ASSESSING COASTAL HYDRODYNAMICS AND SEDIMENT DYNAMICS IN THE MONSOON AFFECTED WESTERN COAST OF SRI LANKA

Gunasinghage Prasadh Gunasinghe

178088D

Degree of Doctor of Philosophy

Department of Earth Resources Engineering

University of Moratuwa

Sri Lanka

August 2025

ASSESSING COASTAL HYDRODYNAMICS AND SEDIMENT DYNAMICS IN THE MONSOON AFFECTED WESTERN COAST OF SRI LANKA

Gunasinghage Prasadh Gunasinghe

178088D

Thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Earth Resources Engineering

University of Moratuwa

Sri Lanka

August 2025

DECLARATION OF THE CANDIDATE

I declare that this is my own work, and this thesis does not incorporate without acknowledgment of any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

Also, I hereby grant to the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic, or other mediums. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 10/08/2025

DECLARATION OF THE SUPERVISORS

The above candidate has carried out research for the PhD thesis under my supervision.

Name of the supervisor: Prof. N.P. Ratnayake

Signature of the supervisor: Date:

Name of the supervisor: Prof. A.S. Ratnayake

Signature of the supervisor: Date:

Name of the supervisor: Dr. G.V.I. Samaradivakara

Signature of the supervisor: Date:

Abstract

Coastal regions along the west coast of Sri Lanka have undergone significant morphodynamic changes over the past decade, shaped by the interplay of natural processes and human activities. These changes, which include shifts in coastal landforms and sediment distribution, have been driven by modifications in hydrodynamics and sediment dynamics, resulting from activities such as river sand mining, harbor expansions, breakwater construction, sand nourishment programs, and flood control measures. These factors have led to notable patterns of coastal erosion and accretion. This study aims to comprehensively assess the coastal hydrodynamics and sediment dynamics influenced by a combination of anthropogenic activities and natural processes along the monsoon-affected west coast of Sri Lanka, with a specific focus on the regions of Kalutara, Ratmalana, and Mount Lavinia, in order to understand the resulting coastal morphodynamic changes. The representative locations (Kalutara, Ratmalana, and Mount Lavinia) were selected for this investigation, as they have experienced notable impacts on sediment transport patterns and erosion/accretion processes, through a combination of field measurements, remotely sensed data, and numerical modeling. Empirical findings from the study reveal distinct seasonal contrasts in coastal erosion and accretion, attributed to the influence of the southwest and northeast monsoons, respectively. During the southwest monsoon season, waves originating from the southwest impact the west coast, triggering heightened longshore currents that transport sediment northward along the coast. Conversely, during the northeast monsoon season, waves approach the west coast from the northwest, initiating longshore currents that move sediment southward along the shoreline. Moreover, the deliberate opening of a sand spit barrier for flood mitigation at the Kalu Ganga (River) resulted in severe erosion at the river outlet. This event hindered the barrier's redevelopment and exacerbated offshore erosion, with depths reaching 1–2 m over a 2 km area. In addition, coastal protection structures like groynes and breakwaters significantly impact beach morphology and sediment distribution. For instance, groynes trap sediment and stabilize beaches, while breakwaters reduce wave energy, mitigating erosion. In contrast, unprotected areas exhibit greater variability in beach width, slope, and sediment characteristics. The shape and orientation of the Ratmalana coastal area strongly influence beach landform development, while the presence of a natural headland in Mount Lavinia affects coastal dynamics. The knowledge gained from this study can inform the implementation of measures to protect and sustainably manage coastal zones. By bridging the gap between scientific understanding and practical application, this study plays a crucial role in promoting resilience and reducing vulnerabilities in the face of changing coastal conditions.

Key words: Coastal erosion, Morphodynamic changes, Hydrodynamics, Monsoon-induced variations, Sediment dynamics

ACKNOWLEDGEMENT

First and foremost, I wish to express my deepest gratitude to my main supervisor, Prof. N.P. Ratnayake, for graciously accepting me as a PhD candidate and for providing unwavering support throughout my research journey. I am profoundly indebted to him for his constant encouragement, understanding, and, above all, his remarkable patience during the most challenging moments of my doctoral pursuit. I am truly grateful to you, Sir, for your invaluable guidance. Secondly, I would like to extend my heartfelt appreciation to my second supervisor, Prof. A.S. Ratnayake, for offering exceptional support, particularly through timely and precise guidance. Your ability to instill confidence in me during moments of self-doubt has been truly remarkable. I sincerely thank you for embodying the essence of mentorship and illuminating the path to learning from mistakes. Thirdly, I want to express my sincere gratitude to my third supervisor, Dr. G.V.I Samaradivara. Your willingness to share your wealth of experiences, provide expert critiques, and consistently encourage me to persevere has been invaluable. Your guidance has helped me navigate through the darkest of times, always reminding me to seek the light at the end of the tunnel. Actually, without their collective expertise, encouragement, and patience, my journey as a PhD candidate would have been significantly more challenging.

Furthermore, I would like to express my sincere gratitude to the past Research Coordinators and the present Research Coordinator, as well as the past and present Heads of the Department of Earth Resources Engineering at the University of Moratuwa. Their invaluable support and guidance have played a significant role in shaping my research journey. Additionally, I wish to extend my heartfelt appreciation to all the academic, academic support, and non-academic staff of the University of Moratuwa. Their dedication in creating a peaceful and conducive environment for my research studies has been instrumental in my progress. Furthermore, I would like to convey my sincere gratitude to the Dean, the Heads of Departments, and all my colleagues in the academic staff, as well as the academic support staff of the Faculty of Built Environment and Spatial Sciences at KDU Southern Campus. Their warm hospitality has provided me with a home away from home, offering a tranquil setting and necessary facilities to successfully complete this endeavor.

I would also like to express my deepest appreciation to a number of remarkable individuals who have stood by me during this crucial period of my life. Among them, I hold in high regard Prof. Ranjith Premasiri, Dr. Nimal Wijayaratna, Dr. A.H. Lakmal, Dr. Thushini Mendis, Dr. Akalanka Silva, Eng. N.P. Dushyantha, Eng. Nilupul Senaratna, Eng. Lilani Ruhunage, Mr. Panchala Weerakon, and the experts who have provided specific information relevant to my research through digital media. Their support and contributions have been invaluable and are cherished deeply.

When I sat down to write my acknowledgments, an overwhelming number of people and memories flooded my mind. It would be impossible for me to mention each and every one of you by name, as the list would be endless. However, I want to express that each of you holds a special place in my heart. I feel truly blessed to have had the privilege of your presence in my life at one time or another, helping me overcome challenges, supporting me through difficult times, and making my journey more meaningful. I am sincerely grateful to each and every one of you. Thank you.

I wish to extend my deepest gratitude and love to my family. I am forever grateful to my late mother, Mrs. Lamaethana, and my father, Mr. Gunasinghe, who dedicated their entire lives to ensuring a better future for us. If my mother were here with us today, she would be overjoyed by my achievement. She always believed in me and had unwavering faith in my abilities. Her faith and trust provided me with the strength to overcome the most challenging moments in my life. Thank you! You are the best mother a son could ever ask for. I am also indebted to my father-in-law, Mr. Lional, and mother-in-law, Mrs. Jayawardhana, for their kindness and love towards my family during my time away from home.

I extend my deepest appreciation, gratitude, and love to my beloved wife, Mrs. Dinusha, who has been the pillar of strength and the backbone of my life, as well as to my lovely children, Kushalya and Lithisha. Thank you for your unwavering patience during my work commitments and for your understanding when I had to miss important events in your lives. I am grateful for your resilience in managing things on your own when I was away from home. Your sacrifices to support my studies are truly cherished.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS