

**MINISTRY OF EDUCATION
AND TRAINING**

**MINISTRY OF AGRICULTURE
AND ENVIRONMENT**

VIET NAM ACADEMY FOR WATER RESOURCES

**THE SOUTHERN INSTITUTE OF WATER
RESOURCES RESEARCH**

LE THI MY DIEP

**RESEARCH ON SALTWATER INTRUSION IN THE
VE RIVER - QUANG NGAI UNDER THE CURRENT
AND FUTURE CONTEXT (CLIMATE CHANGE)**

SUMMARY OF DOCTORAL DISSERTATION

Study: Soil and Water Enviroment

Code: 9 44 03 03

HO CHI MINH CITY - 2025

The Dissertation is completed at

**THE SOUTHERN INSTITUTE OF WATER
RESOURCES RESEARCH**

Supervisors:

1. Assoc. Prof., Dr. LUONG VAN THANH

2. Assoc. Prof., Dr. BUI TA LONG

Reviewer 1: Assoc. Prof., Dr. Nguyen Tien Giang

Reviewer 2: Assoc. Prof., Dr. Trieu Anh Ngoc

Reviewer 3: Assoc. Prof., Dr. Chau Nguyen Xuan Quang

The Dissertation will be defended at the Assessment Committee at The Southern Institute of Water Resources Research, No. 658 Vo Van Kiet Boulevard, Ward Cho Quan, HCMC. At ...on Date..... Month Year 2025.

The Dissertation can be found at:

- National Library of Vietnam
- Library of Vietnam Institute of Water Resources Research
- Library of The Southern Institute of Water Resources Research

CHAPTER I. INTRODUCTION

1.1. The rationale

Climate change (CC) along with natural resource depletion and environmental pollution are topics of particular concern in Vietnam. Climate change increases climate hazards such as natural disasters, reduces productivity, and negatively affects the country's socio-economic development achievements [3].

Vietnam currently has 28 coastal provinces and cities with 125 coastal districts, stretching along a coastline of more than 3,260 km, from Quang Ninh to Kien Giang, so salinity intrusion with climate change in mind is implemented here. some provinces, [3] – [7], [9], [11] – [25] in which attention to climate change has been implemented in some provinces such as Thai Binh [3], Nam Dinh [5], Dong Nai [19], Vinh Long [22], Ben Tre [23].

The thesis chooses the lower Ve River basin as the research area, which is a typical land in the coastal region of Quang Ngai province. The task set for the thesis is to prove the theory and mechanism of salinity intrusion in the region, predict future developments of salinity intrusion, and then come up with mitigation solutions.

From the above practice, the research questions are posed as follows:

- By what mechanism does salinity transmission take place at the Ve River estuary? Is there any appearance of salty seasoning? How does the extent and extent of saltwater intrusion depend on seasonal factors (rainy, dry, dry, flood), terrain, meteorology, hydrology, and oceanography?
- How do climate change factors affect salinity intrusion? Which calculation method is based on the modeling method applied.
- How are solutions to adapt to saltwater intrusion due to climate

change in a typical basin like the Ve River? Collecting fresh water for daily life and activities can be done by the hour and in what locations?.

1.2. Research objectives

1.2.1. Overall objectives

Assessing the impact of saline intrusion on the coastal area of Quang Ngai province under the impact of climate change. Proposing adaptation solutions in extreme weather conditions.

1.2.2. Specific objectives

- Clarifying the salinity transmission mechanism, as well as the formation of salinity wedges, the development of salinity wedges in the Ve River estuary.
- Forecasting saltwater intrusion for climate change scenarios, on that basis to evaluate the impact of climate change on saltwater intrusion.
- Clarifying the dependence of saltwater intrusion on hydrometeorological and topographical factors
- Propose solutions for exploitation in current conditions as well as climate change and water use for affected areas.

1.3. Research contents

- 1) Overview of domestic and international research related to saline intrusion in estuary areas. Based on the analysis of conducted research, clarify the issues that need to be done for the thesis.
- 2) Synthesis of actual hydrometeorological data measured within the study area, including temperature, precipitation, water level, and flow.
- 3) Analyze factors of temperature, precipitation, and evaporation to build a set of parameters for climate change scenarios in the Ve river basin.
- 4) Select mathematical models to serve the thesis, including analytical models to calculate stratification coefficients, hydrological model

groups, hydrodynamic models, salinity transmission models. Perform calibration and testing of models before application.

- 5) Calculate the stratification coefficient to evaluate the stratification at 3 cross-sections based on actual measured data. Two-way and three-tide MIKE application simulates the salinity intrusion mechanism and the formation of a salinity wedge in space and time for the period 2015 - 2019. Assessing the dependence of saline intrusion on hydrometeorological factors and terrain.
- 6) Simulating salinity transmission according to climate change scenarios. Evaluate and compare the current scenario with the climate change scenario, clarifying the reasons for the difference.
- 7) Propose adaptation solutions in the study area based on assessing the impact of saline intrusion under the impact of climate change..

1.4. Theoretical and practical contributions

1.4.1. Main scientific findings

- The thesis applies different mathematical models, classified into hydrological groups: SWAT, NAM, hydraulic group MIKE 21, 3, HD, and salinity transmission model MIKE 21, 3 AD.

- The thesis has analyzed and clarified the salinity transmission mechanism, as well as the formation of salinity wedges, offering options for analyzing the salinity intrusion mechanism. The formation of the salinity wedge for two times of low tide and high tide is analyzed.

- The thesis also evaluated the correlation between salinity intrusion and meteorological, hydrological and topographic factors.

These results contribute to theory and serve as a basis for researchers to decide on choosing approaches and methods to assess the impact of climate change on saltwater intrusion in coastal estuaries.

1.4.2. The practical contributions

- *For saltwater intrusion research:* The thesis was conducted for the

Ve River - a typical river of the Central region and Quang Ngai. The results of the thesis have provided a local salinity intrusion forecast - helping managers have scientifically-based reference materials.

- *For studies that pay attention to climate change:* The developed climate change scenarios and the results of forecasting saltwater intrusion developments are a reference source for updating climate change scenarios in the Ve River basin;

- *For local authorities:* The results of the thesis help authorities at all levels make decisions in environmental resource management and sustainable development solutions with attention to the negative impacts of climate change on the human life in the study area..

1.5. New scientific contributions of the dissertation

1) Propose an approach to help assess the impact of climate change on salinity intrusion. Calculation results according to models based on a database system collected over many years, a bank of models including: hydrology, hydraulics, salinity transmission are aligned to suit the research object. The current situation (baseline) scenario is proposed with a 5-year period long enough from 2015 to 2019 to discover the law of salinity transmission, as well as serve as a comparison with climate change scenarios.

2) Attention has been paid to the impact of climate change factors on saltwater intrusion. The set of climate parameters for climate change scenarios is built based on the method of integrating statistical models, remote sensing, and GIS with documents provided by the Ministry of Natural Resources and Environment.

3) Compare and evaluate the impact of climate change on saltwater intrusion with the current scenario. Clarifying the difference between the current 2015 - 2019 scenario and the 2035 climate change scenario, analyzing the causes of the difference.

4) Finally, based on the results of the thesis, we propose solutions to

respond and adapt to saltwater intrusion in the Ve River estuary.

CHAPTER II. RESEARCH METHODS

2.1. Calculation model of stratification coefficient

To determine the flow mechanism in coastal estuaries, it is divided into 3 types: completely disturbed - Type I (no stratification or weak stratification); semi-disturbed - Type II (medium stratification); weak disturbance - Type III (strong stratification or formation of salt wedges). These three types of vertical mixing and water stratification are identified in the river and sea water mixing zone.

The stratification parameter n is determined according to the following analytical formula:

$$n = \frac{\Delta S}{S_m} = \frac{S_{bot} - S_{surf}}{0,5(S_{bot} + S_{surf})} \quad (2.1)$$

In there :

- ΔS : Vertical salinity difference
- S_m : Average salinity
- S_{bot} và S_{surf} salinity in the bottom and surface layers

Strong disturbance and weak stratification for $n < 0.1$ (Type I) respectively; Partial shuffle and average stratification, when n varies from 0.1 to 1.0 (Type II); Weak disturbance and strong stratification, seasoning with salt when n varies from 1.0 to 2.0 (Type III). The value of n never exceeds 2.0.

2.3. Selecting an analysis option

2.1.1. Select the period of stratification and salt wedge analysis

In order to assess the furthest range of salinity transmission along with the degree of stratification, the research selected for each year in the period 2015 - 2019 selected the most "dry" month, with 5 years being considered, the driest month of the year. fall in different months.

The tidal regime of the Ve River belongs to the irregular semi-diurnal tide area, including two high tides and two low tides per day. The first tide has less water fluctuations than the second tide of the day. The time

of high tide is from 3 am to 8 am, from 8 am to 14 pm low tide, high tide again at 9 pm, and until 3 pm the next day again. The results of salt propagation mechanism, level of stratification were extracted for both low and high tide periods for comparison and evaluation. The time of extraction of salinity is shown in Table 2 1.

Table 2-1. Time to extract results during the dry season for 2018

Time to extract results		Tide characteristics
Low tide	High tide	
3 am 20/07/2018	2 pm 20/07/2018	Foot tide
8 am 20/07/2018	9 pm 20/07/2018	Peak tide

The tidal regime of the Ve River is in the semi-diurnal tidal area, but in the flood season, the rules are not as clear as in the dry season. In the dry season, there are two high tides and two low tides. While in the rainy season, from 0:00 to 7:00 am high tide, from 7 am to 9 am. the tide has low but very light, and continues to rise for the second time in the day until 3 pm, after 3 am low tide. The results of the analysis of the salt propagation mechanism are still extracted for the low tide and high tide period for comparison and evaluation.

2.3.2.Selection of stratified analysis period for climate change scenario

The series of water level and discharge data in 2035 are analyzed, July is selected as the typical month of the dry season, November is the typical month of the selected rainy season. The upstream discharge in 2035 has a difference in the rainy season compared to the years of 2015 - 2019. The results of the calculation and forecast for 2035 show that this difference is due to the decrease in rainfall in the dry season in 2035 by more than half compared to that of the year 2035. with 2018. Similarly, July 20, 2035 was selected to consider the impact of climate change in the study area (Table 2-2).

Table 2-2. Time to extract results during the dry season for 2035

Time to extract results		Tide characteristics
Low tide	High tide	

3 am 20/07/2035	2 pm 20/07/2035	Foot tide
8 am 20/07/2035	9 pm 20/07/2035	Peak tide

2.4. Selection of route to analyze saline intrusion results

2.4.1. Vertically extracted map result route

The results along the river from the estuary (Cua Lo station) to the upstream 6 km, along the left bank, the river center and the middle bank of the river are extracted. On the calculation diagram, the results will be extracted according to the points with the coordinates according to the plan, fixed according to each line. The results along the tributaries will be extracted at the same time to compare the values related to saline intrusion, stratification on the two tributaries.

In order to have a basis for evaluating and comparing salty wedge characteristics, shape change, saline wedge displacement in tidal periods, specific tidal times in each tide, the salinity isoval has a concentration of 1 ‰ was chosen, because this landmark marks brackish water - causing impacts on agricultural activities.

Due to the large flow of the Ve River in the flood season, the difference is much compared to the dry season, so saline intrusion in the Ve estuary is not significant, leading to little specific calculation studies. In this study, in order to fully evaluate the stratification mechanism for the river region according to the seasons of the year, analysis of salinity transmission and stratification was performed for the whole flood season. The time of analysis and calculation, for a low tide and a high tide coincides with the high tide period of the year.

2.4.2. Result extraction route by river cross section

On the basis of salinity calculation, it is possible to extract the results of salinity distribution for river crossings at each location along the river to assess the change of salinity concentration with depth at river crossing locations. In the study, citations will be conducted along two positions MC0 and MC3. A detailed assessment for two cross-sections of the MC0 and MC3 rivers in the Ve river area was carried out. The reason these two

sections were chosen is to take advantage of simulation results, as well as real-time measurements, on the one hand. Besides, MC0 is the saline boundary between the estuary and the sea, the MC3 area is the brackish saline boundary. Cut a cross section perpendicular to the longitudinal axis of the Ve tributary. Typical times for a tide (tide, low tide) in different tidal periods (low tide, high tide) are taken.

2.5.Framework research

The research steps taken include: first, building a data set on climate change, second, running mathematical models to simulate salinity transmission according to the current situation and climate change scenarios, third, comparing the results between Baseline scenario and climate change scenario. Figure 2-1 shows the main steps of the thesis. Specifically, step 1 calculates the floor coefficient, using actual measured data at 3 floors: surface, middle, bottom based on analytical formula. The results of this step allow assessment of stratification at the river mouth (section MC0), saltwater intrusion at location MC3, about 500 m from MC0 and MC4 6 km from the river mouth. Step 2 applies a tested hydrodynamic model to simulate the salinity transmission mechanism along the two banks, river center, cross section, and each layer. Based on a series of results over the 5 years 2015 - 2019 and 2035, assessing the impact of climate change on saltwater intrusion.

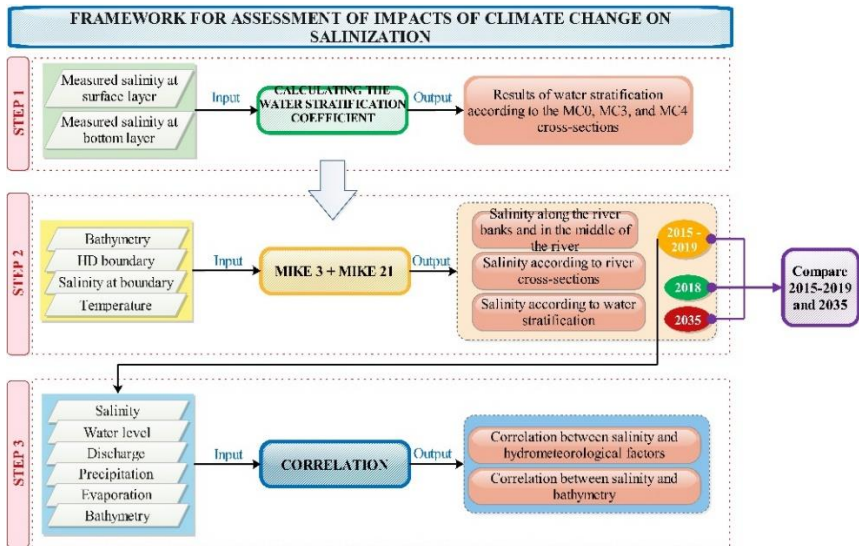


Figure 2-1. Research framework with mathematical models used.

CHAPTER III. RESULTS AND DISCUSSION

3.1. Calculation results of stratification parameter

The layout diagram of survey points is shown in Figure 3-1. From the calculation results, it shows that the Ve River has a strong stratification phenomenon at the estuary and sea locations. Figure 3-2, in which L is the distance from the estuary landmark to the determined location inland. At location MC4, 6km from the river mouth, salinity is no longer stratified and stable. The time of low tide and high tide have opposite rules: low tide tends to gradually increase from the river mouth to upstream, while the time of high tide is the opposite. At the time of low - high tide during the low tide period and at the low tide during the high tide period, the stratification phenomenon is at a strong level or more, however, at the time of the peak tide of the high tide period, the stratification phenomenon is from moderate to strong. but still smaller than at the times listed above. The result of calculating the coefficient n reflects the theoretical nature that when the tide is low, the strong river flow will make the stratification phenomenon stronger. At the same time, the stratification phenomenon in

MC3 is stronger than in MC0 because the MC3 cross-section is more affected by river flow.

From the calculation results, it shows that the Ve River has a strong stratification phenomenon at the estuary and sea locations. However, at location MC4, 6km from the river mouth, salinity is no longer stratified and stable. The result of calculating the coefficient n reflects the theoretical nature that when the tide is low, the strong river flow will make the stratification phenomenon stronger. At the same time, the stratification phenomenon in MC3 is stronger than in MC0 because the MC3 cross-section is more affected by river flow. On October 8, 2018, the trends of the stratification phenomenon were similar to those on October 7, 2018, but the value of parameter n was somewhat smaller.

Although the actual measurement results are still limited so the assessment does not cover the developments in salinity intrusion and stratification characteristics, it is initially confirmed that stratification occurs in the Ve River estuary area. The next calculation results using the MIKE 3 model will supplement this conclusion.

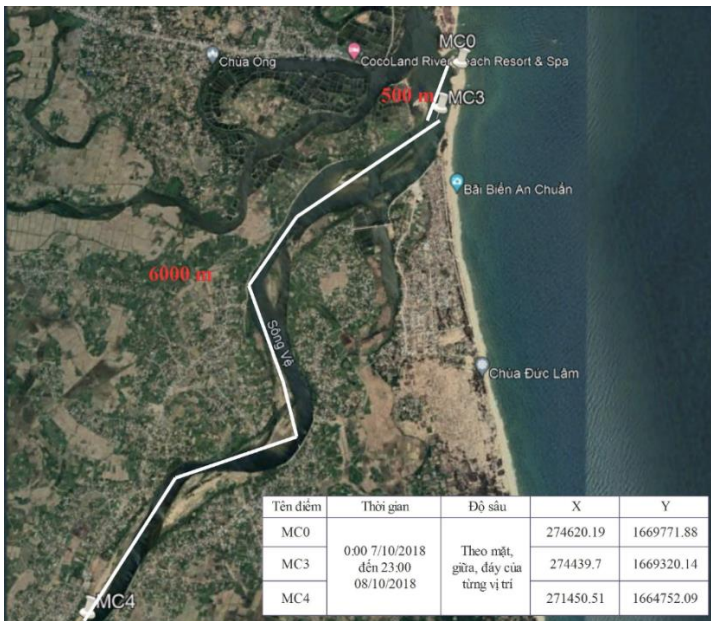


Figure 3-1 Layout diagram of survey points along Ve river.

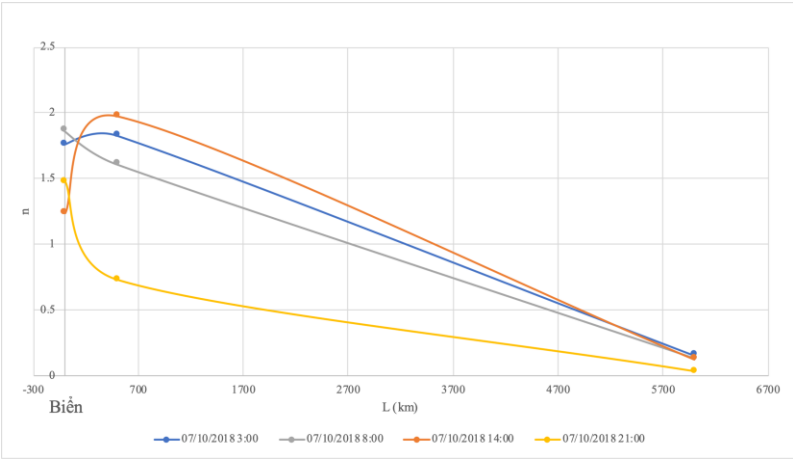


Figure 3-2 Relationship of n and L at the time of foot - peak tide in the high - low tide period, October 7, 2018

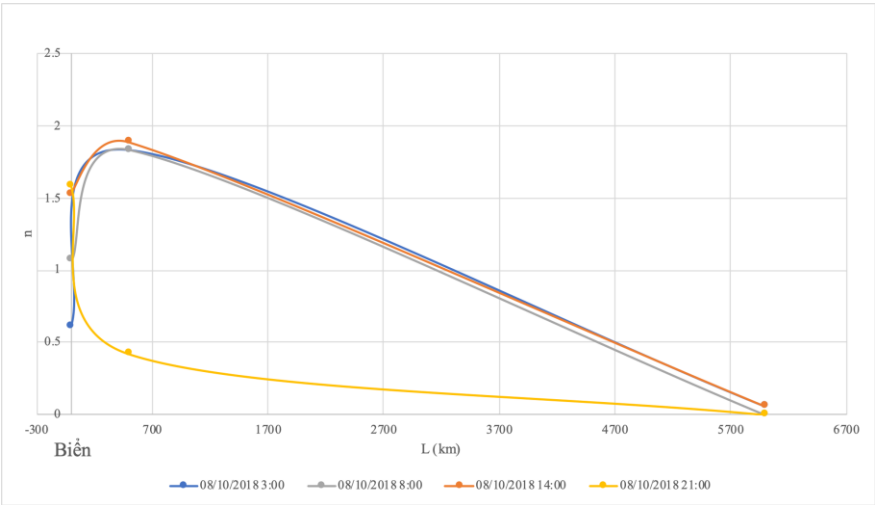


Figure 3-3 The relationship between L and n time of foot - peak tide during high - low tide on October 8, 2018.

3.2. Analysis results of salinity stratification in the Ve river estuary

3.2.1. Analysis of salty wedge in the dry season

The results of running MIKE 3 for the dry season months (February – July), are shown in Figures 3.2 a, c, e. Salinity in the dry season enters the

river branch from the river bottom. According to each depth, salinity has a significant difference. Calculated according to the 1‰ mark, on the surface of the left bank salinity propagates 3.75 km, but at the bottom it can be seen that up to 6 km the salinity is still at 15‰ (Figure 3.2 a); Similarly, on the surface of the river center, salinity can travel 3.5 km, but salinity at the bottom up to 6km is still 15‰ (Figure 3.2 c); The right bank of the Ve River also showed similar results. On the surface, the salinity transmitted 3.3 km down to 1‰, but at the bottom up to 6km there was still 15‰ (Figure 3.2 e). The range of salinity transmission between the left bank, river heart and right bank in the dry season is not significantly different, fluctuating between 200-250m, but salinity on the left bank is transmitted deeper into the river than the right bank and river heart. It can be said that in the dry season, the range of salinity transmission gradually decreases from the left bank to the right bank.

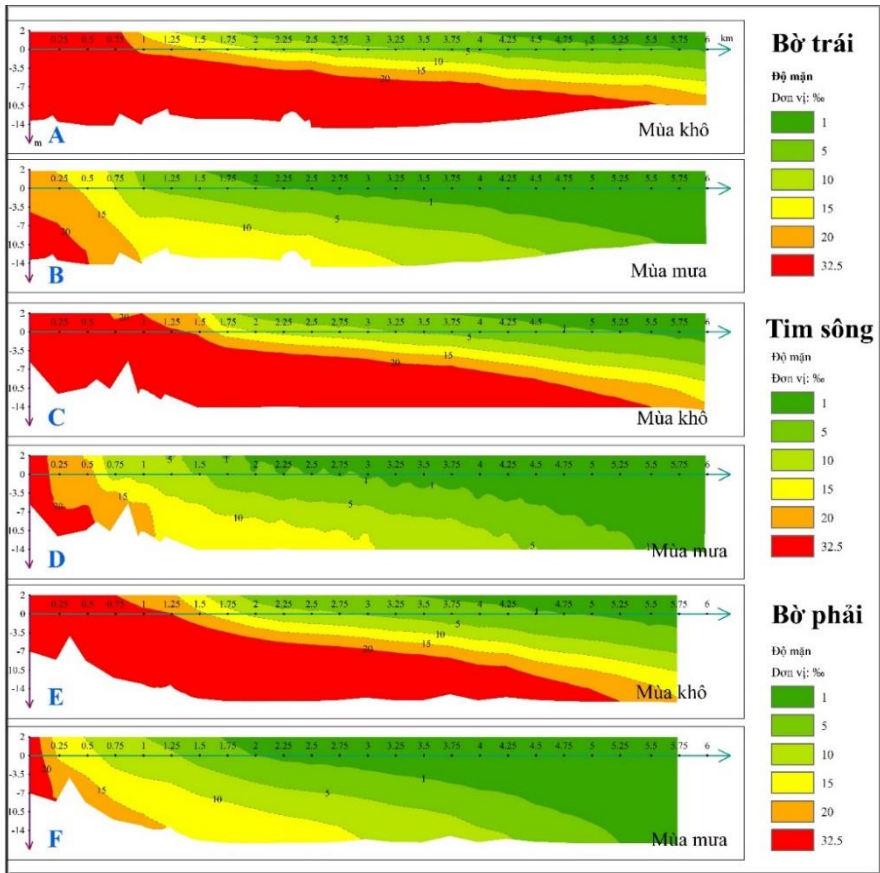


Figure 3.2. Seasonal salinity transmission map in 2018 according to cross-section along the river

3.2.2. Analysis of salinity over time along the river route

Low tide period

At two times of low tide and peak tide during low tide, the salinity isoline of the salinity wedge tends to slope at the river mouth to 1.25km on the left bank, 1km at the river center and 500m on the right bank, when entering the branch. river, the salinity isoline is quite gentle. Therefore, the salinity transmission range gradually decreases from the left bank to the right bank. Specifically, at the time of low tide at 3 o'clock, from the surface of the river, the left bank transmits 1.8km of salinity, the heart of

the river transmits 1.7km and the right bank transmits 1.75km; From the bottom, the salinity transmission range is 5.25 km, 5.25 km, 5km respectively.

High tide period

During high tide, at low tide, the low tide water level drops to 0.6 m. At the surface on the left bank, salinity propagates 1.7 km (Figure 3 6 a); salinity remains stable and propagates 1.7 km in the river center (Figure 3 6 d); On the surface of the right bank, it increases to 1.75km (Figure 3 6 g), from the bottom the salinity transmission range is 5.2km; 5.1km; 4.9km. Similar to the low tide time of the low tide period, the low tide time of the salty high tide period still decreases gradually from the left bank to the right bank.

3.2.3.Cross-sectional analysis of salinity transmission in each period

At the cross section right at the river mouth, salinity increases gradually from left to right; the low tide and peak tide times of the two tidal periods do not change much. At the surface water layer (about 40-50% of the depth of the section) the salinity concentration close to the left bank tends to be smaller, possibly due to flow disturbance. The salinity contour does not tend to curve according to the shape of the cross section, but fluctuates on the surface while the bottom is stable, not affected by the flow.

At section MC3, salinity decreases from left to right, opposite to section MC0. At this location, the salinity distribution on the cross section is different at the time of low tide and peak tide of the two tidal periods. During low tide, the stratified salinity contour curves according to the cross-sectional shape. During high tide, salinity gradually decreases on the right bank but is still stratified according to the cross-sectional shape, the top curves towards the bottom.

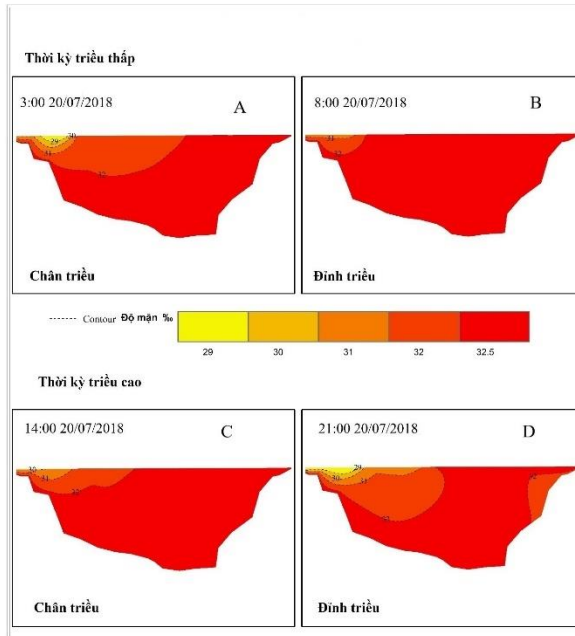


Figure 3.3. Mechanism of salinity transmission in cross section at MC0

3.2.4. Salinity distribution by ground level in each period

The largest range of salinity transmission falls at the time of low tide and peak tide of the low tide period (Figure 3.4 a, Figure 3.4 c), the smallest range of salinity transmission falls at the time of peak tide of the high tide period (Figure 3.4 b, Figure 3.4 d).

In the study, the calculated water layer depth was divided into 3 layers. The depth levels will be numbered starting from the river bottom, level 1, to the surface, level 3.

The distribution of salinity according to depth layers is quite different. The bottom layers (1st and 2nd floors) are uniform (1st and 2nd floors), and on the 3rd floor, streaks and spots begin to appear not only at the river mouth but right at the river branch, tending outward. sea, demonstrating disturbance between flow layers. During the low tide period, the range of salinity intrusion ranges from 1,89 to 5,16 km. At the peak tide time of the low tide period, the range of salinity intrusion at all levels fluctuates between 1,83 – 5,05 km. At the foot of the high tide period, the range of

saltwater intrusion ranges from 1,63 to 4,99 km. At the peak of the high tide period, the range of saltwater intrusion ranges from 1,48 to 4,85 km.

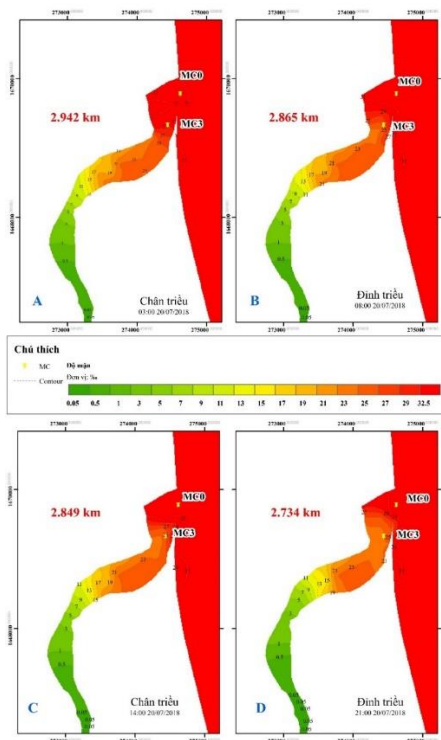


Figure 3.4. Salinity transmission range at peak tide and high tide period

3.3. Compare and evaluate the difference between the current scenario and climate change

3.3.1. Dry season

Regarding the shape of the salinity wedge, the two scenarios have similar salinity isolines of the salinity wedge, but in 2035 it tends to be steeper and thicker. Regarding the salinity intrusion mechanism, in 2035 salinity will still penetrate from the bottom. In both scenarios, there is strong stratification.

Regarding the scope of salinity transmission, as shown above from time to time, the average saltwater intrusion results in the dry season of 2018 and

2035 only differ very little, about 100-300m, the current scenario has a deeper scope of salinity transmission.

3.3.2. Wet season

The picture of salinity transmission in the rainy season under the climate change scenario has unusual changes compared to the results of the current scenario. In the rainy season of 2035, salinity penetrates deeper than in the 2018 rainy season. According to calculations, rainfall according to climate change scenarios in the rainy season decreases compared to 2018, while evaporation increases significantly.

The shape of the salinity isovalue line of the salinity wedge is also clearly different. In 2018, the salinity isovalue line was vertical, and by 2035, it began to have the same shape as previously argued. However, the unchanged point is still the salinity transmission mechanism, salinity still transmits stronger from the bottom than the surface..

3.4. Correlation between saline intrusion and influencing factors

The results presented in 3.1 – 3.3 raise the question of the dependence of the mechanism, extent, and degree of saline intrusion on influencing factors, such as hydrology (flow from the sea - tidal and current regimes) from the river - upstream discharge), regional topography (depth), meteorological factors (precipitation, evaporation). In this section, linear regression analysis for each factor is performed. The factors affecting saltwater intrusion are divided into 3 main groups: meteorology (precipitation and evaporation), hydrological factors (upstream discharge, water level - tidal factors), topography (depth). .

The relationship between salinity and 3 factors: meteorology, hydrology and topography has been built, in the 5 years 2015 - 2019. The results allow to evaluate the influence of the factors ranked in the following order: the following: topography, hydrology and finally meteorology. In other words, salinity intrusion (range, salinity level) in the Ve River depends on

all three factors, but topographic factors rank first in correlation.

3.5. Proposing solutions to apply research results

Locally, in recent times aquaculture has developed, taking brackish water with salinity $< 5\text{‰}$ can be done within a range of km, 2 to 2,25 km from the saline layer to the layer below the water surface 4 - 5 m depending on the sampling location on the shore, up to km can be taken. 6. Livestock require different salinities depending on the time of growth, so taking fresh or brackish water can be chosen over time. during the day (e.g. at low tide, at low tide). In the driest season (July), fresh water can be taken from the upper layer (1,4 m) from a location of 4,75 km. At this distance, the salinity concentration only reaches 0,5 ‰. If salinity is required in the range of 1 ‰ – 0,5 ‰, it can be taken from the surface at the 3,75 km mark. This is a result of practical significance for this locality. This shows that the results of the thesis are new to this area and using a 1 - 2-dimensional model would not be able to produce such results.

Locally, in recent times aquaculture has developed. Taking brackish water with salinity $< 5\text{‰}$ can be done within a range of km, 2 to 2,25 km in the saline layer to the upper layer 4 - 5 m from the water surface depending on the sampling location on the shore, up to km 6 can be taken. Livestock require different salinities depending on the time of growth, so taking fresh water or brackish water can be chosen. according to the time of day (for example, at low tide, at low tide).

It is necessary to pay attention to the impact of climate change as follows: at two times of low tide and peak tide during the low tide period, the salinity isovalue line of the salinity wedge in 2035 is different from the current situation in 2015 - 2019. The salinity isovalue line has The trend is gentle and clearly stratified by depth. The range of salinity transmission is significantly deep, at the time of low tide at 3 o'clock, on the river surface layer, salinity is transmitted to a depth of 1,75 km, and to the river bottom layer, salinity is transmitted to a depth of 5,25 km. The range of salinity transmission in the study area during the low tide period on July 20, 2035 fluctuates between 1,65 – 1,8 km from the surface, 4,95 – 5,25 km from

the bottom. This shows that the construction of sluices to prevent salinity, or solutions to build water supply works and design pumping stations is urgent. The choice of water supply time should be based on scientific results. In particular, when salinity spreads deeply, it is necessary to operate sluices to prevent salinity. This can be considered a practical contribution of this thesis.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In recent years, saltwater intrusion has become a challenge for the central coastal regions. When it goes inland, it has affected agricultural production and people's lives. Along with that, erratic developments of climate change may increase the trend of serious saline intrusion problems. Therefore, research into forecasting saltwater intrusion under climate change scenarios is necessary. Compared to previous studies, using a 1-dimensional model does not allow clarifying the salinity transmission structure in the estuary. Currently, no research has been conducted using 3-dimensional models. Therefore, the graduate student chose a 3-dimensional model with the hope of finding new results for rivers in the Central region. The results of the PhD students will help managers have a scientific basis and to apply it in practice with more evidence. This thesis is the doctoral student's efforts over the past 7 years (2016 - 2023) and still has many shortcomings and limitations, especially in the data collection stage. The main results and contributions of PhD students are shown as follows:

1. Established a mathematical model to simulate saltwater intrusion in the Ve River estuary - a river specific to the Central region. The salinity transmission mechanism, as well as the formation of salinity wedges and the development of salinity wedges in the Ve River estuary, have been clarified. Three analysis options have been selected, including by line, by cross section and by floor. To clarify the current status of salinity intrusion, we chose to export the results according to season: dry and

rainy, and analyzed according to the driest month to clarify the scope of salinity transmission.

2. During the process of analyzing the formation and development of the salinity wedge in the period 2015 - 2019, it was discovered that during the two periods of low tide and peak tide of the low tide period, a salinity wedge appeared 200-meters away from the river mouth. 300m, these salty wedges appear clearly at the end of the tide. Salt wedges continue to appear during the low tide period of the high tide period. Strong river currents mix with ocean currents, creating "sunken holes" that cause salinity wedges to appear.

3. Analyzed the formation of salinity wedges in the climate change scenario for 2035. Analyzed the difference in salinity transmission in 2035 compared to the current status period of 2015 - 2019. According to the climate change scenario, rainfall decreases, evaporation The increase in steam causes the normal flow of the source to decrease significantly, so the river flow decreases. On the other hand, according to the climate change scenario, the water level increases by 15cm, so the sea current pushes salinity stronger than in the period 2015 - 2019.

4. Topographic factors have a strong impact on saltwater intrusion in the Ve River estuary. The steep and shallow Ve River estuary area is the "dam" that prevents salinity from spreading deep into the river branch. Hydrological factors also directly impact the extent of salinity transmission. The impact level of flow and water level factors are inversely proportional to each other. In the dry season, the water level has more impact, in the rainy season, the flow more significant impact. Meteorological factors indirectly affect salinity intrusion in the study area. Precipitation and evaporation factors affect flow, thereby leading to changes in the salinity transmission picture.

Recommendations

- In this study, hydrological, hydraulic and salinity transmission models were used. These are dynamic models with solid research bases, are highly reliable and help solve the tasks of simulating

salinity transmission in the case of climate change.

- The role of real measured data sets at An Chi (hydrology), Ba To (meteorological), Ve River (water level), Quang Ngai (meteorological) plays the role of real measured data for calibration and checking steps. Hydrological modeling needs to continue to be used to calibrate and continue to verify the results of running hydrological models. Only then can we assess the impact of climate change more clearly in the Ve river basin.
- For salinity measurements, it is necessary to continue to carry out measurements to verify the scope and level of salinity transmission in the Ve River estuary area. In the thesis, an effort was made to carry out a systematic measurement for 2018. The data series received played an important role in helping to calibrate the hydraulic model and verify the salinity transmission model to ensure the reliability of the results. judgment.
- It is necessary to consider extreme climate cases in the future when a deep decrease in rainfall, combined with strong evaporation, will lead to the flow upstream being as low as nearly 0, leading to salinity that can penetrate deep into the river. land.
- It is necessary to continue conducting field surveys to actualize and concretize solutions to adapt to climate change. The solutions given in chapter 4 are only theoretical. More systematic and detailed investment is needed to make the proposal more practical.
- It is necessary to set a requirement to establish a database for the Ve river basin to shorten the time to collect and process data for subsequent research.

LIST OF PUBLISHED WORKS OF THE AUTHOR RELATING TO THE DISSERTATION

1. **Le Thi My Diep**, Dang Kha Nhi, Nguyen Chau My Duyen, Luong Van Thanh, Bui Ta Long, 2016. Construction of a model of shared responsibility and interest in mining in the basins – Sai gon basin as a case study. The 3rd Scientific Conference: "Effective Management of Natural Resources and Environment for Green growth" - (SEMREGG 2016). Pp. 369 - 378. ISBN: 978-604-73-4719-3.
2. **Lê Thị Mỹ Diệp**, Bùi Huỳnh Anh, Bùi Tá Long , 2019. *Applying mathematical models swat/nam/mike to build hydrological and hydraulic parameters for flow calculation - in case of Ve river, Quang Ngai*. Vietnam J. Hydrometeorology, vol. 700, no. 6, pp. 1–12, 2019. ISSN: 2525 - 2208
3. **Le Thi My Diep**, Bui Ta Long, 2020. *Application of Mike/Swat for simulation the salt intrusion – a case study in Ve river, Quang Ngai province*. Lowland Technology International Journal, vol. 22, no. 1, pp. 258–267, 2020 (Scopus – 2020). ISSN: 1344-9656
4. Bui Ta Long, **Le Thi My Diep**, 2021. *Modelling the dependence between salinity intrusion and hydrological factors using MIKE 3: a case study of Ve river, Quang Ngai*. Vietnam J. Hydrometeorology, vol. 2021, no. 725, pp. 1–16, 2021, doi: 10.36335/VNJHM.2021(725).1-16. ISSN: 2525 - 2208
5. Bui Ta Long, **Le Thi My Diep**, 2021. *Linking hydrological, hydrodynamic models for saline intrusion assessment – applying for Ve river estuary as a case study*. Vietnam J. Hydrometeorology. Vol. 9, 2021, pp. 87 – 101. 9/2021. ISSN: 2525 – 2208.

