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Introductory Chapter: Morphodynamic Model for Predicting Beach Changes Based on Bagnold's Concept and Its Applications

Takaaki Uda, Masumi Serizawa and Shiho Miyahara

1. Introduction

Beach erosion is caused by an imbalance in the sediment budget of a coast, with the exception of ground subsidence associated with the excessive extraction of groundwater or sea level rise. Seasonal variations on beaches due to the occurrence of storms and calm waves are commonly observed, but the long-term stability of a beach is governed by longshore sand transport [1]. When the amount of sand supplied from rivers and sea cliffs decreases compared with the longshore sand transport of a coast, the inevitable result is beach erosion. Similarly, artificial removal of coastal sediment by dredging or mining results in beach erosion on neighboring coasts. The anthropogenic causes of beach erosion could be mainly classified into four types: (1) obstruction of longshore sand transport, (2) beach changes associated with the formation of wave-shelter zones, (3) decreased fluvial sediment supply, and (4) offshore sand mining or dredging [2]. When a breakwater, jetty, or groyne is extended offshore on a coast with predominant longshore sand transport, part or all of the longshore sand transport is obstructed, causing erosion downcoast and accretion upcoast. Even if waves are incident from the direction normal to the shoreline, longshore sand transport is induced from outside to inside the wave-shelter zone near a large port breakwater, resulting in erosion outside the wave-shelter zone and accretion inside. The dredging of sand deposited behind an oblique breakwater soon induces longshore sand transport from outside to inside the wave-shelter zone, resulting in erosion in the adjacent area. The effect of offshore mining may be extensive, depending on wave conditions, even though sand is not removed directly from the shoreline. Sand movement due to longshore sand transport occurs at depths less than the depth of closure, h_c , which is roughly equal to 10 m on well-exposed beaches. Since sand is continually being exchanged up to this depth, the removal of sand from a depth less than h_c leads to the same results as sand mining near the shoreline.

To solve these erosion problems or prevent the shoreline of a coast from receding earlier, it is important to predict beach changes. In the prediction of beach changes triggered by the imbalance in longshore sand transport, a long-term prediction in an extensive area is often required. The time scale changes yearly to decadal time scales, and the calculation domain reaches even up to 10–100 km. The One-line

model is the most popular tool to predict such beach changes, which represents beach topography by the shoreline position, and beach changes are solved using the total longshore sand transport formula [3–5] described by wave parameters at the breaking point, and the continuity equation of sand [6–9]. This has been applied to many problems with small computational load. The N-line model is an improvement over the One-line model, and beach topography is represented by multiple contour lines. The change in successive locations of each contour line is calculated using longshore and cross-shore sand transport formulae, and the continuity equation of sand [9–15].

Recently, further advanced 3D beach change models, so-called process-based models, have been developed [16–26]. Furthermore, Nam et al. [26] reviewed the previous studies, which included the application of the model for predicting the beach changes around coastal structures. In these models, the depth changes on 2D horizontal grids are predicted using the sand transport formulae expressed by local hydrodynamic parameters, i.e., oscillatory velocity due to waves, nearshore current velocity, and tidal current velocity.

Regarding the sand transport formulae in the process-based models, a number of formulae have been proposed [17, 27–39]. Since recurrent calculations of not only wave field but also nearshore current are required in these process-based models, computational load is much larger than that of the One-line or N-line model, so that application to the long-term prediction in an extensive calculation domain is difficult.

On the basis of these previous studies, the authors have developed models for predicting beach changes applicable to various problems on real coasts [2]. One of them is the contour-line-change model [40] to predict long-term beach changes caused by the imbalance in longshore sand transport, which is a kind of N-line model, and in this model a sand transport equation similar to that by Hanson and Larson [14] is employed. Because the calculation of the nearshore current is not needed in this model as in 3D process-based models, and the computational load is small, it has an advantage in the prediction of long-term topographic changes in an extensive coast where many coastal structures have been constructed. This model then was improved to predict the temporal and spatial changes in the grain size of bed material [41–43]. The authors applied this model to many coasts in Japan to work out the countermeasures against beach erosion [2, 44–51]. However, this model has weak points.

First, in this model, the handling of boundary conditions becomes difficult when offshore coastal structures are constructed in a complicated manner, because tracking the subsequent positions of the contour lines is needed. In this regard, the so-called 3D model has an advantage. Taking this point into account, the authors developed a morphodynamic model (hereafter, “the BG model” named after Bagnold [52, 53]) by applying the concept of the equilibrium slope and the energetics approach, in which depth changes on 2D horizontal grids are calculated instead of tracking the subsequent positions of the contour lines [54, 55]. Second, the application of the contour-line-model to the prediction of topographic changes on a coast with a large shoreline curvature, such as a sand spit, was difficult.

In several previous studies, prediction of the deformation of a sand spit was tried by introducing the curvilinear coordinates along the curved shoreline in the One-line model [56–58], but their application to the prediction of topographic changes around a sand spit with a complicated form was limited. Taking this into account, the BG model was further improved to predict the 3D topographic changes around a sand spit or an isolated sand bar. Ashton et al. [59, 60] showed that sand spits may develop from infinitesimal perturbations on the shoreline under the conditions that the incident wave angle exceeds approximately 45° relative

to the direction normal to the shoreline. The BG model could be applied to these phenomena. In this book, the BG model is introduced with its applications.

In this book, however, we have not introduced the applications of the BG model to the prediction of beach changes on a coast with sand of mixed grain size because of the limits of space. On real coasts, spatial changes in the longitudinal profile associated with changes in the composition of each grain size may occur. The longitudinal slope gradually becomes gentle with increasing content of fine sand, for example, in the wave-shelter zone. These changes in the local slope in and around the wave-shelter zone can also be predicted [61, 62], taking the equilibrium slope corresponding to each grain size and its composition into account. Their applications are shown in [63–65].

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References

- [1] Komar PD. Beach Processes and Sedimentation. London: Prentice Hall International; 1998. 544 p
- [2] Uda T. Japan's Beach Erosion—Reality and Future Measures. 2nd ed. Singapore: World Scientific; 2017. 530 p
- [3] Komar PD, Inman DL. Longshore sand transport on beaches. *Journal of Geophysical Research*. 1970;75:5914-5927
- [4] CERC. Shore Protection Manual, Vicksburg, Mississippi, US Army Coastal Engineering Research Center, Corps of Engineers; 1984
- [5] Kamphuis JW. Introduction to Coastal Engineering and Management. Singapore: World Scientific; 2000. 437 p
- [6] Pelnard-Considere R. Essai de Theorie de l'Evolution des Formes de Ravage en Plages de Sables et de Galets. Societe Hydrotechnique de France, IV'eme Journee de L'Hydraulique Question III, Rapport, 1; 1956, 74-1-10 (in French)
- [7] Hanson H, Kraus NC. GENESIS: Generalised model for simulating shoreline change, Technical Report CERC-89-19. Vicksburg, USA: Coastal Engineering Research Station, US Army Corps of Engineers; 1989. 185 p
- [8] Dabees MA, Kamphuis JW. ONELINE, a numerical model for shoreline change. In: Proceedings of ASCE 27th International Conference on Coastal Engineering, ASCE, Vicksburg, USA; 1998. pp. 2668-2681
- [9] Hanson H, Aarninkhof S, Capobianco M, Jimenez JA, Larson M, Nicholls R, et al. Modelling coastal evolution on early to decadal time scales. *Journal of Coastal Research*. 2003;19:790-811
- [10] Bakker WT. The dynamics of a coast with a groyne system. In: Proceedings of 11th Coastal Engineering Conference (ASCE); 1969. pp. 1001-1020
- [11] Perlin M, Dean RG. A Numerical Model to Simulate Sediment Transport in the Vicinity of Coastal Structures, Misc. Report, No. 83-10. Coastal Engineering Research Center, US Army Corps of Engineers; 1983. 119 p
- [12] Steetzel HJ, de Vroeg JH. Application of a multilayer approach for morphological modelling. In: Coastal Sediments '99, ASCE, Vicksburg; 1999. pp. 2206-2218
- [13] Steetzel HJ, de Vroeg H, van Rijn LC, Stam JM. Long-term modelling of the Holland coast using a multi-layer model. In: Proceedings of 27th International Conference on Coastal Engineering, ASCE, Sydney, Australia; 2000. pp. 2942-2955
- [14] Hanson H, Larson M. Simulating coastal evolution using a new type N-line model. In: Proceedings of 27th International Conference on Coastal Engineering, ASCE, Vicksburg; 2000. pp. 2808-2821
- [15] Dabees MA, Kamphuis JW. NLINE, efficient modeling of 3D beach change. In: Proceedings of 27th International Conference on Coastal Engineering, Sydney, Australia, ASCE; 2000. pp. 2700-2713
- [16] Watanabe A, Maruyama K, Shimizu T, Sakakiyama T. Numerical prediction model of three-dimensional beach deformation around a structure. *Coastal Engineering Journal (Japan)*. 1986;29:179-194
- [17] Watanabe A. 3-Dimensional numerical model of beach evolution. In: Proceedings of Conference on Coastal Sediments '87, ASCE; 1987. pp. 802-817
- [18] Watanabe A. Numerical model of beach topography change. In: Horikawa

K, editor. *Nearshore Dynamics and Coastal Processes*. Tokyo, Japan: University of Tokyo Press; 1988. pp. 241-243

[19] Sato S, Kabiling M. A numerical simulation of beach evolution based on a nonlinear dispersive wave-current model. In: *Proceedings of 24th Conference on Coastal Engineering*; 1994. pp. 2557-2570

[20] Roelvink D, Boutmy A, Stam JM. A simple method to predict long-term morphological changes. In: *Proceedings of 26th International Conference on Coastal Engineering*, Copenhagen, ASCE, New York; 1998. pp. 3224-3237

[21] Leont'yev IO. Modelling of morphological changes due to coastal structures. *Coastal Engineering*. 1999;**38**:143-166

[22] Gelfenbaum G, Roelvink JA, Meijs M, Buijsman M, Ruggiero P. Process-based morphological modeling of Gray Harbor inlet at decadal timescales. In: *Proceedings of Coastal Sediments '03*; 2003

[23] Lesser GR, Roelvink JA, van Kester JATM, Stelling GS. Development and validation of a three-dimensional morphological model. *Coastal Engineering*. 2004;**51**(8-9):883-915

[24] Brøker I, Zyserman J, Madsen EØ, Mangor K, Jensen J. Morphological modelling: a tool for optimisation of coastal structures. *Journal of Coastal Research*. 2007;**23**(5):1148-1158

[25] Kuroiwa M, Shibutani Y, Matsubara Y, Kuchiishi T, Abualtyef M. Numerical model of 3D morphodynamics after offshore nourishment. In: *Proceedings of 31st International Conference on Coastal Engineering*, No. 32, Paper #: sediments. 55; 2010. <http://journals.tdl.org/ICCE/>

[26] Nam PT, Larson M, Hanson H, Hoan LX. A numerical model of beach

morphological evolution due to waves and currents in the vicinity of coastal structures. *Coastal Engineering*. 2011;**58**(9):863-876

[27] Bijker EW. Longshore transport computation. *Journal of the Waterways and Harbors Division*. 1971;**97**(WW4):687-701

[28] van Rijn LC. Sediment transport, part I: bed load transport. *Journal of the Hydraulics Division*. 1984;**110**(10):1431-1456

[29] van Rijn LC. Sediment transport, part II: suspended load transport. *Journal of the Hydraulics Division*. 1984;**110**(11):1613-1641

[30] Bailard JA. An energetics total load sediment transport model for a plane sloping beach. *Journal of Geophysical Research*. 1981;**86**(C11):10938-10954

[31] Dibajinia M, Watanabe A. Sheet flow under nonlinear waves and currents. In: Edge BL, editor, *23rd International Conference on Coastal Engineering*, ASCE, Venice, Italy; 1992. pp. 2015-2028

[32] Soulsby DH. *Dynamics of Marine Sands: A Manual for Practical Applications*. London, England: Thomas Telford Publications; 1997. 249 p

[33] Ribberink JS. Bed-load transport for steady flows and unsteady oscillatory flows. *Coastal Engineering*. 1998;**34**:59-82

[34] Watanabe A, Sato S. A sheet-flow transport rate formula for asymmetric, forward-leaning waves and currents. In: *Proceedings of 29th International Conference on Coastal Engineering*, Lisbon, Portugal; 2004. pp. 1703-1714

[35] Camenen B, Larson M. A general formula for non-cohesive bed load sediment transport. *Estuarine, Coastal and Shelf Science*. 2005;**63**:249-260

- [36] Camenen B, Larson M. A unified sediment transport formulation for coastal inlet application, Coastal Inlets Research Program, Final Report ERDC/CHL CR-07-1, US Army Corps of Engineers, Washington, DC; 2007
- [37] Camenen B, Larson M. A total load formula for the nearshore. In: Proceedings of Coastal Sediments '07 Conference, ASCE, Reston, VA; 2007. pp. 56-67
- [38] Ribberink JS, van der A DA, Buijsrogge RH. SANTOSS Transport Model—A New Formula for Sand Transport Under Waves and Currents, Report SANTOSS_UT_IR3. Enschede, The Netherlands: University of Twente; 2010
- [39] Van der A DA, Ribberink JS, van der Werf JJ, O'Donoghue T, Buijsrogge RH, Kranenburg WM. Practical sand transport formula for non-breaking waves and currents. Coastal Engineering. 2013;76:26-42
- [40] Serizawa M, Uda T, San-nami T, Furuike F, Kumada K. Improvement of contour-line change model in terms of stabilization mechanism of longitudinal profile. In: Coastal Sediments '03; 2003. pp. 1-15
- [41] Uda T, Kumada T, Serizawa M. Predictive model of change in longitudinal profile in beach nourishment using sand of mixed grain size. In: Proceedings of 29th ICCE; 2004. pp. 3378-3390
- [42] Kumada T, Uda T, Serizawa M, Noshi Y. Model for predicting changes in grain size distribution of bed materials. In: Proceedings of 30th ICCE; 2006. pp. 3043-3055
- [43] Uda T, Serizawa M. Model for predicting topographic changes on coast composed of sand of mixed grain size and its applications (Chapter 16). In: Angermann, L. editor. Numerical Simulations-Examples and Applications in Computational Fluid Dynamics, INTEC; 2010. pp. 327-358. <http://www.intechopen.com/articles/show/title/model-for-predicting-topographic-changes-on-coast-composed-of-sand-of-mixed-grain-size-and-its-appli>
- [44] Kumada T, Uda T, Serizawa M. Quantitative evaluation of controlling effect of headland on longshore sand transport using a model for predicting changes in contour lines and grain size. In: Coastal Sediments '07; 2007. pp. 2446-2459
- [45] Yoshioka A, Uda T, Aoshima G, Furuike K, Ishikawa T. Field experiment of beach nourishment considering changes in grain size and prediction of beach changes. In: Proceedings of 31st ICCE; 2008. pp. 2694-2706
- [46] Nishitani M, Uda T, Serizawa M, Ishikawa T. Measurement and prediction of deformation of conveyor belts carrying gravel and fine sand off Shimizu coast. In: Proceedings of 31st ICCE; 2008. pp. 2570-2582
- [47] Kumada T, Uda T, Matsu-ura T, Sumiya M. Field experiment on beach nourishment using gravel at Jinkoji coast. In: Proceedings 32nd ICCE, sediment.100; 2010. pp. 1-13. http://journals.tdl.org/ICCE/article/view/1076/pdf_178
- [48] Miyahara S, Uda T, Furuike K, Serizawa M, San-nami T, Ishikawa T. Effect of sand bypassing at Sakuma Dam in Tenryu River as a measure against erosion of Tenryu River delta coast. In: Proceedings of 32nd ICCE, sediment.106; 2010. pp. 1-12. http://journals.tdl.org/ICCE/article/view/1049/pdf_165
- [49] Furuike K, Uda T, Serizawa M, San-nami T, Ishikawa T. Quantitative prediction of sand discharge into a submarine canyon off Morito River on Seisho coast, Japan. In: Proceedings

of 32nd ICCE, sediment.107; 2010. pp. 1-13. http://journals.tdl.org/ICCE/article/view/1050/pdf_166

[50] Ishikawa T, Uda T, Furuike K, Yoshioka A. Regional sediment management considering volume of sand and grain size. In: *Coastal Sediments '11*; 2011. pp. 2033-2046

[51] Ishikawa T, Uda T, San-nami T, Furuike K. Verification of effect of gravel nourishment on Hamamatsu-shinohara coast, Japan. In: *Coastal Sediments '15*, CD-Rom, No. 47; 2015. pp. 1-14

[52] Inman DL, Bagnold RA. Littoral processes. In: Hill MN, editor. *The Sea*. Vol. 3. New York: Wiley; 1963. pp. 529-533

[53] Bagnold RA. Mechanics of marine sedimentation. In: Hill MN, editor. *The Sea*. Vol. 3. New York: Wiley; 1963. pp. 507-528

[54] Serizawa M, Uda T, San-nami T, Furuike K. Three-dimensional model for predicting beach changes based on Bagnold's concept. In: *Proceedings of 30th ICCE*; 2006. pp. 3155-3167

[55] Serizawa M, Uda T, San-nami T, Furuike K, Ishikawa T. BG-model predicting three-dimensional beach changes based on Bagnold's concept and applications. In: *Proceedings of 4th International Conference on Asian and Pacific Coasts 2007*; 2007. pp. 1165-1179

[56] Jiménez JA, Sánchez-Arcilla A. Modelling of barrier-spit system evolution at decadal scale. In: *Coastal Sediments '99*. Reston, VA: American Society of Civil Engineers; 1999. pp. 1724-1738

[57] Jiménez JA, Sánchez-Arcilla A. A long-term (decadal scale) evolution model for microtidal barrier systems. *Coastal Engineering*. 2004;**51**:749-764

[58] Watanabe S, Serizawa M, Uda T. Predictive model of formation of a sand spit. In: *Proceedings of 29th ICCE*; 2004. pp. 2061-2073

[59] Ashton A, Murray AB, Arnault O. Formation of coastline features by large-scale instabilities induced by high angle waves. *Nature*. 2001;**414**:296-300

[60] Ashton A, Murray AB. High-angle wave instability and emergent shoreline shapes: 1. Modeling of sand waves, flying spits, and capes. *Journal of Geophysical Research*. 2006;**111**:F04011. DOI: 10.1029/2005JF000422

[61] Serizawa M, Uda T, San-nami T, Furuike K, Ishikawa T, Kumada T. Model for predicting beach changes on coast with sand of mixed grain size based on Bagnold's concept. In: *Coastal Sediments '07*; 2007. pp. 314-326

[62] Noshi Y, Uda T, Serizawa M, Kumada T, Kobayashi A. Model for predicting bathymetric and grain size changes based on Bagnold's concept and equilibrium slope corresponding to grain size composition. In: *Proceedings of 32nd ICCE, sediment.15*; 2010. pp. 1-13. http://journals.tdl.org/ICCE/article/view/1075/pdf_177

[63] Ishikawa T, Uda T, San-nami T, Hosokawa J. Verification of shore protection effect of beach nourishment on Chigasaki coast. In: *Proceedings of the 7th International Conference on Asian and Pacific Coasts (APAC 2013)* Bali, Indonesia, September 24-26, 2013; 2013. pp. 1-8

[64] Ishikawa T, Uda T, Miyahara S, Serizawa M, Fukuda M, Hara Y. Recovery of sandy beach by gravel nourishment—example of Ninomiya coast in Kanagawa Prefecture, Japan. In: *Proceedings of 34th ICCE*; 2014. pp. 1-15. https://journals.tdl.org/icce/index.php/icce/article/view/7107/pdf_411

[65] Uda T, Ishikawa T, San-nami T, Hosokawa J, Sasaki T, Furuike K. Shore protection by gravel nourishment on Chigasaki-naka coast and preventive measure against gravel diffusion to nearby beach. In: Proceedings of Civil Engineers, Japan, Vol. 70, No. 2; 2014. pp. I_702-I_707 (in Japanese)

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