

Water collector location for the rang dong textile industrial park

Pham Van Duong¹, Trinh Thi Hue, Tran Thi Thu Huong

The Technological Centre of Engineering Infrastructure and Urban Environment, Hanoi Architectural University, Hanoi, Vietnam

Abstract. For coastal region, the saline intrusion is one of the major issues to be concerned because it has a direct and long-term impact on the socio-economic growth. Rang Dong Textile Industrial Park is specifically designed for the large-scale textile project, located in Rang Dong Town, Nghia Hung District, Nam Dinh Province, with a daily water demand of 170,000m³ per day. The Industrial Park (IP) is located close to the sea, surrounded by 2 big rivers, Day River and Ninh Co River with ambulant water sources. However, the surface water in this region is suffered from the saline intrusion issue. Therefore, in order to supply sufficient water amount for the industrial park, it is important to determine and select the water collector location for the clean water treatment plant in the industrial park. In the present study, the calculation of saline intrusion in the downstream of Day River is simulated with MIKE11 model, which is built based on the salinity data of water in Nhu Tan, Ba Lat, Phu Le & Dong Quy stations. The simulation results show that at the selected location of the water collector, 25km from the sea gate, the salinity maintaining time of water 4‰ per month is almost unaffected; the salinity maintaining time of water 1‰ per month only accounts for 1%-4% days in the month, meeting the water supply demand of the industrial park.

Keywords: Industrial Park, MIKE 11 model, saline intrusion, water collector

1 Introduction

Rang Dong Textile Industrial Park is located in Rang Dong Town, Nghia Hung District, Nam Dinh Province, with an area under the phase I planning of 519.6 hectares, with a daily water demand of 170,000m³ per day [4]. It is required that the salinity of over 1‰ will not account for more than 10% of the water supply time in a month and the maximum salinity level will not exceed 4‰ [6-13].

The construction site of Rang Dong Textile Industrial Park is a coastal alluvial land which has been built and renovated with the dyke system and irrigation system for aquaculture. The terrain is relative flat, gradually sloping from North to South, East to West.

¹ Corresponding author: phamvanduong112@gmail.com

This region is strongly and directly impacted with the tide, and subjects to possible alluvial deposits from Day River and Ninh Co River (Figure 1).



Figure 1. Location of study area

The regime of tide in the Rang Dong Sea is the diurnal tide one. The average tidal amplitude is from 1.5-1.7m, the highest tidal amplitude of 3.31m and the lowest tidal amplitude of -0.11m. Through the system of rivers and channels, the diurnal tide improves the process of acidic removal and desalt in the fields getting more better. The flow in the Ninh Co River and Day River in combination with the diurnal tide has accreted in the area of two river sides, resulting the large coastal alluvial grounds (mainly toward the West and East).

In the dry season, the water amount in the river is small, the tide deeply and strongly intrudes and brings salt water into the river with salinity intrusion of 1‰, 30-50km from the sea gate, hindering the water collection for economic sectors.

In every dry season, the flowrate of the freshwater source decreases, the flowrate of tide increases, which has a great impact on the water collection at the main sluices, causing difficulties for agriculture production in the fifth-month rice, spring crop. In 2010, the salinity increased and deeply intruded into the estuary, affecting the water collection activities for green zone in the Winter crop and people's daily life. The salinity not only limits the water collection period at the main sluices, leaks through the sluices, causing salinization to the agricultural topsoil in the irrigation basin, but also sometimes has a direct impact on rice productivity for using the water source with high salinity [5].

In order to assess the saline intrusion condition in the Rang Dong Textile Industrial Park, the present study used the salinity measurement data in the period of 2010-2017 at the hydrographic station of Nhu Tan on Day River and the hydrographic station of Phu Le on Ninh Co River.

The statistics of salinity characteristic at the two above stations show that the highest salinity ranges from 25‰ to 34‰, the lowest salinity ranges from 0.1‰ to 3‰, and the salinity concentration at Phu Le hydrographic station on Ninh Co River is higher than at Nhu Tan hydrographic station on Day River.

In the period of 2010-2017, 2010 was the year when saline intrusion synchronously occurred at both Nhu Tan hydrographic station and Phu Le hydrographic station, followed by 2012, 2013, 2016 and then 2017. The highest salinity synchronously occurring on both Day River and Ninh Co River was in February, mainly on 08th – 10th, 19th – 20th & 25th – 27th of February. So it can be seen that the highest salinity usually occurs in the driest month (the lowest flow) of the year.

In order to assess the saline intrusion condition in the study area, the method used is the hydrodynamic modelling method in combination with the mass (salinity) propagation method in the river. The study team has selected the MIKE11 model set with hydrodynamic modules (HD) and mass propagation (AD) for simulation.

2 Method

2.1 Model

MIKE11 is a one-dimension hydro-dynamic model used for simulation of irregular flows in the river, open channel. MIKE11, developed by the Denmark Hydraulic Institute, is a specialized engineering software for simulation of water flowrate, quality and sediment transportation in the estuaries, rivers, irrigation systems, channels and other water bodies' transportation, in which the hydrodynamic module (HD) used for flow calculation is the main one.

The basic feature of MIKE11 model system is a complex module structure consisting of various module types added to each simulation of river system related phenomena. A part from the above described hydrodynamic module (HD), the MIKE system includes other modules such as hydrography module (NAM) with data interpolation; mass t propagation module (AD) with mass propagation properties (salinity, suspension or decomposition, ...) used for simulation of diffusion process of those compounds; water quality module (WQ) used for simulation of biological transformation processes of compounds in the river; sediment transportation module with cohesive property (sticky) and non-cohesive property (non-sticky).

Hydrodynamic module (HD)

In order to calculate the flow in the river channel, the MIKE11 model applied the one-dimensional Saint Venant equation set (equation of conservation of momentum & equation of conservation of mass) and the 6-alternating node Q,H differential diagram by Abbott and Ionescu, (1976) [14,15]:

- Continuity equation:

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \quad (1)$$

- Momentum equation:

$$\frac{\partial Q}{\partial t} = -\frac{\partial \left(\alpha \frac{Q^2}{A} \right)}{\partial x} + gA \frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0 \quad (2)$$

Where: Q - flowrate (m³/s); A – sectional area (m²); q – Input flowrate per length unit along the river (m²/s); C – Chezy coefficient; α – Momentum fixed coefficient; R – hydraulic radius (m).

Mass propagation module (AD)

AD module is based on the solute mass conservation equation [14,15]:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x} \left(AD \frac{\partial C}{\partial x} \right) = -AKC + C_2q \quad (3)$$

Where: A: Sectional area (m²); C: density (kg/m³); D: Diffusion coefficient; q: Input flowrate per length unit along the river (m³/s); K: Biochemical degradation coefficient (K is only conducted when the phenomena or consideration process is related to the biochemical reactions).

Biochemical degradation coefficient K covers so many biochemical reactions and phenomena, which is not required to be considered in the conventional substance transmission problem.

2.2 Model setup

In the present study, two modules under MIKE11 were used for simulation of salinity (HD and AD modules). In HD module, two input data groups include:

- Spatial based data includes the river channel system and its cross-section;
- Time based data includes data of time based water level and flowrate of a number of hydro-meteorological stations located in the national hydro-meteorological monitoring network under the area of Nam Dinh Province and its vicinity (period of 2001-2017), and is the initial condition at the calculated boundaries; salinity measurement data at the four hydrographical stations under the area of Nam Dinh Province and its vicinity: Nhu Tan station on Day River, Phu Le station on Ninh Co River, Ba Lat station on Hong River and Dong Quy station on Tra Ly River from December of previous year to May of following year (period of 2010-2017). The data used in the present study was collected from the Hydro-meteorological Data and Information Centre – Vietnam Meteorological and Hydrological Administration.

Calculation boundary condition

Boundary condition is divided into 2 types:

Upper bound (water level or flow rate bound) is the actual water level or flow rate measured at the upper nodes of the calculation diagram, specifically:

Is the actual water level process curve measured at the upstream locations of Hoang Long River, Day River, Dao River and Hong River (the actual water level measured at Gian Khau station, Phu Ly station & Hung Yen station).

Lower bound (water level bound) is the actual water level measured or calculated at the lower nodes of the calculation diagram, normally at tidal level stations, specifically:

Is the actual water level process curve measured at the estuaries of Day River, Ninh Co River, Hong River and Tra Ly River (the actual water level measured at Nhu Tan station,

Phu Le station, Ba Lat station and Dong Quy station). Calculation diagram and simulation are shown in Figure 2.

Table 1. Boundary condition in MIKE 11 hydrodynamic model

No	Station, location	River arm	Bound grade	Bound type
1	Hung Yen	Hong	H~t	Upper bound (actual measurement)
2	Phu Ly	Day	H~t	
3	Gian Khau	Hoang Long	H~t	
4	Ba Lat	Hong	H~t	Lower bound (actual measurement)
5	Phu Le	Ninh Co	H~t	
6	Dong Quy	Tra Ly	H~t	
7	Nam Dinh	Dao	Q~t	Calibration, validation
8	Truc Phuong	Ninh Co	Q~t	
9	Nhu Tan	Day	H~t	

Selection of simulation time

Selection of hydrodynamic flow calculation year. In order to assess the saline intrusion level at the coastal estuary area, the period usually selected for calculation is the driest period of the year, which it is also necessary especially for water collection problem because not only the salinity level is assessed but also the maximum flowrate can be obtained.

The theoretical frequency curve is a probability distribution model used in the hydrological calculation, which is relative consistent with the physic al properties of hydrological phenomena. In our country, the design flow characteristics are usually calculated based on the Pearson III probability distribution curve (P.III).

In Nam Dinh Province, there are two flowrate measurement stations, namely Nam Dinh hydrological station and Truc Phuong station. Based on the resulting P.III theoretical probability curve, it can be shown that in 2015 and 2016, the flowrate is small and the frequency ranges from 70% to 85%. Therefore, it can be seen that these years are under the group of years with little water amount, occurring in Nam Dinh Province. Based on this, the study used the data set in 2015 for model calibration and the data set in 2016 for hydrodynamic model validation.

Selection of simulation period for saline intrusion. Based on the flowrate data of Nam Dinh hydrological station and Truc Phuong station, the present study conducted the statistics of the smallest flowrates in January, February and March of years in the period of 2001-2017, showing that the smallest flowrate occurring in Nam Dinh Province is mainly in February of the year: for example, in February, 12/16 occurrences of smallest flowrate at Nam Dinh station, 10/16 occurrences of smallest flowrate at Truc Phuong station. Thus, the smallest flowrate in this area mostly occurs in February. Based on this, the present study selected salinity measurement data set in February of years in the period of 2013-2016 at Nhu Tan station (13km from the sea gate) for saline intrusion simulation.



Figure 2. Network diagram of hydro- meteorological stations and its vicinity

Selection of simulation time

Selection of hydrodynamic flow calculation year. In order to assess the saline intrusion level at the coastal estuary area, the period usually selected for calculation is the driest period of the year, which it is also necessary especially for water collection problem because not only the salinity level is assessed but also the maximum flowrate can be obtained.

The theoretical frequency curve is a probability distribution model used in the hydrological calculation, which is relative consistent with the physical properties of hydrological phenomena. In our country, the design flow characteristics are usually calculated based on the Pearson III probability distribution curve (P.III).

In Nam Dinh Province, there are two flowrate measurement stations, namely Nam Dinh hydrological station and Truc Phuong station. Based on the resulting P.III theoretical probability curve, it can be shown that in 2015 and 2016, the flowrate is small and the frequency ranges from 70% to 85%. Therefore, it can be seen that these years are under the group of years with little water amount, occurring in Nam Dinh Province. Based on this, the study used the data set in 2015 for model calibration and the data set in 2016 for hydrodynamic model validation.

Selection of simulation period for saline intrusion. Based on the flowrate data of Nam Dinh hydrological station and Truc Phuong station, the present study conducted the statistics of the smallest flowrates in January, February and March of years in the period of 2001-2017, showing that the smallest flowrate occurring in Nam Dinh Province is mainly in February of the year: for example, in February, 12/16 occurrences of smallest flowrate at Nam Dinh station, 10/16 occurrences of smallest flowrate at Truc Phuong station. Thus, the smallest flowrate in this area mostly occurs in February. Based on this, the present study selected salinity measurement data set in February of years in the period of 2013-2016 at Nhu Tan station (13km from the sea gate) for saline intrusion simulation.

3 Results

The model was calibrated in 2 steps with hydrological data and salinity level in the period of January 01st to April 30th, 2015 by replacing the parameters in the model (Manning coefficient in the HD module and diffusion coefficient in AD module) until the model

results is consistent with the actual measured results. The model was validated using the basic data set in the period of January 01st to April 30th, 2016.

3.1 Model calibration

HD model calibration was conducted by changing the manning coefficient in the range of 0,03-0,018.

Figure 3 and Figure 4 show the representative results for Nam Dinh station and Truc Phuong station. It is shown that the model results are consistent with the actual measured results in the terms of both values and trends. Figure 5 shows the representative results for Nhu Tan station for AD model calibration.

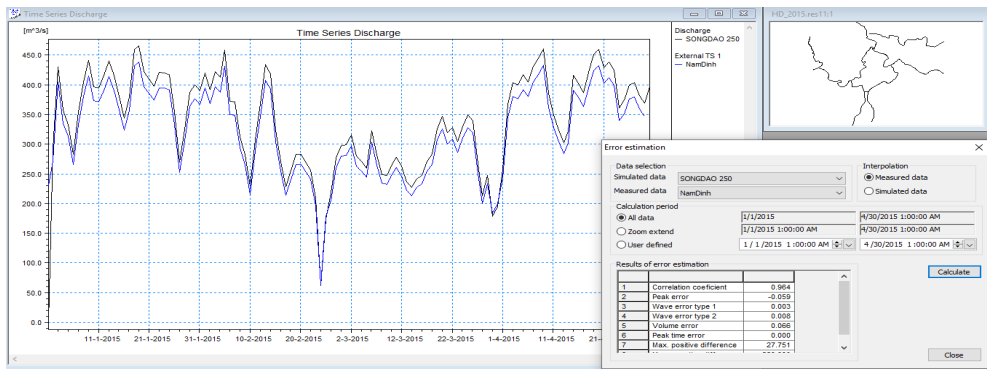


Figure 3. Comparison of calibration results of actual water level measured and calculated from the model at Nam Dinh station in 2015

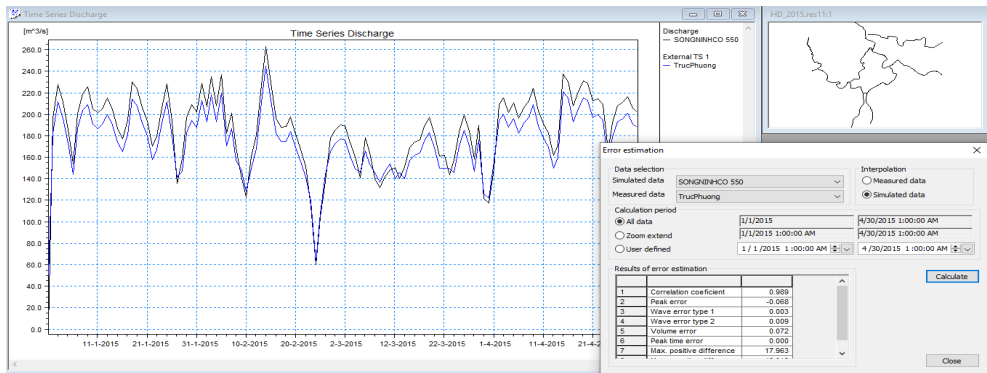


Figure 4. Comparison of calibration results of actual water level measured and calculated from the model at Truc Phuong station in 2015

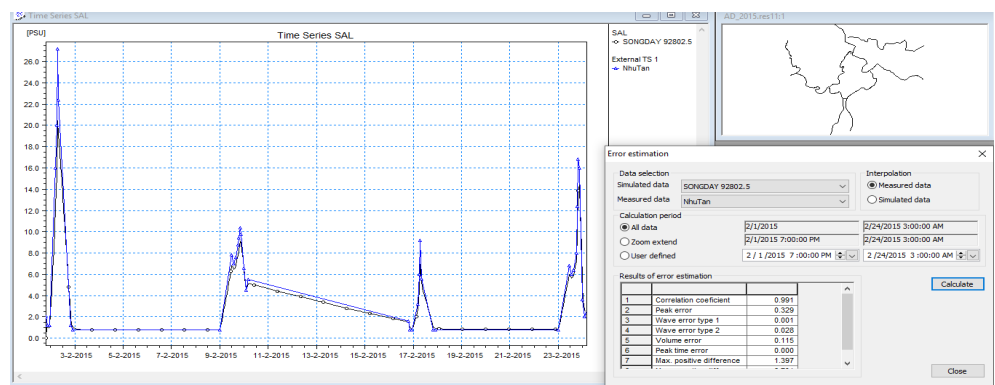


Figure 5. Comparison of calibration results of actual salinity level measured and calculated from the model at Nhu Tan station in 2015

3.2 Model validation

It is validated with database of the year of 2016, specifically as follows:

Figure 6 and Figure 7 show the representative results for Nam Dinh station and Truc Phung station for HD model validation. Figure 8 shows the representative results for Nhu Tan station for AD model validation.

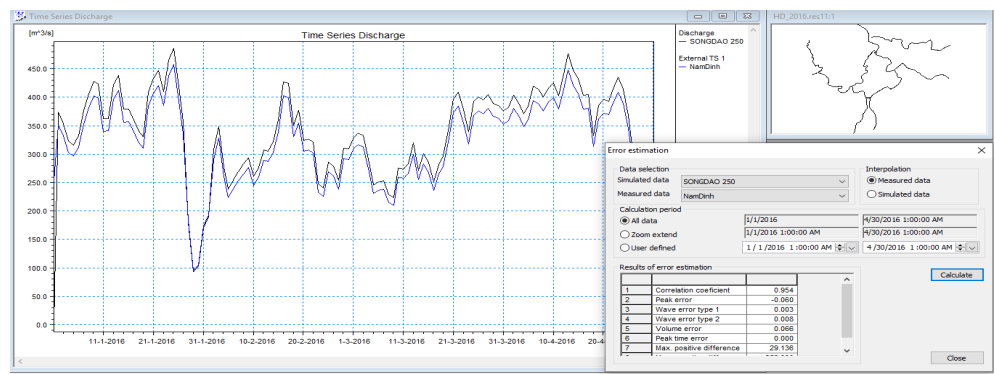


Figure 6. Comparison of calibration results of actual water level measured and calculated from the model at Nam Dinh station in 2016

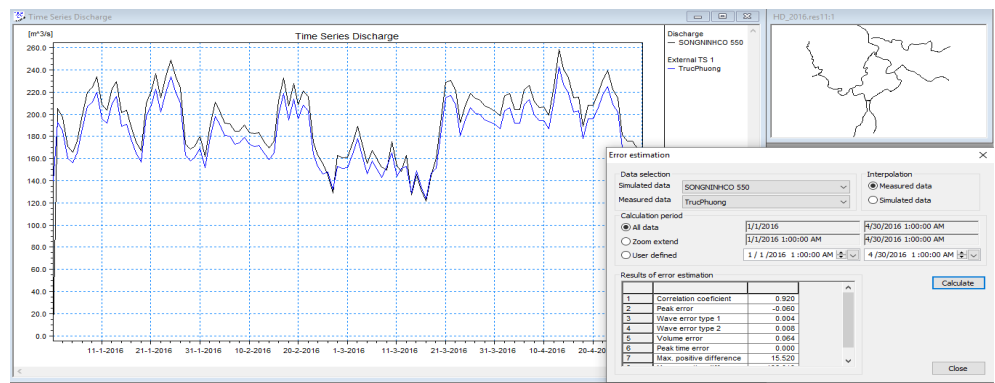


Figure 7. Comparison of calibration results of actual water level measured and calculated from the model at Truc Phuong station in 2016

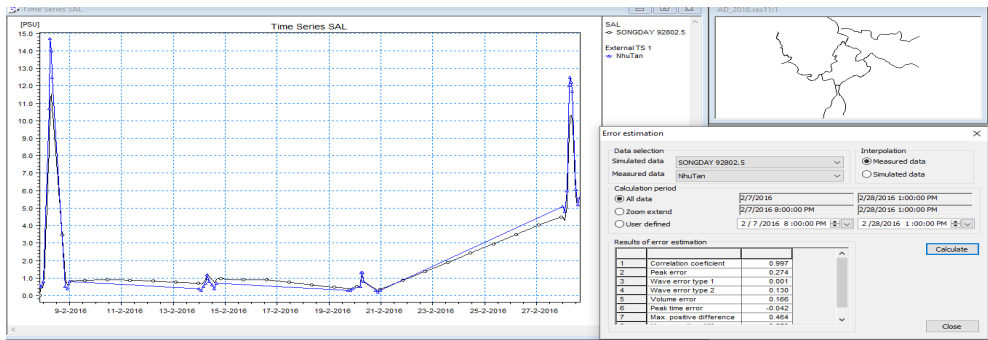


Figure 8. Comparison of calibration results of actual salinity level measured and calculated from the model at Nhu Tan station in 2016

Calibration and validation of the salinity divert model is more complicated than that of hydro-dynamic model because the salinity is affected by several factors. Furthermore, results of AD model are very sensitive to diffusion coefficient. However, the comparison between the model results and actual measured results shows that the model results are consistent with the actual measured results in terms of both values and trends, which can be the basis for salinity predict in the future.

4 Discussion

4.1 Evaluation of simulation quality

In order to evaluate the simulation quality of HD hydrodynamic flow of MIKE11 model with the flow in the rivers in the area of Nam Dinh Province, the following evaluation criteria were used in the report:

a. *Evaluation of calculated results and actual measured results with coefficient of Nash – Sutcliffe:*

$$NSE = 1 - \frac{\sum_{t=1}^T (Q'_m - Q'_0)^2}{\sum_{t=1}^T (Q'_0 - \bar{Q}_0)^2} \tag{4}$$

$NSE \in (-\infty, 1)$

Where: Q'_0 : actual measured value at time t ; Q'_m : caculated value at time t ; $\bar{y}$: average actual measured value;

- $NSE = 1$: Exact model simulation of the actual measured monitoring sequence;
- $NSE > 0,75$: Good model simulation;
- $0,5 < NSE < 0,75$: Acceptable model simulation;
- $NSE < 0,5$: non-reliable model simulation.

b. *Evaluation with total error*

$$F = \frac{1}{n} \sum_{i=1}^n (Q_{td}^i - Q_{tt}^i) \Delta t \quad F = \frac{1}{n} \sum_{i=1}^n (Q_{td}^i - Q_{tt}^i) \Delta t \tag{5}$$

Where: Q_{td}^i is the actual measured flow rate at the period of i ; Q_{tt}^i is the calculated flow rate at the period of i .

- $F < 5\%$: Good flow simulation;
- $10\% < F < 5\%$: Acceptable flow simulation;
- $F > 10\%$: non-reliable flow simulation.

The evaluation results of hydrodynamic flow simulation quality with MIKE 11 model are shown as below:

Table 2. Evaluative criteria of flow simulation quality at Nam Dinh station

No	Evaluative criteria	Model calibration	Model validation
		2015	2016
1	Nash – Sutcliffe (NSE)	0.96	0.95
2	Total error – F (%)	6.6	6.6

In order to evaluate the reliability of saline intrusion simulation at the estuary of Day River, two evaluation criteria were used in the study:

- Nash – Sutcliffe criteria: same as the evaluation of hydrodynamic flow.
- Peak error criteria: Peak error between the actual measured value and calculated value, unit %.

Table 3. Evaluative criteria of flow simulation quality at Truc Phuong station

No	Evaluative criteria	Model calibration	Model validation
		2015	2016
1	Nash – Sutcliffe (NSE)	0.98	0.92
2	Total error – F (%)	7.2	6.4

Table 4. evaluative criteria of saline intrusion simulation at the estuary of Day River

No	Evaluative criteria	2015	2016
1	Nash – Sutcliffe criteria	0.99	0.90
2	Peak error criteria	3.3	2.7

The evaluation results are as Table 4.

Based on the results in Table 2, Table 3 and Table 4, it can be seen that:

MIKE 11-HD model well simulates the hydrodynamic flow in the rivers under the area of Nam Dinh Province and its vicinity, Nash criteria at both Nam Dinh station and Truc Phuong station are very high (from 0.92 to 0.98), total error is in range of 5%÷10%, which means that the model simulation is acceptable.

MIKE 11-AD model also well simulates the evolution of saline intrusion at the estuary of Day River at Nhu Tan hydrological station with very high Nash, $Nash \geq 0.9$ (Table 4) and maximum salinity value error of less than 5%, which shows that MIKE 11-AD model ensures the reliability in saline retrusion simulation at the estuary of Day River.

4.2 Maximum saline intrusion distance in the main flows

Based on the saline intrusion model assessed in Section 3, the study investigated level of saline intrusion in 2015 and 2016. At the same time, the obtained report also predicts the saline intrusion levels for the estuary area of Day River according to the scenario of climate change (CC) to 2030 and 2050. The scenario of saline intrusion prediction for the estuary area of Day River is as Table 5.

Table 5. The scenario of saline intrusion prediction for the estuary area of Day River in the climate change conditions

No	Scenario description	Scenario name	
		Scenario 1	Scenario 2
1	flow condition	Changes on the rainfall and rising of sea level to the year of 2030 according to the scenario of RCP6.5 [1]	Changes on the rainfall and rising of sea level to the year of 2050 according to the scenario of RCP6.5 [1]
2	Characteri-stics of salinity source	The average salinity level in February of the year 2015 and 2016 at Nhu Tan Hydrological station	

The evaluation results of saline intrusion at the estuary area of Day River are as follow.

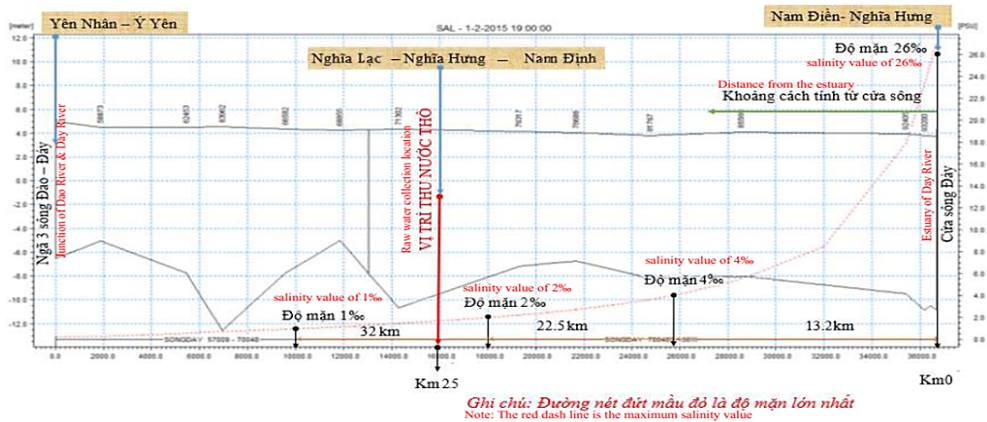


Figure 9. Evolution of saline intrusion at Day River’s estuary in the dry season in 2015

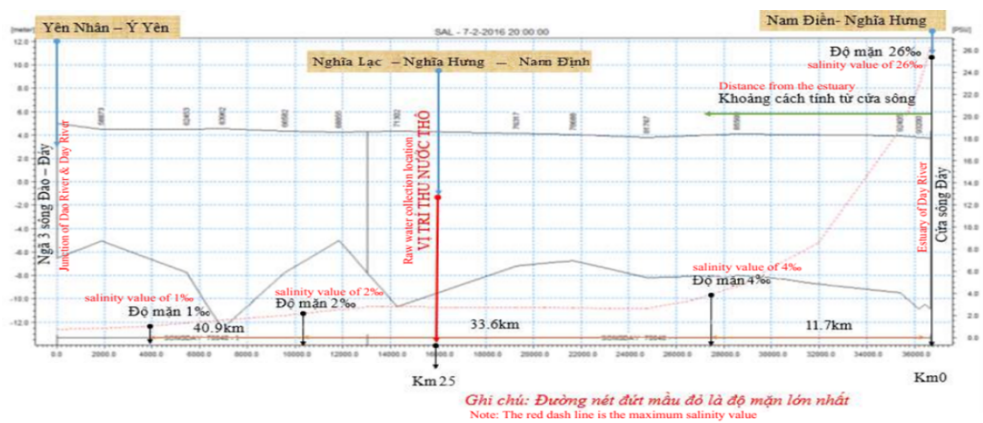


Figure 10. Evolution of saline intrusion at Day River’s estuary in the dry season in 2016

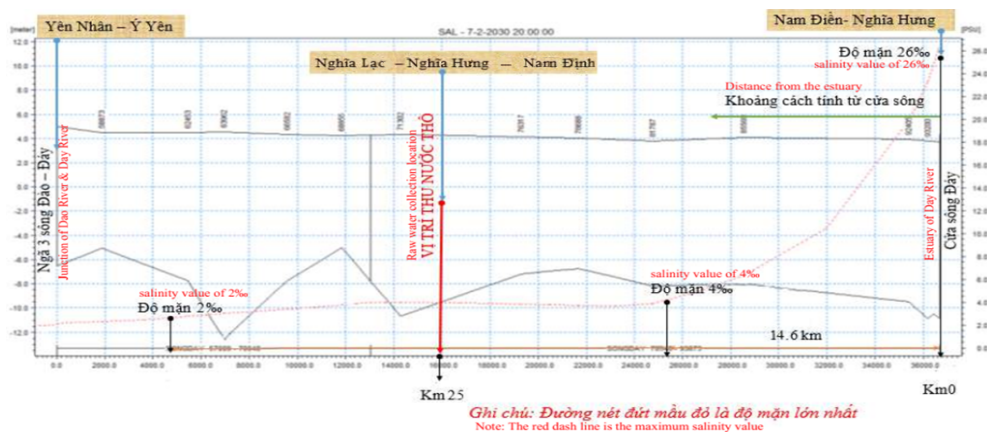


Figure 11. Predict of saline intrusion at Day River’s estuary in the dry season in 2030 – scenario 1

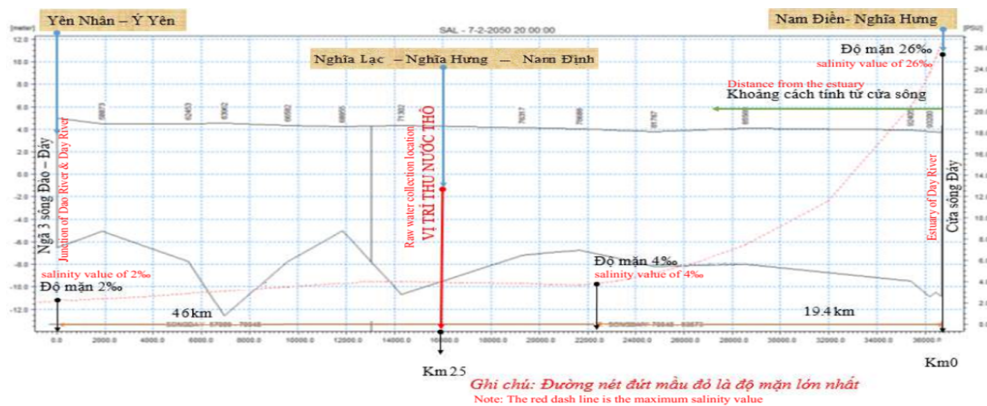


Figure 12. Predict of saline intrusion at Day River’s estuary in the dry season in 2050 – scenario 2

Saline intrusion depth on the main flows shows that in the cycle of February every year when the flow rate is small, the salinity value of 1‰ will intrude to the inland with distance

of 42km; and the salinity value of 4‰ can intrude to the inland with distance of 14.4km (Figure 9, Figure 10).

With the results of saline intrusion at the estuary of Day River according to the scenario of climate change to 2030 and 2050, it can be seen that the situation of saline intrusion at the estuary of Day River tends to intrude higher and higher into the river (Figure 11 – Figure 12), specifically as follows:

- The area with salinity value of 4‰ intruding into the river is 12.2km to 19.4km from the estuary of Day River, in which the highest saline intrusion is in 2050, with the average saline intrusion distance of approximately 15.8km.
- The area with salinity value of 2‰ intruding into the river is 41km to 46.2km from the estuary of Day River, in which the lowest saline intrusion is in 2025, with the average saline intrusion distance of approximately 43.6km from the estuary.
- The area with salinity value of 1‰ is generally far from the sea and intrude quite high into the inland, with the highest saline intrusion distance of 55.3km from the estuary.

Based on the simulation results from the above-studied model and the current situation of existing channels and references [3,4], the surface water collector location for the clean water treatment plant in the Rang Dong Textile Industrial Park is about 25km from the sea gate, located in Nghia Lac Commune, Nghia Hung District, Nam Dinh Province (TB1 location – Figure 1). This is a convenient location to install the water collector because the salinity maintaining time of water 1‰ of each month only accounts for approximately 1% - 4% of days in the month while the salinity value of 4‰ has almost no affect.

5 Conclusion

The results of present study show that the model has simulated the hydrodynamic-hydrological regime of saline intrusion in the current conditions and climate change conditions quite accurately.

At the expected location for water collector installation for the clean water treatment plant in the Rang Dong Textile Industrial Park, the salinity maintaining time of water 1‰ of each month only accounts for approximately 1% - 4% of days in the month. The salinity value of less than 4‰ totally meets the requirements of the industrial park. Therefore, it is appropriate to install the water collector at this location.

Reference

1. Ministry of natural resources and environment, The scenario of climate change and rising of sea level in Vietnam (2020).
2. Ministry of natural resources and environment, National technical regulation on surface water quality, Regulation QCVN 08-MT:2015/BTNMT (2015).
3. Ministry of construction, design standard water supply – external networks and facilities, Standard TCXDVN 33:2006, (2006).
4. Le Dung, Water collection works - Water supply and drainage pumping station (Construction Publisher, 2011).
5. The People's Committee of Nam Dinh, Province on approval of master plan on water resources of Nam Dinh Province to 2020, oriented to 2030, Decision No.124/QĐ-UBND, 15/01/2016.

6. The People's Committee of Nam Dinh, Province on Establishment of Rang Dong Textile Industrial Park, Nam Dinh Province, Decision No. 1151/QĐ- UBND, 01/6/2021.
7. The People's Committee of Nam Dinh, Province on approval the local adjustment of the construction zone planning of Rang Dong Textile Industrial Park, Nam Dinh province, Decision No. 1662/QĐ-UBND, 10/7/2020;
8. The People's Committee of Nam Dinh, Province on approval the local adjustment of construction zone planning of Rang Dong Textile Industrial Park, Nam Dinh province, scale 1/2000 at 02 lots K and Q, Decision No. 2087/QĐ- UBND, 20/8/2020.
9. The People's Committee of Nam Dinh, Province on approval the local adjustment of the construction zone planning of Rang Dong Textile Industrial Park, Nam Dinh province, Decision No. 623/Q-UBND, 28/3/2019;
10. The People's Committee of Nam Dinh, Province on approval of general construction planning of Rang Dong Textile Industrial Park in Nam Dinh province to 2035, Decision No. 1208/QĐ-UBND, 26/6/2015.
11. The People's Committee of Nam Dinh, Province on changing of investor in construction investment project of Rang Dong Textile Industrial Park, Nam Dinh province, Decision No. 2103/QĐ-UBND, 21/10/2015.
12. The People's Committee of Nam Dinh, Province on approval of construction zone planning of Rang Dong Textile Industrial Park, Nam Dinh Province, scale of 1/2000, Decision No. 2572/QĐ-UBND, 02/12/2015.
13. The People's Committee of Nam Dinh, Province on assigning the investor to build and trade infrastructure in Rang Dong Textile Industrial Park, Nam Dinh province, Decision No. 2188/QĐ-UBND, 27/11/2014.
14. Denmark Hydraulic Institute (DHI), MIKE 11 User Guide, DHI (2012).
15. Denmark Hydraulic Institute (DHI), Reference Manual, MIKE 11 - A modeling system for rivers and channels, DHI (2012).