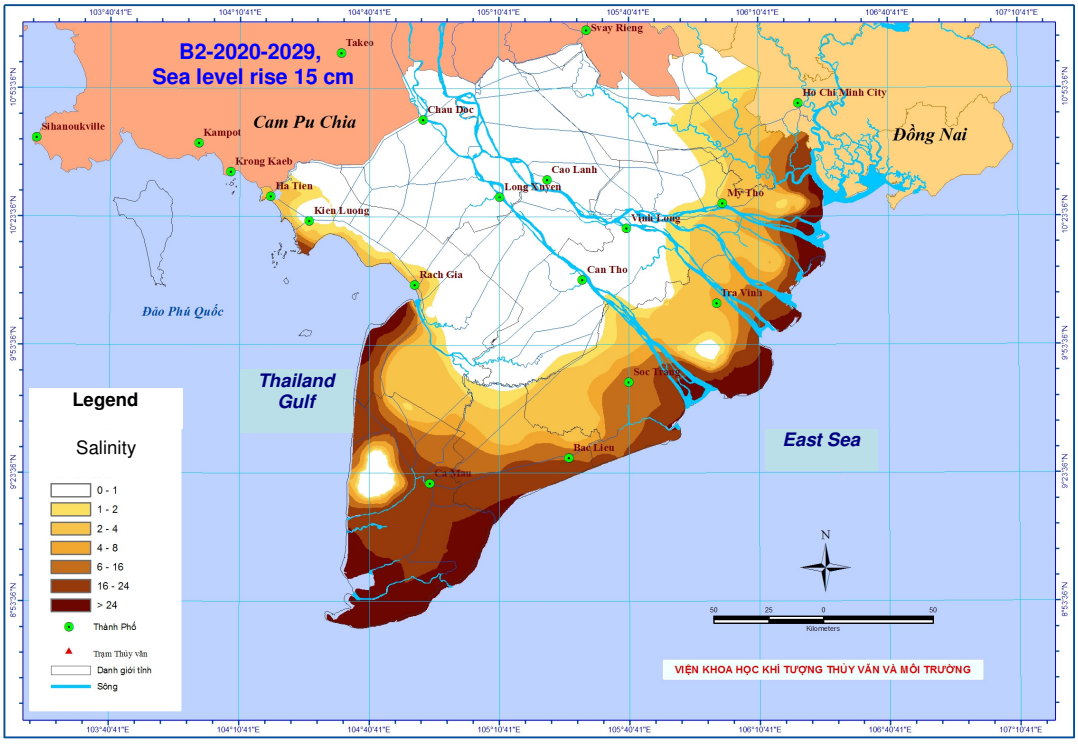


Figure 3. Change in flooded area in Cuu Long Delta, scenario B2.

3. Impacts on salinity intrusion

In the project, the intrusion events are calculated in each 10-year period, the base period is 1991-2000; the future periods are 2010-2019; 2020-2039; 2040-2049. Combination of average flow from March to May with the SLR and salinity respectively 15, 23, 30 [3] will be editing the input to simulate the process of salinity intrusion on the entire system. The calculated result shows that the salinity intrusion distance of CC scenarios increases compared with the baseline scenario (Figure 4). The maximal increases in the main rivers can reach by 10 km. The maximal 1g/l salinity boundary in the Co Chien River is 5km far from Vinh Long City (9.5 km deeper than base period) and on the Hau River is 3 km far from Can Tho City (8.8 km higher than base period). The maximal 4g/l salinity boundary on Co Chien River is 22.5 km far from Vinh Long city (9.2 km deeper than the base period) and on Hau River through Can Tho city (8.4 km higher than the base period) (table 1).


Baseline 1991-2000
Takeo
Svay Rieng
Ho Chi Minh City
Chau Doc
Sihanoukville
Kampot
Cam Pu Chia
Đồng Nai
Krong Kaeb
Cao Lanh
Ha Tien
Long Xuyen
My Tho
Kien Luong
Vinh Long
Rach Gia
Can Tho
Tra Vinh
Đảo Phú Quốc
Thailand Gulf
Soc Trang
East Sea
Bac Lieu
Ca Mau
N
50 25 0 50
Kilometers
Legend
Salinity
0 - 1
1 - 2
2 - 4
4 - 8
6 - 16
16 - 24
> 24
Thành Phố
Trạm Thủy văn
Danh giới tỉnh
Sông
VIỆN KHOA HỌC KHÍ TƯỢNG THỦY VĂN VÀ MÔI TRƯỜNG
Bản đồ xâm nhập mặn-kịch bản nền


B2-2020-2029,
Sea level rise 15 cm
Takeo
Svay Rieng
Ho Chi Minh City
Chau Doc
Sihanoukville
Kampot
Cam Pu Chia
Đồng Nai
Krong Kaeb
Cao Lanh
Ha Tien
Long Xuyen
My Tho
Kien Luong
Vinh Long
Rach Gia
Can Tho
Tra Vinh
Đảo Phú Quốc
Thailand Gulf
Soc Trang
East Sea
Bac Lieu
Ca Mau
N
50 25 0 50
Kilometers
Legend
Salinity
0 - 1
1 - 2
2 - 4
4 - 8
6 - 16
16 - 24
> 24
Thành Phố
Trạm Thủy văn
Danh giới tỉnh
Sông
VIỆN KHOA HỌC KHÍ TƯỢNG THỦY VĂN VÀ MÔI TRƯỜNG

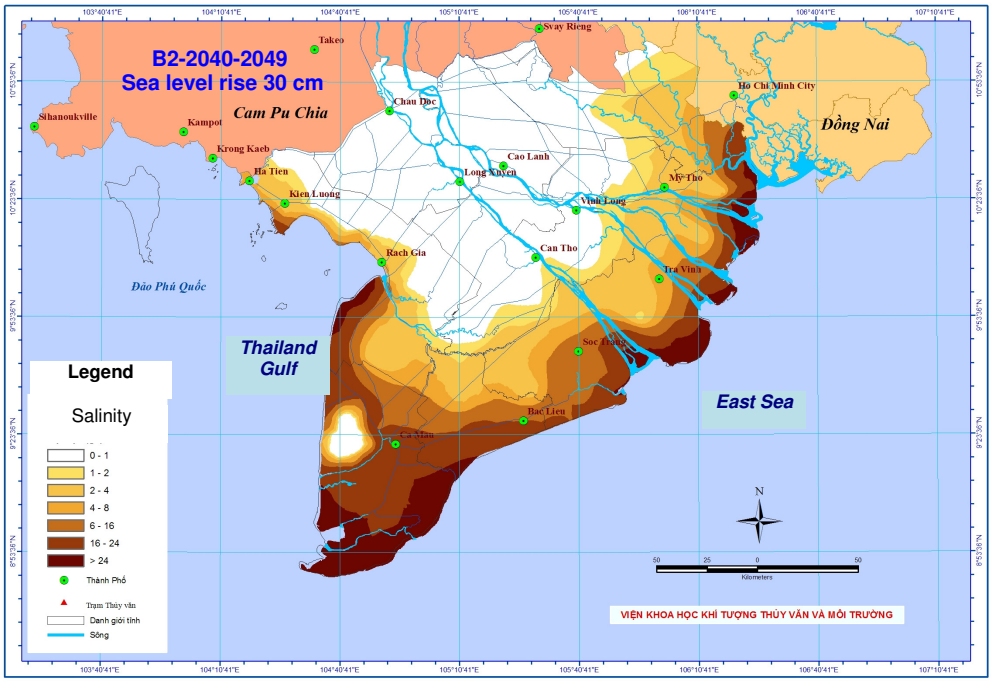


Figure 4. Salt water intrusion map of Cuu Long Delta [5].

Salinity intrusion will be quite severer for the Cuu Long River Delta. Over the next 30 years, the area under salinity intrusion at >4‰ is about 1,605,200 ha occupied 41% area of all Cuu Long Delta more 255,100 ha than baseline. The area under salinity >1‰ is 2,323,100 ha (59% of natural area), increasing 193,200 ha compared with present time. In the next 20 years, land use area under salinity intrusion >4‰ is 1,851,200 ha (47% of natural are), larger than baseline (1991-2000) about 439,200 ha. With salinity >1‰, the affected area is 2,524,100 ha (64% of natural are), more than baseline about 456,100 ha.

Table 1. Change in distance of salinity intrusion corresponding to salinity of 1‰ and 4‰ at the rivers of the 7 study basins in scenario B2 [5]

Rivers	Distance of salinity intrusion corresponding to salinity of 1‰ at period (km)			Distance of salinity intrusion corresponding to salinity of 4‰ at period (km)			Change in distance of salinity intrusion corresponding 1‰ relative to the period 1980-1999 (km)		Change in distance of salinity intrusion corresponding 4‰ relative to the period 1980-1999 (km)	
	1980-1999	2020-2039	2040-2059	1980-1999	2020-2039	2040-2059	2020-2039	2040-2059	2020-2039	2040-2059
Hau	62.5	67.1	71.1	49.9	54.1	58.1	4.6	8.6	4.2	8.2
Co	62.8	67.6	72	50.3	55	59.2	4.8	9.2	4.7	8.9
Chien	63.1	69.8	72.7	51	57.5	60.2	6.7	9.6	6.5	9.2
My	120	124	129	95	98.8	103.7	4.0	9.0	3.8	8.7
Tho										
Vam										
Co										
Tay										

The 1‰ salinity boundary on Co Chien River is 5 km far from Vinh Long city (deeper 9.5km than baseline), it is 3 km far from Can Tho city (deeper 8.8km than baseline) on Hau River. The distances for 4‰ salinity boundary are 9.2 km deeper than present on Co Chien River and 8.4 km deeper than baseline on Hau River.

Nearly four-fifths of the area of the Ca Mau peninsular is under salinity intrusion (except the western part of Hau River). The entire area of projects Go Cong, Bao Dinh, North Ben Tre, Mo Cay, South Mang Thit and Tiep Nhat are surrounded and intruded by salinity. Apart from the cities and towns of Ben Luc, Rach Gia and Ha Tien, others will also be affected by deeper salinity intrusion. These include My Tho, Vinh Long and Can Tho.

4. Conclusions

CC in Mekong River Basin heavily affects flows into Vietnam. The maximal monthly flow increases progressively. The trend of flooding is more and more increasing in Cuu Long Delta. By 2050, the maximal flooded area which is more than 0.5 m depth will be up to 68.3% of the entire area of Cuu Long Delta, and this will increase by nearly 30% of the natural area compared with the flood situation in 2000. Flood season will come earlier and also reduce later with longer duration that's why it is much more difficult to drain water and arrange crops.

The average flow in dry season tends to increase gradually. Combination of the low flows and SLR makes salinity level increase that appears more and more severe in Cuu Long Delta. My Tho, Vinh Long and Can Tho will be added into the list of cities threatened by saltwater. In this condition, we find difficulties in agricultural production and water supply for coastal areas. Coastal provinces in Cuu Long Delta will have more difficulties when the salinity level is more than 10 kilometers length in 50 years.

It is necessary to have overall solutions to deal with CC and SLR such as infrastructural planning, dike systems, salinity prevention culverts, drainage and strengthening international cooperation.

Acknowledgements

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