TẠP CHÍ ISSN: 1859-316X, e-ISSN: 3093-3161
KHOA HỌC CÔNG NGHỆ HÀNG HẢI
JOURNAL OF MARINE SCIENCE AND TECHNOLOGY

ANALYSIS AND EVALUATION OF DESIGN WATER LEVELS ALONG THE COAST OF VIETNAM USING OBSERVED DATA AT SEVERAL OCEANOGRAPHIC STATIONS

PHÂN TÍCH VÀ ĐÁNH GIÁ CÁC MỰC NƯỚC THIẾT KẾ DỌC BỜ BIỂN VIỆT NAM THEO DỮ LIỆU ĐO ĐẠC THỰC TẾ TẠI CÁC TRẠM ĐO

NINH THU TRANG[1], LE THI HUONG GIANG[1*], NGUYEN QUANG LUONG[2]

[1]Faculty of Civil Engineering, Vietnam Maritime University

[2]Faculty of Civil Engineering, Thuyloi University

**Corresponding email: gianglh.ctt@vimaru.edu.vn*

DOI: https://doi.org/10.65154/jmst.2025.i84.891

Abstract

The article presents the results of water level characteristics (tidal water level, meteorological surge) at monitoring stations in the past 30 years. Analysis of extreme values corresponding to probabilities at observational stations comparing the design water level of sea dikes from Quang Ninh to Kien Giang (available in Vietnam Standard TCVN 9901:2023) shows a very large difference, the larger the recurrence period, the larger the water level difference. In particular, at Hon Dau station, Hon Ngu station and Vung Tau station, the design water level according to Vietnam Standard (TCVN) is higher than the analysis from measured data, on the contrary, at Son Tra and Quy Nhon stations, the water level according to Vietnam Standard TCVN 9901:2023 is lower than the design water level from observed data.

Keywords: *Design water level, meteorological surge, tidal water level, probability.*

Tóm tắt

Bài báo trình bày kết quả các đặc trưng mực nước (Mực nước triều, nước dâng do khí tượng) tại các trạm quan trắc trong 30 năm qua. Phân tích các giá trị cực trị tương ứng với tần suất tại các trạm đo thực tế, so sánh với mực nước thiết kế của đê biển từ Quảng Ninh đến Kiên Giang (theo Tiêu chuẩn Việt Nam TCVN 9901:2023) cho thấy sự chênh lệch rất lớn; chu kỳ lặp lại càng dài thì chênh lệch mực nước càng lớn. Đặc biệt, tại các trạm Hòn Dấu, Hòn Ngư và Vũng Tàu, mực nước thiết kế theo Tiêu chuẩn Việt Nam (TCVN) cao hơn so với kết quả phân tích từ số liệu đo đạc thực tế; ngược lại, tại các trạm Sơn Trà và Quy Nhơn, mực nước theo TCVN 9901:2023 lại thấp hơn mực nước thiết kế từ số liệu đo đạc thực tế.

Từ khóa: *Mực nước thiết kế, nước dâng do khí tượng, mực nước triều, tần suất.*

1. Introduction

Vietnam has a coastline of 3,260km, located on the west coast of the East Sea. In particular, the tidal characteristics are very diverse in nature and magnitude, stretching from North to South [1]. This area is directly and most strongly influenced by important atmospheric pressure zones, which are the equatorial-tropical low pressure trough passing through the area, the subtropical high pressure band in the north and the Indian Ocean high pressure in the south. Due to the process of continental-oceanic interaction, these atmospheric pressure zones have large differentiation and fluctuations according to the annual cycle, with a typical monsoon regime. Sea level fluctuations in the coastal area of Vietnam include tidal oscillation bands, synoptic oscillations and long-term scales. Tidal oscillations have periodic components and energy correlations between diurnal, semi-diurnal and shallow water groups that are different in different coastal sections. Synoptic oscillations have periods of several days and contribute significantly to the overall variance of water levels. In addition to the tidal oscillation component that plays the largest role, there are other oscillations with significant amplitudes such as water level oscillations due to the influence of storms and monsoons [2]. According to the results of the study evaluating the accuracy of the design water levels according to the sea dike design technical standards (2012 version) at 9 coastal locations from Quang Ninh to Kien Giang, there are quite large discrepancies [3].

The study of extreme water levels is one of the most important issues in the design of coastal structures. In order for the extreme value analysis results to be close to reality, the input data must have

a series of continuous years of stational data. Therefore, this paper used a series of data of about 30 years at 5 oceanographic stations along Vietnamese coast (see Fig.1) for a comparative analysis of the design water levels of sea dike structures (Vietnam Standard TCVN 9901-2023) [4].

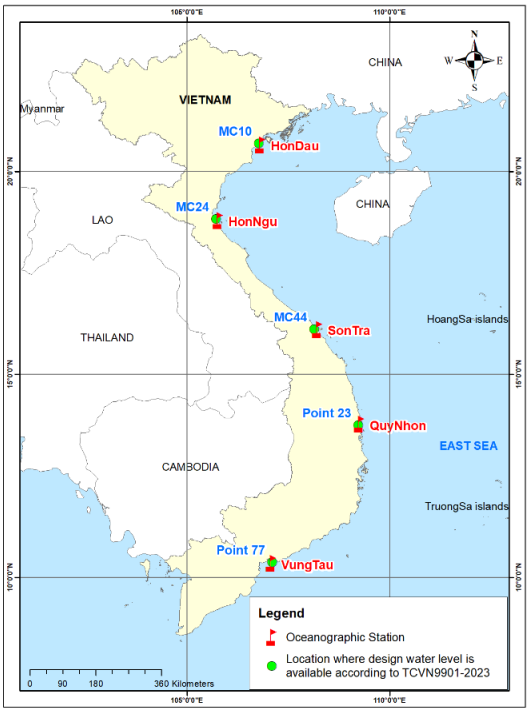

Figure 1. Locations of oceanographic stations and available design water levels according to Vietnam Standard TCVN 9901-2023

2. Research methodology

The main tidal analysis methods that have been built and developed include: nonharmonic analysis, harmonic analysis, and response analysis [5, 6]. The similarity of these tidal analysis methods is the application of the relationship between astronomical knowledge and sea level changes shown through observation data. In order to determine the extreme water levels, the theoretical probability curves at the observation stations are built using the Pearson-III probability distribution integration method and the initial statistical parameter set is calculated using the moment method.

3. Results and discussion

3.1. Analysis and evaluation of tidal regime

The tidal regime determined from the results of harmonic analysis of tidal data can be determined through one of two form factors with the general calculation method being the ratio between the total amplitude of typical diurnal waves and the amplitude of typical semi-diurnal waves: The form factor F according to Defant [7] or the form factor K according to Duvanin [8] and Courtier [6]. Each form factor is accompanied by a different corresponding tidal regime classification scale [7, 8].

The formulas and scales for the classification of tidal regimes by means of the two coefficients F and K are listed as follows:

$$F = \frac{A_{K1}+A_{O1}}{A_{M2}+A_{S2}} \quad (1)$$

$0 \le F < 0.25$: Semi-diurnal;

$0.25 \le F < 1.5$: Mixed, mainly semi-diurnal;

$1.5 \le F \le 3.00$: Mixed, mainly diurnal;

$F > 3.00$: Diurnal.

$$K = \frac{A_{K1}+A_{O1}}{A_{M2}} \quad (2)$$

$0 \le K < 0.5$: Semi-diurnal;

$0.5 \le K < 2.0$: Mixed, mainly semi-diurnal;

$2.0 \le K \le 4.00$: Mixed, mainly diurnal;

$K > 4.00$: Diurnal.

Note: $A_{K1}, A_{O1}, A_{M2}, A_{S2}$: Amplitude of water level fluctuations due to the effects of corresponding tidal.

Table 1. Amplitude of tidal waves, calculation results of form factor coefficient, and tidal regime

No.	Station	Tidal wave amplitude				Form factor coefficient		Tidal regime
		O1	K1	M2	S2	*F*	*K*	
1	Hon Dau	0.741	0.673	0.056	0.043	14.33	25.44	Diurnal
2	Hon Ngu	0.53	0.453	0.276	0.092	2.67	3.56	Mixed, mainly diurnal
3	Son Tra	0.109	0.178	0.173	0.057	1.24	1.65	Semi-diurnal
4	Quy Nhon	0.26	0.316	0.175	0.07	2.36	3.3	Mixed, mainly diurnal
5	Vung Tau	0.421	0.574	0.778	0.302	0.92	1.28	Mixed, mainly semi-diurnal

TẠP CHÍ ISSN: 1859-316X, e-ISSN: 3093-3161
KHOA HỌC CÔNG NGHỆ HÀNG HẢI
JOURNAL OF MARINE SCIENCE AND TECHNOLOGY

Table 2. Characteristic tidal levels at oceanographic stations

Characteristic tidal level (m)						
Notation	**Definition**	**Hon Dau**	**Hon Ngu**	**Son Tra**	**QuyNhon**	**Vung Tau**
HAT	Highest Astronomical	1.97	1.45	0.74	1.05	1.58
MHW	Mean High Water	1.07	0.76	0.31	0.51	0.99
MSL	Mean Sea Level	0	0	0	0	0
MLW	Mean Low Water	-1.06	-0.95	-0.36	-0.54	-1.53
LAT	Lowest Astronomical Tide	-1.81	-1.65	-0.75	-1.12	-2.86

Table 3. Results of comparing design water levels by probability at oceanographic stations

Probability (%)	WATER LEVEL (m)														
	Hon Dau			Hon Ngu			Son Tra			Quy Nhon			VungTau		
	Observed	MC10 (TCVN 9901:2023)	Discrepancy	Observed	MC 24 (TCVN 9901:2023)	Discrepancy	Observed	MC 44 (TCVN 9901:2023)	Discrepancy	Observed	Point 23 (TCVN 9901:2023)	Discrepancy	Observed	Point 77 (TCVN 9901:2023)	Discrepancy
0.5	2.3	4.75	2.3	2.2	4.55	2.3	2.0	2.1	0.0	2.0	1.35	-	1.8	2.83	0.9
1	2.3	3.994	1.6	2.1	3.894	1.7	1.9	1.695	-	1.8	1.189	-	1.8	2.458	0.
2	2.3	3.381	1.0	2.0	3.305	1.2	1.7	1.387	-	1.7	1.101	-	1.7	2.112	0.
5	2.2	2.727	0.4	1.9	2.608	0.6	1.5	1.056	-	1.4	1.078	-	1.6	1.734	0.
10	2.1	2.322	0.1	1.8	2.136	0.2	1.3	0.852	-	1.3	1.07	-	1.6	1.641	-
20	2.1	1.971	-	1.7	1.706	-	1.1	0.681	-	1.1	1.052	-	1.6	1.579	-
50	1.9	1.535	-	1.5	1.196	-	0.9	0.496	-	0.9	1	0.0	1.5	1.557	0.
99.9	1.1	1.153	0.0	1.2	0.85	-	0.7	0.364	-	0.7	0.876	0.1	1.3	1.474	0.

The results of the analysis of tidal levels (see Tables 1, 2) show that the magnitude and characteristics of tides also change along the coast of Vietnam. Hon Dau station has a **diurnal tidal regime** with the magnitude of 3.78m. Hon Ngu station and Quy Nhon station have **mixed, mainly diurnal tidal regime**, in which the number of diurnal tides is more than that of semi-diurnal tides; the tidal magnitudes at Hon Ngu station and Quy Nhơn station are 3.1m and 2.17m correspondingly. Son Tra station and Vung Tau station have **mixed, mainly semi-diurnal tidal regime**, in which the number of semi-diurnal tides is more than that of diurnal tides; the tidal magnitudes at Son Tra station and Vung Tau station are 1.49m and 4.4m correspondingly.

Derived meteorological surges along the coast of Vietnam within each year are analyzed (see Fig. 2). The yearly highest surges at the stations show a gradual decrease from North to South. The areas with high surge of greater than 1m frequently occurs is from Hon Dau station to Son Tra station. This area is often affected by storms. The highest surge is at Hon Ngu station (1.79m).

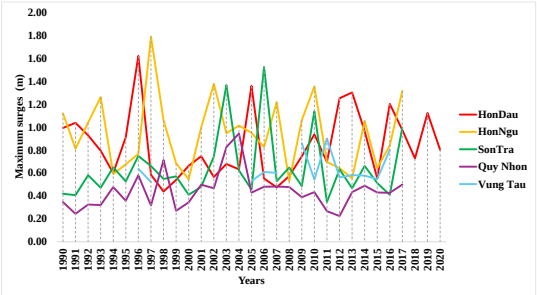

Figure 2. Maximum surges at various oceanographic stations (1990-2020)

3.2. Design water level

The comparison results of water levels according to the probabilities of the monitoring stations and Vietnam Standard TCVN9901-2023 show differences along the coast from North to South (See Table 3, Figs 3, 4).

At Hon Dau station (***diurnal tidal regime***) corresponding to Cross-section 10 in Vietnam Standard TCVN 9901-2023. The design water level corresponding to probabilities >2%, Vietnam

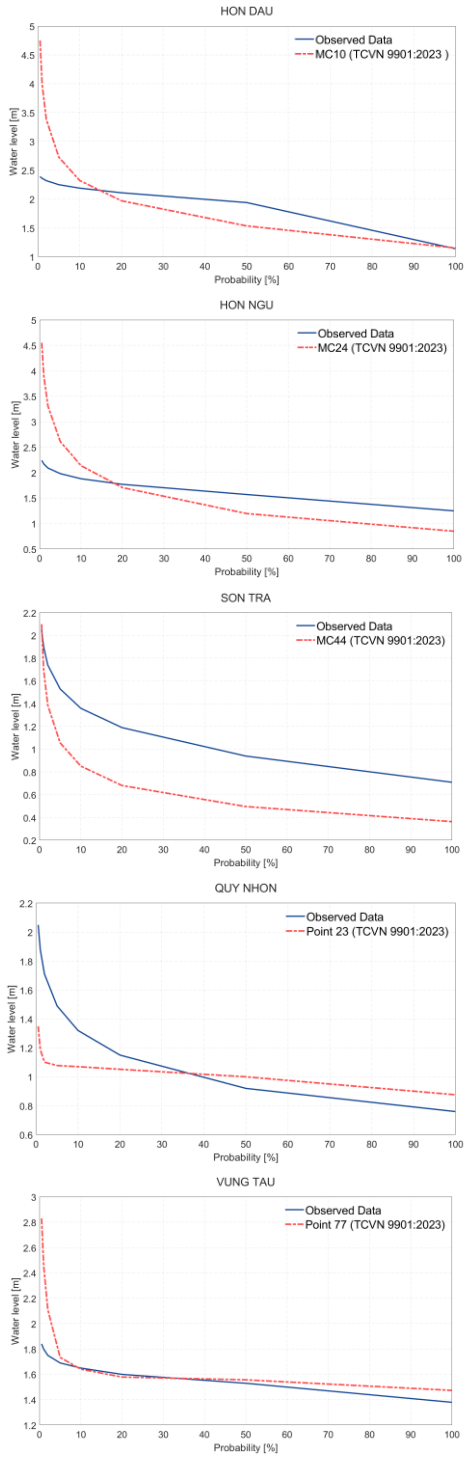

Figure 3. Extreme water levels according to observed data and Vietnam Standard TCVN9901:2023 at 5 stations

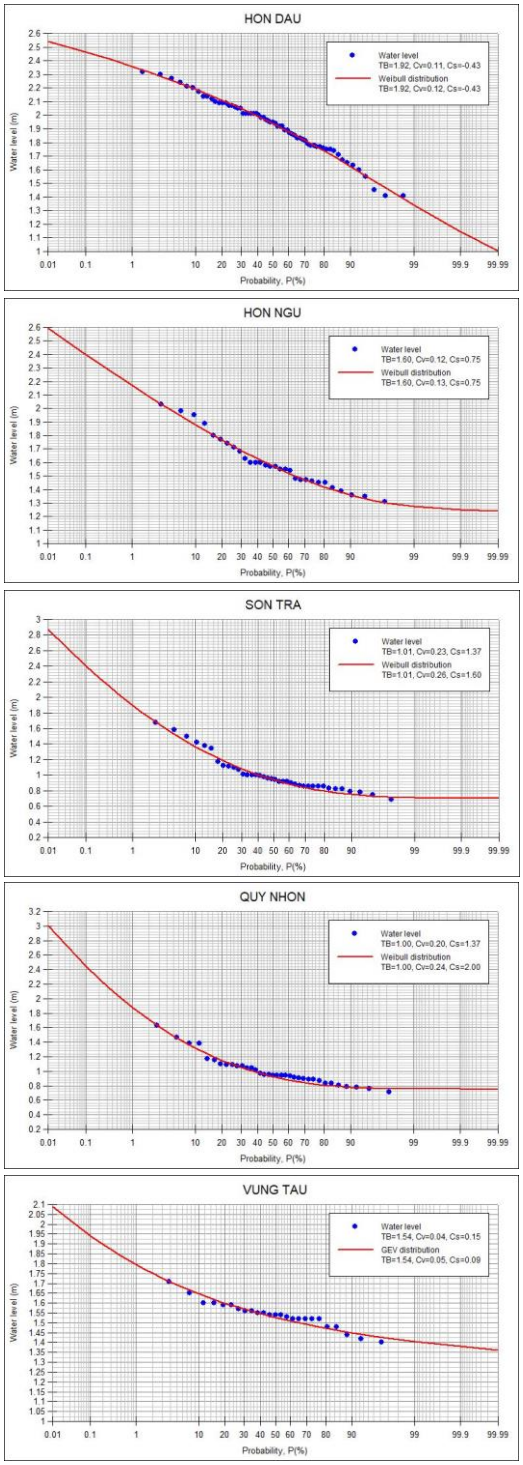

Figure 4. Water level probability curve at observational stations

Standard TCVN 9901-2023 is higher than the observation from 1.06 to 2.23 m (45.7-98.7% higher) and the probability from 10% to 5% is higher from 0.13 to 0.48 m (6-21.2% higher). On the contrary, the design water level <10%, Vietnam Standard TCVN 9901-2023 is lower than the observation by 0.14-0.41m.

At Hon Ngu station (***mixed, mainly diurnal tidal regime***) corresponding to Cross-section 24 in Vietnam Standard TCVN 9901-2023. The design water level

TẠP CHÍ ISSN: 1859-316X, e-ISSN: 3093-3161
KHOA HỌC CÔNG NGHỆ HÀNG HẢI
JOURNAL OF MARINE SCIENCE AND TECHNOLOGY

corresponding to the probability >2%, Vietnam Standard TCVN 9901-2023 is higher than the observation from 1.22m to 2.31m (58.1-103.1% higher) and the probability from 10% to 5% is higher from 0.26m to 0.63m (12.6-31.7% higher). On the contrary, the design water level <10%, Vietnam Standard TCVN 9901-2023 is lower than the observation by 0.06-0.4m.

At Son Tra station (***mixed, mainly semi-diurnal tidal regime***) corresponding to Cross-section 44 in Vietnam standard TCVN 9901-2023. The design water level in Vietnam Standard TCVN 9901-2023 is lower than the observation from 0.21-0.51m. At Quy Nhon station (***mixed, mainly diurnal tidal regime***) corresponding to Cross-section 23 in Vietnam Standard TCVN 9901-2023. The design water level corresponding to probabilities >20% is lower than Vietnam Standard TCVN from 0.1m to 0.7m (8.5-34.1% lower) than the observation. On the contrary, the design water level is higher than the observation from 0.08m to 0.12m.

At Vung Tau station (***mixed, mainly semi-diurnal tidal regime***) corresponding to Cross-section 77 in Vietnam Standard TCVN 9901-2023. Design water level corresponding to probabilities >10%, Vietnam standard TCVN 9901-2023 is higher than observation from 0.04m to 0.99m (2.6-53.8% higher).

4. Conclusion

The analysis results from the 30-year water level observation series at oceanographic stations show the diverse tidal characteristics along the coast of Vietnam. In addition to the dominant tidal level, Vietnamese coast is also affected by meteorological surges (seasonal and storm) with heights greater than 0.25m and 1.0m in case of storms depending on the location of the storm. The extreme value analysis results show that the design water level in the Vietnam Standard TCVN 9901:2023 has a very large error compared to the observation. Especially the rare probabilities greater than 2% are very different (up to 103.1%). In the North and South, the design water levels according to Vietnam Standard (TCVN) are higher than the actual ones. Whereas, in Central Vietnam, the design water levels are lower. This is the input data for calculating other characteristics such as design waves. If the water level is high, the waves will travel deeper, causing large impacts on the structure. Conversely, if the design water level is low, the wave impacts on the structure will be small. Therefore, when calculating and designing, it is necessary to check, monitor, measure and continuously update over time up to the design phase.

REFERENCES

[1] Pham Van Huan (2002), *Marine Dynamics - Part 3: Tides* , VNU Publishing House, Hanoi.

[2] Hoang Trung Thanh (2011), *Research on characteristics of sea level variation along the coast of Vietnam*, Doctorate Thesis in Geography, Institute of Meteorology, Hydrology and Environment, Hanoi.

[3] Nghiem Tien Lam (2013), *Assessment of the accuracy of design water levels according to the technical standards for sea dike design (2012 version)*. Proceedings of the 2013 Annual Scientific Conference, pp.169-170;

[4] TCVN 9901:2023 (2023), *Sea dikes - Design requirements*, Appendix B.

[5] Codiga, DL (2011), *Unified Tidal Analysis and Prediction Using the UTide Matlab Functions*, GSO Technical Report, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, 59p.

[6] Courtier, A. (1938), *Classification of Tides in Four Types, Conférences sur les Marées*, Service Hydrographique de la Marine Française, Paris, pp.50-58.

[7] Defant, A. (1961), *Physical Oceanography*, Vol II.

[8] Duvanin (1897), *AI, Tides and Tidal stream in the Indian Archipelago*, Batavia.

Received:	07/08/2025
Revised:	30/10/2025
Accepted:	30/10/2025