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# Research and Assessment of Changes in Surface Water Resources in Thai Binh Province, Vietnam and Proposal of Protection Solutions to 2030, Orientation to 2035

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**Abstract:** Located in the downstream area of the Hong River-Thai Binh river system, one of the two largest river systems in Vietnam, Thai Binh is a province with abundant surface water resources. However, the reports and figures show that the annual flow and seasonal flow distribution in the Hong river-Thai Binh river basin have many changes, and under the impact of climate change and sea-level rise, together with the ineffective management and exploitation methods, water resources in general, surface water resources in particular in the study area are having many changes in both quantity and quality. The report focuses on analysing the trend of this valuable resource change, and based on the impact factors, consulting experts, the author has proposed a number of solutions to sustainably protect surface water resources in the study area.

**Key words:** surface water resources, water security, integrated management, sustainable development, Thai Binh Province

## 1. Introduction

Today, ensuring water security for sustainable socio-economic development is a big challenge for all countries and territories in the world. The problems caused by water have caused enormous damage in all fields of human life. This is increasingly serious, especially in developing countries like Vietnam.

Located in the largest river basin of Vietnam, Thai Binh is considered to have abundant water resources, especially surface water resources. With the long history of territorial exploitation, surface water resources have long been a natural advantage, bringing rich wet rice agriculture to Thai Binh province: providing irrigation water for 106,811ha of agricultural land (in 2019); ensuring food security not only for over 1.9 million people (in 2019), but also providing a large number of export goods with high economic value to the market; nearly 100% of people have access to clean water (according to the report of the Department of Agriculture and Rural Development of Thai Binh province); The value of industrial production and services is constantly increasing (in 2020, the production value of agriculture – forestry – fishery, industry, construction and service of the whole province reaches 24.5% - 42.6% - 32.9% respectively). Despite facing many difficulties, especially the complicated development of the global epidemic Covid-19, which has had a significant impact on the socio-economy of countries in the world and Vietnam, including the study area; However, in 2020, with the efforts of authorities and local people, Thai Binh is still a locality with remarkable economic growth. Thai Binh is striving to become one of the provinces with remarkable economic growth, many units in the province announced new countryside in excitement to welcome the 13th National Congress.

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One of the difficulties and challenging questions in development policies towards the sustainable development of local leaders is the issue of water security. Currently, the surface water source of Thai Binh province is facing many problems, which are the alarming decline in water quality, change of flow, change of in water flow in both flood and dry seasons have caused significant damage to the province's production and directly affected the quality of life of the people. The causes were initially identified as the lack of effectiveness of the integrated management mechanism of water resources at all departments; The sense of exploitation and use is still weak of a number of parts of the people; Water use conflicts between sectors have not been completely resolved; lack of association with the upstream side; increasing impact of climate change and sea-level rise, etc. In-depth research on the dynamics of changes in surface resources in Thai Binh province needs more attention than ever.

## 2. Data and Research Methods

*2.1 Data*

Collect data on field surveys, measure in the field and analyse in the room related to water resources (humidity, rainwater, surface water) from 2010 to December 2020 of the Center for Analysis of Natural Resources and Environment, Department of Natural Resources and Environment of Thai Binh Province, Thai Binh Hydrometeorology Center, Center for Meteorology and Hydrology of Thai Binh, combined with recorded data during field trips at the important study area. In addition, the documents to be exploited include: irrigation planning; Land planning; traffic planning; socio-economic development planning; documents on the environment, resources; Climate Change & Sea Level Rise planning for Thai Binh province; map documents; Maps (administration, distribution of rainwater, river systems, etc).

*2.2 Research Methods*

Based on the viewpoints of approaching objects, research areas, in order to assess water resource changes in Thai Binh province, the author chooses many research methods: Document analysis method; Inheritance method; Geographic Information System (GIS) application mapping method; Methods of investigation, field survey; Assessment method; Expert method.

## 3. Research Results and Discussion

Surface water resources are water sources that exist regularly or infrequently in terrestrial water bodies such as rivers, natural lakes, water basins (artificial basin), wetlands, fields and ice (of which, river water is the main and most important component in surface water resources).

*3.1 Summary of River Network Characteristics in Thai Binh Province*

Thai Binh has a dense network of rivers, surrounded by rivers: Hong river, Luoc river, Hoa river. Running in the middle of the province is Tra Ly River, dividing Thai Binh into two zones: the North and the South. These rivers form 5 large estuaries: Ba Lat, Lan, Tra Ly, Diem Ho, Thai Binh.

In addition, Thai Binh also has an intertwined inner-field river system, which is responsible for the irrigation of the fields and the daily life of the people.

The seasons of changes in surface water resources (including the volume and quality of water resources) in Thai Binh province are identified including the following main reasons:

1) The management and protection of surface water resources in Thai Binh province are ineffective: there is no integrated management of water resources, no close connection with neighbouring and upstream localities in integrated river basin management; there is overlap between departments in water resource management leading to accountability in the

event of water incidents; lack of staff in water management and expertise, etc.

2) A part of people has poor awareness of using and exploiting water resources (not yet economical and not associated with protecting this valuable resource); many enterprises, organizations and individuals exploiting and using water are still single-sector, single-field, the production doesn't pay attention to the environmental impact assessment, the amount of untreated discharge to the soil and water environment was still large, etc.

3) Due to climate change, sea level rise: The increase in global temperature has caused sea-levels to rise, the current state of the fresh-salt boundary is moving inland, besides, the weather disturbance caused a series of extreme phenomena: storms, droughts, etc. Thereby affecting the rainwater distribution in both space and time, greatly affecting the flow regime in the river basins in Vietnam in general, on the Hong river-Thai Binh river basin in particular, of which, Thai Binh is located in the territory of the downstream area of the system.

The change with more and more bad expressions is one of the concerns of the managers of Thai Binh province because the consequences greatly affect the planning and socio-economic development policies of the study area.

### *3.2 Trend of Surface Water Resource Changes in Thai Binh Province*

In the process of studying the dynamics of surface water resources in Thai Binh province, the author bases on the measurement results collected in the environmental measuring stations (hydrological stations, rainwater measuring stations, salinity measuring stations) and the analytical results in the sample room of surface water at observed locations on the river system in Thai Binh province for assessment.

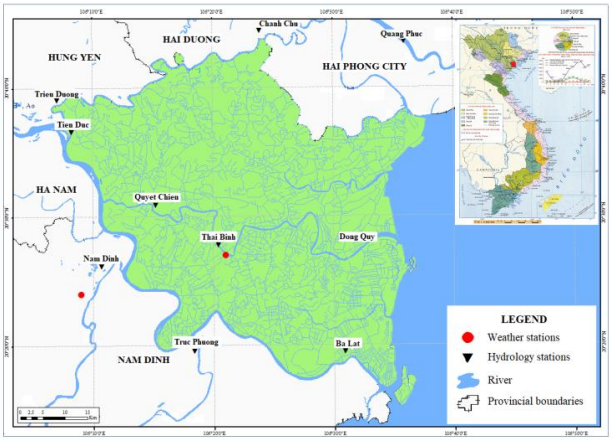


**Fig. 1 River network in Thai Binh province.**

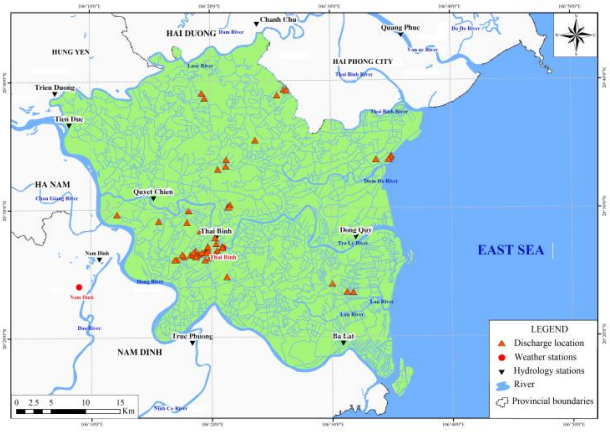


**Fig. 2 Location of discharge sites by administrative unit of Thai Binh province.**

#### 3.2.1 Trend of Annual Flow Changes

There is no hydrological station to monitor river water flow in Thai Binh province because the province is located in the area affected by the tide. Therefore, considering the cause of the river flow in this place, the rain is considered the main source of surface flow for rivers and replenishes groundwater for the aquifers. In addition, with characteristics located downstream of the Hong river-Thai Binh river basin, flow from major rivers on the Hong river-Thai Binh river system provides a large number of water resources for Thai Binh province. Therefore, to assess the trend of water resource change in major rivers in Thai Binh province, we can use the actual flow data measured at the water discharge station, on the Hong river branch such as Trieu Duong station, Quyet Chien station, and especially the flow measurement data at the Hanoi station, because

the Hanoi station is the upstream hydrological station, which controls the flow into Thai Binh province.

a) Changes in Flow Over Time

Analysis of the monthly flow distribution at Trieu Duong and Quyet Chien stations shows that the flow from July to September accounts for most of the total annual flow. However, it was found that the total flow in the period of 2000-2019 tended to decrease compared to the period of 1973-1999 at both measuring stations. The results of the seasonal flow distribution statistics and analysis show that at Quyet Chien station, the average flow in the flood season and dry season in the period of 1973-1999 tends to increase and maintain this trend in the period of 2000-2019; at Trieu Duong station, the flow in the flood season and dry season in the period of 1973-1999 tends to increase, while these characteristics tend to decrease in the period of 2000-2019; This is clearly shown through the monthly and the seasonal flow distribution at the hydrological stations in Thai Binh province. The statistical results of calculating the average annual flow, flood season, dry season show that at Quyet Chien station: the total annual flow volume in the period of 2000-2019 decreases by 5.8 billion $m^3$ compared to the period of 1973-1999, the average total volume of the flood season months and the total volume of dry season months at Quyet Chien station tend to decrease, however, the total volume of the driest month tends to increase from 0.38 billion $m^3$ in the period of 1973-1999 to 0.44 billion $m^3$ in the period of 2000-2019. At Trieu Duong station: total annual flow, a total of flood season months and total flow volume in dry season tend to decrease in recent years; it is similar to the flow change trend at Quyet Chien station, the total flow of the driest month tends to increase from 0.28 billion $m^3$ to 0.31 billion $m^3$.

b) Change in Flow by Space

The total annual flow volume by the administrative unit of Thai Binh province in the period of 1973-2019 shows that the total flow volume in this period tends to decrease the total volume by space, the flow passing through the northern districts of Thai Binh province tends to decrease more strongly than the districts in the south of Thai Binh province.

**Table 1 Annual flow volume by administrative unit of Thai Binh province.**

| **Period** | | **1973-1999** | | **2000-2019** | | **Total volume difference (billion $m^3$)** |
|---|---|---|---|---|---|---|
| **District/city** | Acreage ($km^2$) | Modul ($l/s/km^2$) | Total volume (billion $m^3$) | Modul ($l/s/km^2$) | Total volume (billion $m^3$) | |
| Hung Ha | 212.9 | 4308.5 | 28.9 | 3048.9 | 20.5 | -8.5 |
| Dong Hung | 205.8 | 4335.5 | 28.1 | 2998.7 | 19.5 | -8.7 |
| Vu Thu | 200.5 | 4389.6 | 27.8 | 2954.1 | 18.7 | -9.1 |
| Thai Binh City | 44.3 | 4324.0 | 6.0 | 2976.9 | 4.2 | -1.9 |
| Kien Xuong | 215.5 | 4254.8 | 28.9 | 2983,.5 | 20.3 | -8.6 |
| Quynh Phu | 208.4 | 4137.6 | 27.2 | 3016.2 | 19.8 | -7.4 |
| Thai Thuy | 257.7 | 4220.0 | 34.,2 | 3007.3 | 24.4 | -9.9 |
| Tien Hai | 217.5 | 4236.,0 | 29.1 | 2992.6 | 20.5 | -8.5 |

The calculation results of the annual flow of districts/cities of Thai Binh province show that: the total flow volume and flow modulus passing through the districts have tended to decrease in recent years, the reduction rates range from 1.9 billion $m^3$ to 9.9 billion $m^3$. It is found that the largest total flow volume is through Thai Thuy district and the smallest total flow volume is through Thai Binh province. Flow modulus in the period of 1973-1999 of districts ranged from 4200 $l/s/km^2$ to 4300 $l/s/km^2$ while in the period of 2000-2019 the range decreased from about 3000 $l/s/km^2$ to 3100 $l/s/km^2$. Therefore, the flow change trend is similar to the trend of rainwater change in Thai Binh province in recent years, both rainwater and flow tend to decrease

in volume, these analyses and assessments will help planners to come up with reasonable water use and sharing options for Thai Binh province and ensure socio-economic development in the current increasingly strong climate change context.

3.2.2 Trends in Surface Water Quality Changes

To assess the current status and changes in water quality in the river in Thai Binh province, the author uses the annual monitoring data of Thai Binh Department of Natural Resources and Environment: the annual monitoring data (chain of assessment from 2011 to 2019 with 28 positions in the system under the study area). After collecting, summarising, analysing and calculating, monitoring results of pollutants on rivers in Thai Binh province compared with the Standards issued by the Ministry of Natural Resources and Environment (QCVN 08-MT: 2015/BTNMT) according to the standard A2 column — Use for domestic water supply purposes but must apply appropriate treatment technology or for irrigation or navigation purposes and other purposes with low quality water requirements, the author found that the water quality on the main rivers and inland rivers of Thai Binh province has many complicated changes.

Table 2 shows the concentration of some substances on rivers in Thai Binh province by period and average in 2019.

**Table 2 Average concentrations of surface water pollutants on rivers in Thai Binh province, 2011-2019**

| River | TSS (mg/l) | | COD (mg/l) | | $BOD_5$ (mg/l) | | $NH4^+$(mg/l) | | Coliform (MNP/100ml) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Rainy season | Dry season | Rainy season | Dry season | Rainy season | Dry season | Rainy season | Dry season | Rainy season | Dry season |
| Hong | 30.0 | 30.8 | 16.6 | 16.7 | 7.4 | 7.3 | 0.19 | 0.18 | 4594 | 4478 |
| Hoa, Luoc | 31.4 | 32.8 | 18.7 | 19.2 | 7.6 | 7.4 | 0.22 | 0.21 | 4759 | 4507 |
| Tra Ly | 28.4 | 30.9 | 18.2 | 16.6 | 8.0 | 7.4 | 0.20 | 0.20 | 4453 | 4606 |
| Kien Giang | 31.0 | 32.2 | 26.7 | 26.1 | 11.4 | 11.6 | 0.86 | 0.91 | 9309 | 7796 |
| Tien Hung | 30.6 | 33.1 | 21.4 | 22.0 | 9.0 | 9.0 | 0.24 | 0.24 | 5525 | 5875 |
| Diem ho, Sa Lung | 31.7 | 34.8 | 26.0 | 24.4 | 11.6 | 10.4 | 0.26 | 0.45 | 6600 | 5868 |
| Some other inland rivers | 32.4 | 34.5 | 26.9 | 25.3 | 10.8 | 10.9 | 0.28 | 0.47 | 5580 | 5813 |
| **QCVN 08-MT:2015/ BTNMT (Column A2)** | **30** | | **15** | | **6** | | **0.3** | | **5000** | |

a) Water Quality Changes on Hong River (the Section Passing Through Thai Binh)

*TSS concentration:* It was found that the concentration of TSS in the dry season of the Hong river passing through Thai Binh province had the highest value of 50 mg/l in 2011, in the following years, the TSS concentration decreased until 2017, it tended to increase, and in 2019, there was a monitoring location with TSS concentration exceeding A2 threshold. Meanwhile, in the rainy season, the TSS concentration was higher than the dry season, and statistically, in the last 3 years, in the rainy season in 2017-2019, the TSS concentration at all monitoring sampling locations on the Hong river exceeded the A2 threshold.

*COD concentration:* Calculation results show that COD concentration on the Hong river tends to increase over the years, the graph of COD concentration in the dry and rainy seasons shows that in the past 3 years, COD concentration exceeded the A2 threshold in both rainy and dry seasons.

*$BOD_5$ concentration*: Results of $BOD_5$ concentration change in rainy and dry seasons at 4 water quality sampling locations in the Hong river basin show that $BOD_5$ concentrations exceed standards in both rainy and dry seasons with the largest $BOD_5$ concentration of 11.0 mg/l. It can be found that the highest $BOD_5$ concentration is in the position on the river, which flows through Nam Hai commune, Tien Hai district.

*$NH_4^+$ concentration:* the change of $NH_4^+$ concentration on the Hong river section in the dry and rainy season shows that the $NH_4^+$ concentration on this river section is still under the A2 threshold, but the concentration tends to increase over the years.

*Coliform concentration:* In the dry season, the concentration tended to decrease gradually, reaching below the A2 threshold in the last 2 years.

b) Water Quality Changes in Both Luoc and Hoa Rivers

*TSS concentration:* It can be found that the concentration of TSS in the dry and rainy season on the Luoc river tends to increase gradually, but on the Hoa river, the TSS concentration at the two test locations on the Hoa river exceeds the A2 threshold for both seasons. Meanwhile, the TSS concentration gradually decreased in 2019, below the A2 threshold for both the dry and rainy seasons.

*COD concentration:* The graph of COD concentration changes on both rivers in the rainy and dry seasons has tended to increase gradually in recent years, especially in the rainy season in 2019, COD concentration doubled compared to the average of previous years.

*$BOD_5$ concentration:* Analysis results of $BOD_5$ measurement at 03 sampling locations show that the $BOD_5$ concentration on Hoa River and Luoc River tends to increase in both rainy and dry seasons. The highest $BOD_5$ concentration is measured on the Hoa river in Thuy Truong commune, Thai Thuy district with a concentration of 11 mg/l, nearly double the standard A2; while in the dry season, the highest concentration is at the location on the Luoc River, section through An Khe commune, Quynh Phu district with the value of 11mg/l measured in 2017 and 2018.

*$NH_4^+$ concentration:* Basically, $NH_4^+$ concentration is still within the allowable limit in both the dry and rainy seasons on the Hoa and Luoc rivers and has tended to decrease gradually in 2019. There was only one location on the Hoa river with the $NH_4^+$ concentration exceeding the A2 threshold in the rainy season in 2017 with the value of 0.32 mg/l.

Coliform concentration: The graph of changes of Coliform concentration in the dry and rainy season on the Luoc river tended to decrease gradually in 2019, but the concentration of Coliform on the Hoa river in the rainy season tended to increase. At the measuring location in 2019, it exceeded the A2 threshold of 1000 MPN/100 ml.

c) Water Quality Changes on Tra Ly River

Through experimental analysis results in the room, the researcher found that the concentration of TSS in the rainy and dry seasons on the Tra Ly river in 2011 was quite high at the sampling locations. After that, the TSS concentration tended to decrease gradually, but from 2017-2019 the TSS concentration tended to increase and the location with the highest TSS concentration was at the beginning of the flow into the Thai Binh River — this is the intersection position, so it was affected by the water quality of Thai Binh river. In the rainy season from 2017 to 2019, the TSS concentration exceeded the A2 threshold at all 4 test locations along the Tra Ly river.

*COD concentration:* Sampling results from 2011 to 2019 in the rainy and dry seasons on the Tra Ly river showed that in 2016, COD concentrations decreased sharply, however, it tended to increase again in the period of 2017-2019. From 2017-2019, COD concentrations exceeded the A2 threshold at all sampling locations on the Tra Ly river in both the dry and rainy seasons.

*BOD5 concentration:* the graph of changes in $BOD_5$ concentration on Tra Ly river in the dry season and rainy season shows that: $BOD_5$ concentrations in the dry season have exceeded the A2 threshold from 2011 until now, the highest concentration was in 2016 with the value of 12 mg/l - double the A2 threshold at Duc Duong sewer, Tra Giang commune, Kien Xuong district, after that, it tended to decrease gradually from 2017 to 2019. In the dry season, the highest $BOD_5$ concentration was 13 mg/l in 2015 at Tra Ly bridge, and then gradually decreased over the years of

2016-2018, until 2019, the $BOD_5$ concentration tended to increase.

*$NH_4^+$ concentration:* According to analysis results, $NH_4^+$ concentration in the dry season on Tra Ly river from 2011 to 2019 tended to increase gradually, but still reached the A2 threshold. $NH_4^+$ concentration in the rainy season had 01 position exceeding the threshold at Tra Ly Bridge in 2019 with the concentration of 0.35 mg/l, exceeding the A2 threshold of 0.5 mg/l.

*Coliform concentration:* Coliform concentration changes on Tra Ly river showed that in the dry season, the highest concentration was in 2014 with the maximum value of 9000 MNP/100 ml, exceeding the A2 threshold of 4000 MPN/100 ml. In the rainy season, the highest concentration was nearly 7000 MPN/100 ml at Tra Ly bridge in 2019.

d) Water Quality Changes in Kien Giang River

*The TSS concentration* in Kien Giang river tends to increase in both rainy and dry seasons. The highest concentration of TSS in the dry season was 42 mg/l and in the rainy season, it was nearly 50 mg/l in 2019.

*COD concentration:* The graph of COD concentration in the dry and rainy seasons on the Kien Giang river showed that the COD concentration increased gradually from 2011-2014, then gradually decreased from 2014 to 2019. The highest COD concentration in 2014 was at Den bridge, Vu Phuc commune, Thai Binh city in the dry season was 50 mg/l and in the rainy season, it was 45 mg/l. COD concentrations on Kien Giang River exceeded the A2 threshold at all sampling locations in the rainy and dry seasons.

*$BOD_5$ concentration:* It was similar to the trend of changing COD concentration, $BOD_5$ concentration also increased gradually from 2011-2014 and tended to decrease from 2014-2019. The highest concentration of $BOD_5$ in the dry season is 27 mg/l at Phuc Khanh T-junction and in the rainy season is 22 mg/l. $BOD_5$ concentrations on Kien Giang river exceeded the A2 threshold at all sampling locations in the rainy and dry seasons.

*$NH_4^+$ concentration:* It can be found that at the two sampling locations, Phuc Khanh T-junction and Den bridge, Vu Phuc commune, $NH_4^+$ concentration exceeds the A2 threshold in both dry and rainy seasons. However, in 2019, the concentration of $NH_4^+$ decreased sharply, in the rainy season of 2019, there was no sampling location on the Kien Giang river with the NH4 concentration exceeding the A2 threshold. The highest concentration of $NH_4^+$ in the dry season in 2014 was at Phuc Khanh T-junction with the value of 3.7 mg/l. $NH_4^+$ concentration was highest in the rainy season in 2017 at the Phuc Khanh T-junction with a value of 2.2 mg/l.

*Coliform concentration:* Coliform concentration in the dry season increased sharply in 2014 with the largest value of 35000 MPN/100ml, 5 times higher than the A2 threshold, however, in the years of 2015-2019, the concentration decreased sharply and was relatively stable at over 10000 MPN/100ml. In the rainy season, Coliform concentration tends to decrease gradually. However, the concentration of Coliform in Kien Giang river exceeds the A2 threshold along the river in both dry and rainy seasons.

e) Water Quality Changes on Some Inland Rivers With Water Quality Measurement Locations

- Water quality changes on Tien Hung river

*TSS concentration:* In 2011, Tien Hung River was only measured at one location in Doan Hung commune, Hung Ha district. The graph of TSS changes in the dry and rainy season of Tien Hung River showed that the TSS concentration in 2011 (35 mg/l in the dry season and 54 mg/l in the rainy season) on the river was relatively high, then decreased gradually from 2012-2019, however, the TSS concentration was still above the A2 threshold in both dry and rainy seasons.

*COD concentration:* COD concentration exceeds the A2 threshold in both rainy and dry seasons on Tien Hung river, the highest value in the dry season was 28 mg/l in Doan Hung commune, Hung Ha district in

2011 and the highest value in the rainy season was 33 mg/l in 2012. However, we can see a gradual decrease in COD concentrations at the sampling locations on Tien Hung River from 2017-2019.

*$BOD_5$ concentration:* It was similar to the changing trend of COD, $BOD_5$ concentration on Tien Hung river, it also tended to decrease in 2019, $BOD_5$ concentration exceeded the A2 threshold by 1.5 to 2 times in both dry and rainy seasons. The highest $BOD_5$ concentration in the dry season was 12 mg/l in Doan Hung commune, Hung Ha district in 2016 and the highest value in the dry season was 11 mg/l.

*$NH_4^+$ concentration:* $NH_4^+$ concentration in the dry season was below the A2 threshold from 2011-2013 and 2015-2019, particularly in 2014, $NH_4^+$ concentration of Tien Hung river exceeded the A2 threshold with the highest value of 0.419 mg/l in Doan Hung commune, Hung Ha district. In the rainy season, most locations still have $NH_4^+$ concentration reaching the A2 threshold, except for the river section passing through Doan Hung commune, Hung Ha district.

Coliform concentration: Coliform concentration changes showed that: the highest concentration in the dry season was 8000 MPN/100 ml in 2014 at Tien Hung river in Doan Hung commune; the highest concentration in the rainy season was 9500 MPN/100 ml at the downstream of Nguyen bridge. The concentration of Coliform in the rainy season has tended to increase from 2017 to now.

- Water quality changes on Diem Ho and Sa Lung rivers

*TSS concentration:* The TSS concentration on Diem Ho river in the dry season is approximately the A2 threshold, while the TSS concentration in the dry season of Sa Lung river exceeds the threshold, the highest concentration in the dry season on Sa Lung River is 48 mg/l. In the rainy season, the TSS concentration in the Diem Ho river was highest in 2011 with a value of 51 mg/l, then gradually decreased over the years to reach below the A2 threshold, however by 2019, the TSS concentration in the rainy season on the Diem Ho river increased to 45 mg/l, exceeding the A2 threshold. The trend of TSS changes in the rainy season on the Sa Lung River is similar to that of the Diem Ho River, the TSS concentration decreased from 2011 to 2018 and then increased in 2019.

*COD concentration:* COD concentration in the dry season on 2 rivers was constantly changing: decreasing from 2011 to 2014, increasing from 2015-2016 and then decreasing from 2017-2018, increasing again in 2019. The concentration of COD in the rainy season tended to decrease from 2015-2019, the highest concentration on the Sa Lung river was 39 mg/l in 2015 and the highest concentration on the Diem Ho river was 25 mg/l in 2014.

*$BOD_5$ concentration*: $BOD_5$ concentration tended to increase gradually from 2014 to 2019 on both Diem Ho and Sa Lung rivers. The $BOD_5$ concentration in the rainy season increased from 2011 to 2015 and then tended to decrease from 2016 to 2019. The $BOD_5$ concentrations exceeded both the dry and rainy seasons on the Diem Ho and Sa Lung rivers.

*$NH_4^+$ concentration:* $NH_4^+$ concentration in the dry season on Diem Ho river tended to increase from 2011 to 2019 and only exceeded the A2 threshold in 2019, while the concentration of $NH_4^+$ in the dry season on the Sa Lung River strongly changed, the concentration of $NH_4^+$ exceeded the A2 threshold in 2011-2013 and 2019. $NH_4^+$ concentration in the rainy season on Diem Ho river increased from 2011-2016 and then decreased gradually. The concentrations in 2016 and 2018 exceeded the A2 threshold. The concentration of $NH_4^+$ in the rainy season on the Sa Lung River increased from 2011 to 2017, the highest concentration in 2017 was 1.0mg/l, decreased in 2018 and increased again in 2019.

*Coliform concentration:* Coliform concentration in the dry season on Diem Ho river does not change much, the concentration has changed around the A2 threshold over the years of monitoring; while the concentration on the Sa Lung River tended to decrease gradually from 2014 to 2019. Coliform concentration in the rainy

season tended to increase on both rivers, the concentration in 2018 and 2019 increased gradually and both exceeded the A2 threshold.

- Changes in water quality on some other inland rivers with water quality measurement locations

*TSS concentration:* It can be found that the TSS concentration in the dry and rainy season on some inland rivers in Thai Binh province in 2011 was the highest, the maximum value in the dry season was 46 mg/l and the rainy season was 55 mg/l in 2011. After that, the TSS concentration in rivers tends to decrease gradually. In 2018 and 2019, the TSS concentration was lower than the A2 threshold.

*COD concentration:* COD concentration exceeded the A2 threshold on all inland rivers in both rainy and dry seasons with the highest value in the dry season of 50 mg/l on the Long Hau river in 2013; the rainy season was 38 mg/l on the Long Hau river in 2016.

*$BOD_5$ concentration:* $BOD_5$ concentration exceeding the threshold on all inland rivers has a real value measuring analysed water quality in both the dry and rainy seasons. The highest $BOD_5$ concentration in the dry season was 16 mg/l in the Long Hau river in 2016 and the highest in the rainy season was 18 mg/l in the Paris River in 2015.

*$NH_4^+$ concentration:* $NH_4^+$ concentration in the dry season on rivers: Paris river, Co river, Lu river reached the A2 threshold while that of Long Hau, Long and Cau Go rivers exceeded the A2 threshold with the highest $NH_4^+$ value of 0.67 mg/l in the Long Hau river in 2013. The concentration of $NH_4^+$ in the rainy season on the Pai River, Co River, and Lu River is below the A2 threshold, the concentration of Cau Go, Long River and Long Hau River exceeds the A2 threshold and the highest value is 1.8 mg/l.

*Coliform concentration:* Coliform concentration in inland rivers exceeds the A2 threshold in dry and rainy seasons. The highest concentration of Coliform in the dry season was 8600 MPN/100 ml on Cau Go river in 2013 and the highest concentration of Coliform in the rainy season was 10000 MPN/100ml on Long Hau river in 2013.

### *3.3 Proposing a Number of Solutions to Limit the Risks Caused by Changes in Surface Water Resources in Thai Binh Province to 2030, Orientation to 2035*

The above overview shows that surface water resources in Thai Binh province, in general, tends to decrease in recent decades, especially in the context of climate change, the temperature tends to increase and sea level increases; This will increase the risk of reducing rainwater and flow in Thai Binh province, and at the same time increasing saline intrusion into major rivers and inland rivers. In addition, the increasingly strong socio-economic development, especially the development of industrial clusters and industrial parks, increases the source of untreated waste into the natural environment, which increases the risk of water quality degradation in rivers in the province. Facing the current trend of surface water resources changes, the author has proposed a number of solutions to protect surface water resources for Thai Binh province to serve the sustainable socio-economic development of the province until 2030, orientation to 2035 as follows:

3.2.1 Non-work Solutions

- Issue legal documents on water resources; Establish mechanisms and policies for economical, efficient and sustainable water exploitation and use under the authority of the Provincial People's Committee, creating a full legal corridor for the management associated with environmental protection of all kinds of water resources in general and surface water resources in particular.

- Develop systems, tools and software to manage and supervise the exploitation, operation and use of surface water resources and groundwater resources.

- Strengthen the popularization and education on the law on exploitation and sustainable use of water resources.

- Promote the licensing of exploitation and use of water resources in accordance with the law.

- Invest in researching and building a system for monitoring, warning, and notification of water quality and water pollution incidents in Thai Binh province.

- Improve the responsibilities of wastewater management units, monitor wastewater discharge activities of industrial parks and industrial clusters after they are put into operation.

- Develop programs and plans to invest in technical equipment to serve the state management on water resources at the provincial level.

- Promote scientific and technical research and transfer of technology for the economic exploitation and use of water resources; solutions for water resource development, using a combination of surface water and groundwater; build and perfect models for integrated river basin management.

3.2.2 Work sSlutions

- Invest in the construction of concentrated wastewater treatment plants for districts of Thai Binh province.

- Build a wastewater collection system for livestock and crops to apply effective treatment methods to ensure that wastewater meets the permitted standards before being discharged into rivers and lakes in the province.

The main cause of water shortage is the lower water level, the works on the river cannot exploit water. For water exploitation to ensure that according to the selected allocation plan, it is necessary to upgrade, create and build new water resources regulating, exploiting and developing works. Specifically:

- Study the construction of works blocking large estuaries: Barrage on Tra Ly river; improve and upgrade culverts under dykes, pumping stations; dredge the main shaft of the river, grade 1; solidify the system of irrigation and drainage canals; solidify some main axis rivers; modernize the irrigation system.

- Implement approved irrigation planning:

+ Upgrade culverts under dykes: Dredge river leading behind culverts to ensure water supply for Dai Nam (Quynh Phu) and Tan De (Vu Thu) areas. At the same time, in order to ensure that there is no danger of water shortage, it is necessary to upgrade Duc Duong culvert; repair Nham Lang culvert; Viet Yen (Hung Ha), the North of Kien Xuong district and supplying power to Thong Nhat pumping station (Tien Hai).

+ Invest in dredging main rivers and river branches to ensure irrigation for the whole system such as dredging Tien Hung and Sa Lung rivers.

+ Dredge the grade II rivers of Tien Hung river increases the capacity of water carrying and water storage: Yen Long, Ba Trai River, Dong Cong River, Hoang Nguyen River, Cua Bac River, River 217, Sa Lung River - Dong Xuan. Dredge the grade II rivers of Kien Giang river: Cu Lam River, Bung River, Lang River, Sung River, Bach River, Ngu Tong River, Ngo Xa River, Hoang Giang River, Bong Tien River, Vua Roc River, Lam Giang River, Huong river, Coc Giang river.

+ Build new Phu Lac culvert (B = 3 m, Zd= -1.0) to supplement water source for Hong An - Hung Ha area.

- Study and propose building an automatic monitoring network, monitor exploitation, use and protection of water resources in the province. Strengthen the work of water environment protection in urban areas and industrial parks, delineate linens for hygiene protection and prohibit exploitation.

- Build irrigation systems, dykes to prevent saline intrusion. Develop an appropriate irrigation regime for areas planned for rice production, aquaculture zones, develop a process of opening and closing a reasonable saline prevention culvert to meet the requirements of taking saltwater, preventing salinity, discharging alum and storing fresh;

- Improve and rational use of saline soil: The system of canals passing through the alum soil areas need to choose reasonable solutions to limit the oxidation of acid-generating materials causing acidity in surrounding areas and groundwater sources;

- Water management in inland canals must be calculated according to the washing regime, irrigation regime for all crops;

- Invest in building saline prevention culverts at estuaries; Repair and upgrade existing saline prevention culverts,

- Build irrigation areas typical for aquaculture, specializing in vegetables and crops for export (oriented to use crops and animals in saline areas such as rice model, aquaculture model, etc.). Build embankments to protect Con Vanh, Con Den in order to efficiently exploit Con Vanh, Con Den areas.

## 4. Conclusion

The results in the report show that:

The upper surface flow volume of rivers flowing in Thai Binh province depends very much on the distribution of water resources from the upstream hydrological stations. After monitoring the total annual flow of the districts in Thai Binh province in the period of 1973-1999 and 2000-2019, it shows that the total flow volume passing through the Northern districts of Thai Binh province tends to decrease more strongly than the districts in the south of Thai Binh province.

In terms of surface water quality in the study area, the main cause of pollution is industrial production activities, livestock breeding, cultivation and wastewater from urban areas and service activities. According to the evaluation results of the monitoring data series from 2011 to 2019, the author concludes: the water quality of rivers in Thai Binh province has concentrations of TSS, COD and BOD5 exceeding the permitted standard A2. And the indicators NH4 and Coliform are only local pollutions at a few times. Thus, up to now, the water quality on rivers in Thai Binh province only ensures the water supply for irrigation purposes, water in the river can still be supplied for domestic use but needs to be treated before being used.

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