

Response to Reviewers' Comments

On manuscript Number: **NHESS-2024-176**

Title: Catastrophic beach erosion induced by littoral drift on nearby beach after Samcheok LNG's massive coastal reclamation project

R#: Reviewer number (1, 2); **C#**: Comment/Response number; **A**: Authors' response.

Line number in **Marked** copy of **R1** manuscript: **L#**

Note: Words/phrases/sentences that represent the response to the Editor and Reviewers' comments are highlighted in **BLUE/RED** color in the revised manuscript, while those from our own revision are also typed in **BLUE/RED**.

A **Clean** copy is also produced, upon deleting the parts struck out and retaining only those newly added in **BLUE/RED**.

First of all, the author would like to express sincere thanks to the editor and two reviewers who reviewed this paper. The author responded to all comments individually in the following sections. Please refer to the line numbers in the two reviewers' comments (**R#-C#**) are information about the manuscript before correction and supplementation.

Reviewer #1:

Reviewer #1: A. General comments

R1-C0: Reviewer X has read the manuscript (MS) for "nhess-2024-176" (PDF).

This MS reports the analysis of 10 satellite images of beach changes (2021.03.13 to 2022.12.12) at Samcheok LNG terminal, verification of beach changes using numerical calculations (with longshore transport, LST) and empirical bay shape model (PBSE – Hsu and Evans, 1989 with software MeePaSoL – Lim et al., 2021), and suggestion applying groins to protect/prevent beach from erosion prior to the construction of a large-scale coastal development project.

Overall, the layout of the presentation (e.g., sections and sub-sections) is in good order and all results are valuable for coastal managers, planners, and engineering consultants on a large-scale coastal project, from which beach erosion and shoreline rotation could occur, during or after the construction, arising from changes of nearshore wave field.

The title of the MS "Catastrophic beach erosion induced by littoral drift on nearby beach after Samcheok LNG's massive coastal reclamation project" is catchy and attractive, especially in using the words "catastrophic" and "massive". In reality, beach erosion downdrift of a harbor breakwater is the norm, which has been known for decades and also documented (e.g., Hsu et al., 1993; Hsu et al., 2000; Uda, 2010). Therefore, the state of beach erosion at the scale of about 40 m may be referred as "severe", which can be expected, instead of "catastrophic".

In addition, the beach that suffered erosion is not at "nearby", but more specifically at "downdrift", or "immediately downdrift". The main cause to erosion at Samcheok was not directly "induced by littoral drift", instead, it was associated with "wave-induced nearshore circulation that transported sediment within the shadow zone of the diffracted waves in the lee of a harbor breakwater or detached breakwater" (e.g., Gourlay, 1974; 1981). In addition, the preventive strategy using groins to control erosion can be found in Hsu et al. (2000), who reported examples of Japanese experience in the 1970-80s.

A1-C0: Thank you for your positive comments on this paper. Following your comments and combining it with the suggestions from other reviewers, we have revised the title to "Severe

beach erosion induced by shoreline deformation after a large-scale reclamation project for Samcheok LNG terminal in Korea."

Regarding your comments on "induced by littoral drift", since the nearshore circulation caused by diffraction ultimately leads to littoral drift and results in erosion, we consider these expressions to be similar. For further clarification, we have also added your comment to the revised version. Additionally, we have added the reference you mentioned, Hsu et al. (2000), to the discussion section as follows.

Reviewer #1: B. Specific Comments

R1-C1: (L1-2) Title of the paper: Suggestion --- May be modified as

“Severe beach erosion induced by shoreline rotation after a large-scale reclamation project for Samcheok LNG terminal in Korea”?

A1-C1: We have revised the title as you suggested:

Severe beach erosion induced by shoreline deformation after a large-scale reclamation project for Samcheok LNG terminal in Korea

R1-C2: (L30-31) “These marine life habitats contribute to water pollution, significantly affecting marine ecosystems and jeopardizing coastal infrastructures, housing, and facilities, ...”: Is this statement correct?

A1-C2: The sentence in your comment was removed as it was deemed unnecessary and inappropriate to the topic of the paper, although it can be confirmed in the cited reference.

R1-C3: (L43-45) “... the double headland method..., it resulted in excessive diffracted waves...”: What is the “excessive” in diffracted waves?

A1-C3: The expression “excessive diffraction waves” was deemed inappropriate and changed to “excessive beach distribution by diffraction waves”.

R1-C4: (L47-48) “Changing wave fields caused by ports and coastal structures influence coastal sediment transport, leading to shoreline alterations and erosion.”:

What was the mechanism behind this phenomenon?

A1-C4: Beach erosion caused by coastal structures is a topic covered in many literatures. However, there were some awkward parts in the expression in the sentence, so we modified it as follows. We also cited a paper that covered this mechanism.

- Wave deformation caused by coastal structures mainly influences the longshore sediment transport, leading to shoreline reshaping (Lim et al., 2021).

R1-C5: (L52-53) “... LST is considered more influential than episodic cross-shore sediment transport in driving significant shoreline change over extended periods.”:

Should we say that “LST” was the consequence of the change in nearshore wave field, but not the direct or primary cause to erosion at Samcheok?

(See the last paragraph under A. Specific Comments)

A1-C5: Based on your comment, we have replaced it with the following:

- LST, which is a consequence of the change in the nearshore wave field, is considered more influential than episodic cross-shore sediment transport in driving significant shoreline change over extended periods.

R1-C6: (L70-71) “ ... significant wave diffraction from reclaimed revetment or breakwaters constructed outside ports.”:

Why “significant wave diffraction”? What is the “reclaimed revetment” and “breakwaters constructed outside ports”?

A1-C6: To make it clearer, the sentence has been revised as follows:

- Although this model is widely used in engineering consulting, it underestimates results in scenarios with wave diffraction from large-scale coastal structures (Lee and Hsu, 2017).

R1-C7: (L124-127) “...The coastal waters of Samcheok...have high waves. ... Wolcheon Beach, the root mean square (RMS) wave height is estimated to be 1.14 m...”:

Should we classify wave height in the order of 1.14 m as “high wave”? (See also Fig. 3a for wave height)

A1-C7: The expression “high wave” was removed because it was judged not to meet global classifications.

R1-C8: (L128-137) “Figure 4...the resulting rose diagram of LST components (green: north, orange: south). ... The dominant direction of wave incidence for the static equilibrium of Wolcheon Beach was found to be 34.2N...” and Fig. 4:

Given the dominate wave direction was 34.2N, then the average straight shoreline in equilibrium at Wolcheon Beach before 2011.03.13 had inclination from 124.2N to 304.2N (Left panel of Fig. 2 in the MS):

(calculation: $N34.2o + 90o = N124.2o$; $N34.2o + 270o = N304.2o$).

Consequently, the LST direction in summer (South to North) should be within 90 – 124N and in winter (North to South) within 304 – 338N, respectively.

However, the directions indicated above differ from the rose diagram for LST shown in Fig. 4 in the MS, which was centered around 230N in summer (Green, South to North) and centered around 180N in winter (Orange, North to South), respectively, all showing seaward LST.

PLEASE CONFIRM/VERIFY!

A1-C8: The littoral rose shown in Figure 4 is different in degree from that shown in the wave rose. A simple calculation from the average value of the wave direction is the result extracted from the wave rose. However, if littoral rose is expressed in the same way as wave rose, the direction of littoral drift may be reversed, which may confuse readers.

As per your comment, there may be a misunderstanding that littoral rose is related to the angle with respect to the wave direction, so I added the following sentence:

- The angle shown in Figure 4 represents the wave direction with respect to the wave rose. Figure 4 also shows the littoral rose according to wave rose, drawn symmetrically around the vertical line of the dominant direction ($N124.2^{\circ}$ - $N304.2^{\circ}$).

R1-C9: (L135) Figure 3: “Annual” values for mean wave height, wave period, and wave direction” are meaningless, because they do not represent the seasonal variations (summer and winter), especially during the period of investigation between 2011.03.1 and 2012.12.12.

A1-C9: The annual mean value shown in Figure 3 is significant in that the wave climate has not changed much over a long period of time. Wave climate is the first thing to consider when analyzing the causes of beach erosion. However, according to Figure 3, the wave climate in Samcheok did not change significantly, so we can find out that severe beach erosion occurred due to other factors. We have added sentences for this explanation as follows:

- Figure 3 shows that wave climate, one of the main causes of beach erosion, has not changed significantly in Samcheok.

R1-C10: (L218-222, Figure 9) "...the downdrift control point X ...":

Should point X be behind the initial shoreline in Fig. 4 after beach erosion?

A1-C10: The definition sketch shows that the beach is open beyond the downdrift point. Therefore, unlike a closed cell, it may not be located behind the initial shoreline because of the continuous sediment supply.

R1-C11: (L259) "..., subjected to LST towards the estuary of the Gagok Creek due to diffraction waves.": Yes, but more explicitly, due to nearshore current circulation induced by diffracted waves, which carry sediment

A1-C11: We have revised the expression as you suggested.

R1-C12: (L265-266) "...shoreline deformation began on August 17, 2021...": This occurred as LST moving within 90 – 112N or 90 – 124N ? (See also (L128 –137) above)

A1-C12: As previously answered in **A1-C8**, this paper analyzes the severe beach erosion caused by the Samcheok LNG development rather than the shoreline deformation resulting from the change in wave climate. Therefore, we simulate a numerical model using the annual mean wave as input and analyze the cause of severe beach erosion.

R1-C13: (L267-270) "This is because shoreline change...lasts for long periods due to the LST by the oblique inflow of waves under ordinary wave conditions with a low wave height rather than the deformation by high waves.":

Wordy sentence. Please revise!!

A1-C13: It has been revised to make sentences clearer by removing unnecessary and redundant expressions.

R1-C14: (L321-326 and Figure 16) "Figure 16 compares the LST rate vectors... The numerical results show a consistent LST vector pattern towards the LNG terminal revetment except for the initial results, but the results obtained from satellite images do not always show a vector towards the LNG terminal revetment due to the effect of transient high wave inflow.":

Was this true (effect of transient high wave inflow)? where the high waves came?

In winter, the entire Wolcheon Beach might be covered within the shadow zone induced by the diffracted waves (please see the Samcheok LNG 20211023.jpg below; or Fig. 2b in MS), whereas in summer, oblique wave reflection from or along part of the slightly curved revetment

wall could form a short-crested wave system that transported sediment out and away from the revetment toward the beach?

A1-C14: In the case of high waves (including not only extreme surge waves from the NE but also larger-than-usual easterly waves exceeding 2–3 meters from E), the deep water in front of the newly constructed revetment likely resulted in a significant influence of wave reflection, as observed in satellite imagery.

Therefore, the following explanation has been added:

- The most reasonable cause of this phenomenon is that, due to the deep-water construction of the LNG terminal revetment, oblique wave reflection from or along part of the slightly curved revetment wall could have formed a short-crested wave system, transporting sediment away from the revetment and toward the beach.

R1-C15: (L327-330) “Figure 17 compares LST vectors with each other on average over the entire analysis period (from March 13, 2012 to Aug. 6, 2012)...”:

The term “on average” can only compare the end results, not the transient temporal process of this investigation during the 1.5 years, thus invalidating the purpose of comparison! Therefore, Figure 17 does not support the comparison it intended to serve.

In addition, the “entire” period was from “2021”, not “2022”! A typo?

A1-C15: The expression means the average over the monitoring period from remote sensing. However, as per your comment, “on average” may be misleading so we have removed it.

In addition, we have revised to the entire period, “2011”.

R1-C16: (L338-343; Figure 18 on L347-349) “Figure 18 compares the average magnitude of the LST vectors from each end grid and the cumulative amount of longshore sediment towards the LNG revetment. The positive number... towards the LNG...negative number towards the opposite direction of the LNG revetment. ... showed severe undulation... by smoothing through the back-and-front values... a fairly similar trend...”:

(From Figure 18) Can authors explain the reason why LST obtained from satellite images decreased during the period of 255th-290th days and 305th-330th days, respectively, and LST away (negative numbers) from the revetment during 280th-295th days and 335th-370th days, respectively?

A1-C16: Landsat-7 has a resolution of 30 m, which includes errors in the monitoring results presented in this paper. Therefore, the LST extracted from satellite images in Figure 18 includes negative values, unlike the numerical results. To compensate for this, the smoothed satellite image results have also been included in Figure 18.

Therefore, the relevant content has been added as follows:

- Landsat-7 has a resolution of 30 m, which includes errors in the monitoring results presented in this paper. Therefore, the LST extracted from satellite images in Figure 18 includes negative values, unlike the numerical results.

R1-C17: (L351-355) “When the reclamation project was planned, action was not taken owing to the absence of means with which to predict such large-scale erosion in advance. ...assessing

the impact of the construction... the rotation of the shoreline... by applying PBSE... groins can serve as representative coastal structures for LST control.”:

Yes, the statement is correct. Additional notes of “shoreline reshaping” or “rotation of shoreline” can be found in Klein et al. (2023).

Groin system had been installed on Oarai Harbor and Iwafune Harbor in Japan to control erosion in the 1980s (see Hsu et al., 1993; 2000).

At moderate length (protrusion), groins may be effective to mitigate local erosion, but cannot modify the curvature of an embayed shoreline given by the PBSE.

A1-C17: Thank you for your comment. We have added appropriate references to these sentences based on your comments.

R1-C18: (L395-398, Conclusions) “... When the reclamation project at the Samcheok LNG terminal was planned about 10 years ago there was no adequate means to predict such large-scale erosion in advance. Therefore, if numerical predictions like this study are carried out, various countermeasures are possible. ... so installing groin in advance can most effectively reduce erosion. Applying PBSE...”: Use “were”?

Agreed!

Since the early 1990s, there are abundant of helpful knowledge available for shoreline changes at downdrift of harbors in Japan (see Uda, 2010), but perhaps none of the members on a planning committee (from government agency, academic, engineering consults, and NGO body) in any country outside Japan have the up-to-date knowledge to deal with this type of beach erosion problem (with shoreline rotation from straight to embayed), so leading to do- nothing or construction of conventional hard structures.

Without a preventive strategy proposed at the planning stage, such as the one outlined in the MS, a large sum of taxpayer’s funds will be wasted on managing the beach erosion downdrift of a harbor following a large coastal project.

Ironically, similar scenario of beach erosion has occurred in many countries, rich or poor, developed or under-developed.

A1-C18: Thank you for your comment. We have added appropriate contents and references to these sentences based on your comments in Conclusions.

Reviewer #1: C. Technical Corrections

Language editing is strongly recommended for the entire MS to improve the readability and the overall quality of the paper, especially on the use of “determiner (a/an/the/this etc.) and revise the wordy sentences throughout the entire MS.

R1-C19: (L100) “... Wolcheon Beach which mainly suffered erosion damage...”: Wordy sentence?

A1-C19: The sentence was too long as your comment, so we split it into two sentences.

R1-C20: (L111) “... a trade port equipped with a 1,800 m breakwater,”: Why ‘equipped’?

A1-C20: We have deleted “equipped,” as it is an unnecessary expression.

R1-C21: (L113) "... when public water reclamation began.": What is this?

A1-C21: We have deleted "when public water reclamation began." as it is an unnecessary expression.

R1-C22: (L124-125) "The coastal waters of Samcheok...are deep (maximum depth of 3,000 m or higher; average depth of 1,300 or less)":

Are the numbers (depth) correct? Use word "more"? Please note that the edge of the continental shelf has an average depth about 150 – 200 m!

A1-C22: We have used the word "more" as your comment. The depth referred to here is the depth at the Samcheok LNG terminal. To make the subject clearer, "LNG terminal" has been added to the sentence.

R1-C23: (L139-140) "... in Samcheok coastal waters. The waters are significantly affected by the flow of waves rather than the tide.": Why "significantly" and "the flow of waves"?

A1-C23: To make it clearer, the sentence has been revised as follows:

- Due to the small tidal range, the beach are usually affected by the wave-induced currents rather than the tide.

R1-C24: (150-151) "the occurrence of a coastal erosion problem that considerably threatens the lives, properties, and livelihoods....": Wordy sentence!

A1-C24: The sentence has been removed as it was unnecessary for the development of the paper.

R1-C25: (L157) "Towing to the construction...": Typo error?

A1-C25: The sentence has been revised to "after the construction".

R1-C1: (L160-162) "Owing to the absence of the data... gravity $s = 2.65$, which were obtained from the sand sample collected from the sandy beach located in the sane watershed system were applied.":

Wordy sentence!

A1-C26: To make it clearer, the sentence has been revised as follows:

- Owing to the absence of the data in the target area, porosity $p = 0.42$ and sand gravity weight $s = 2.65$ are applied, as these are representative values in South Korea.

R1-C27: (L176) "... as Liu and Jezek (2004) pointed out a long time ago, this often still requires rigorous....": Poor sentence!

A1-C27: To make it clearer, the sentence has been revised as follows:

- However, as Liu and Jezek (2004) pointed out long ago, extracting the shoreline still often requires rigorous terrain correction, geocoding, and radiometric correction and balancing.

R1-C28: (L178) “However, as shown in the figure, However, as you can see in the figure, ...”: Careless and rough without checking!

A1-C28: We have removed redundant expressions.

R1-C29: (L321) “...two temporally adjacent aerial photographs...”: Use “consecutive”?

A1-C29: We have revised to “consecutive satellite images”.

R1-C30: (L396-397) “...if numerical predictions like this study are¹ carried out, various² countermeasures are³ possible.”:

1 Use “were”? 2Use “proper” or “effective”? 3Use “could be”?

A1-C30: Thank you for your comment. We have made revisions based on your comment.

R1-C31: D. Additional References other than those already included in the MS

Gourlay, M.R., (1974). Wave set-up and wave generated currents in the lee of a breakwater or headlands. Proc. 14th Inter. Conf. Coastal Eng., pp. 1976–1987.

Gourlay, M.R., (1981). Beach processes in the vicinity of offshore breakwaters. Proc. 5th Aust. Conf. Coastal Eng., pp.129–134.

Hsu, J.R.C., Uda, T., Silvester, R., (1993). Beaches downcoast of harbours in bays. Coastal Eng., 19, 163–181.

Hsu, J.R.C., Uda, T., Silvester, R., (2000). Shoreline protection method – Japanese experience. in Herbich, J.B. (ed.), Handbook of Coastal Engineering, Chapter 9, McGraw Hill, 9.1–9.77.

Klein., A.H.F., Vargas, a., Raabe, A.L.A., Hsu, J.R.C., (2023). Visual assessment of bayed beach stability with computer software. Computers & Geomechanics, 29, 1249–1257.

Uda, T., (2010). Japan’s Beach Erosion: Reality and Future Measures. Advanced Series on Ocean Eng., v. 31, World Scientific, 418 pp.

A1-C31: Thank you for your comment. We have added appropriate references to these sentences based on your comments.