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Center for Applied Coastal Research

Effect of Net Cross-shore Sand Transport on Beach Profiles

University of Delaware

Sravani Mallavarapu
Nobuhisa Kobayashi
Tingting Zhu

Outline

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2. Experiment in Wave Flume
3. Data Analysis for Three Tests
4. Conventional Shoreline Translation Model
5. New Equilibrium Profile Model
6. Field Application of New Model (steady)
7. Conclusions

1. Introduction

- The concept of an equilibrium beach profile (Dean 1991) is convenient and adopted for beach nourishment design and shoreline response modeling.

- Periodic beachfill placement may make nourished beaches steeper to transport placed sand offshore.

- Frequent overwash may reduce beach slope to accommodate onshore sand transport.

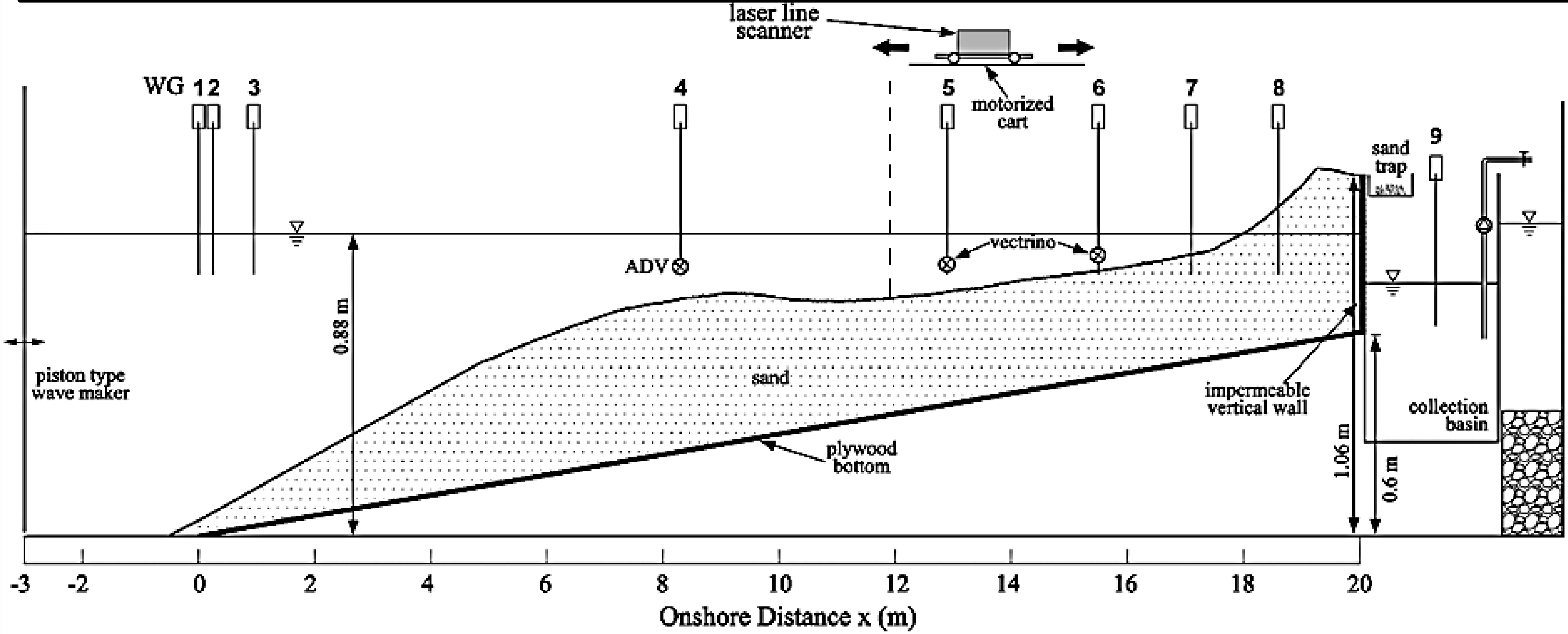
- The degree of equilibrium profile modification caused by periodic beachfill placement or overwash may be difficult to quantify for natural beaches whose profiles change with water level and wave conditions.

- No reliable model exists to predict long-term beach profile evolution including periodic beachfill placement or frequent overwash.

- A laboratory experiment was conducted to measure the equilibrium profile modification.

2. Experiment in Wave Flume

Experimental setup at start of Test Z with zero net sand transport rate



Well-sorted fine sand : median diameter = 0.18 mm ;porosity = 0.4

Incident waves at WG1 : Hmo = 17 cm

(400-s run) Tp = 2.6 s

Sequences of three tests with zero (Z), negative (N) and positive (P) net cross-shore sand transport.

Test	Cross-shore sand transport	Water depth (cm)	Number of runs	Duration (s)
Z	Zero (equilibrium)	88	10	4,000
N	Negative (offshore)	88	20	8,000
P	Positive (onshore)	92	20	8,000

For N test : Total sand placement of 48 cm^3/cm
average rate = 0.006 $cm^3/cm/s$

For P test : Measured wave overtopping rate q_o
sand overwash rate q_{bs} with
average overwash rate = 0.0034 $cm^3/cm/s$

Zero(Z) net cross-shore sand transport test

- 115 cm wide flume
- No wave overtopping
- Measured profiles of Z0,Z5 and Z10
- Profile changes of about 2mm from Z5 to Z10

Negative(N) net cross-shore sand transport test

- Initial profile N0 was final profile of Z10
- No wave overtopping
- Placed sand volume

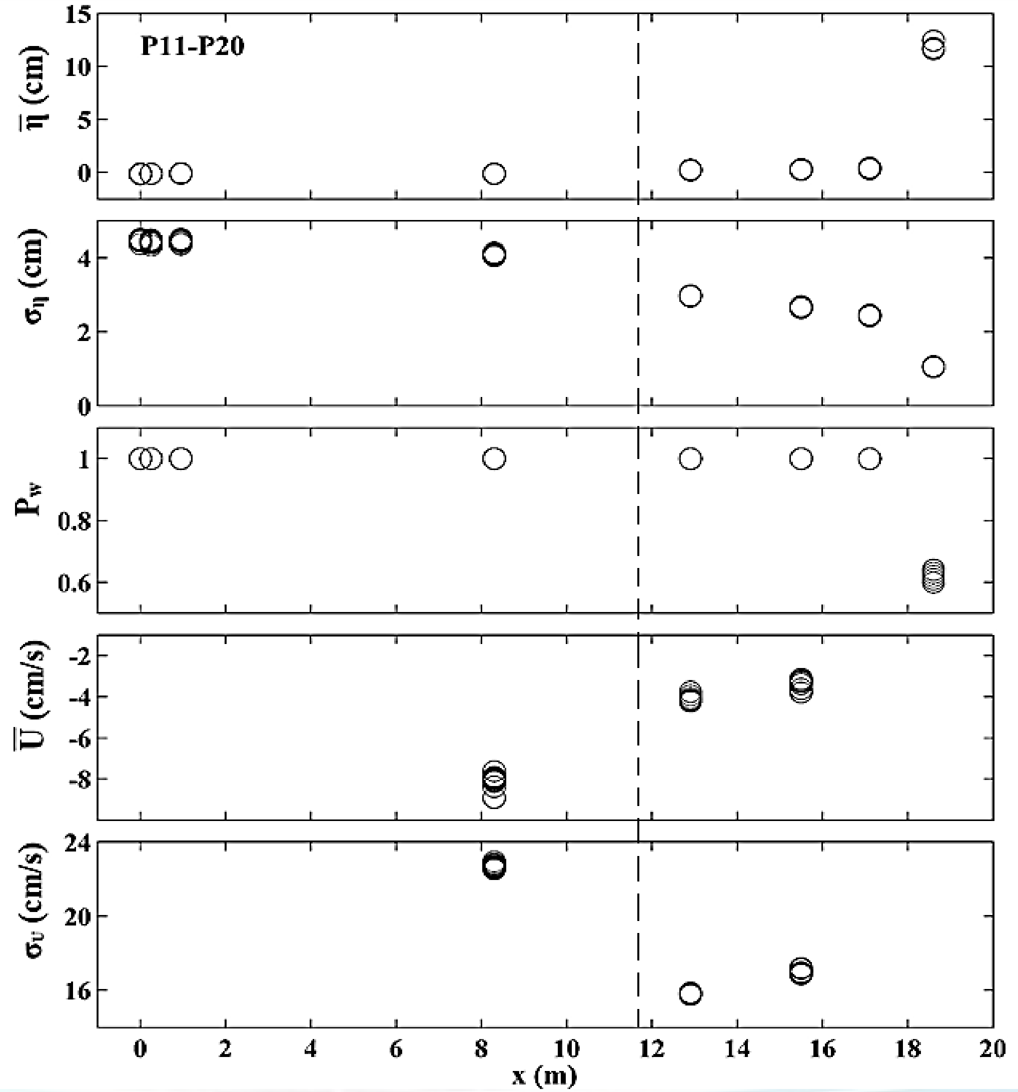
  12 cm^3/cm on N0 and N5

  24 cm^3/cm on N10
- Measured profiles of N5, N10 and N20

Positive(P) net cross-shore sand transport test

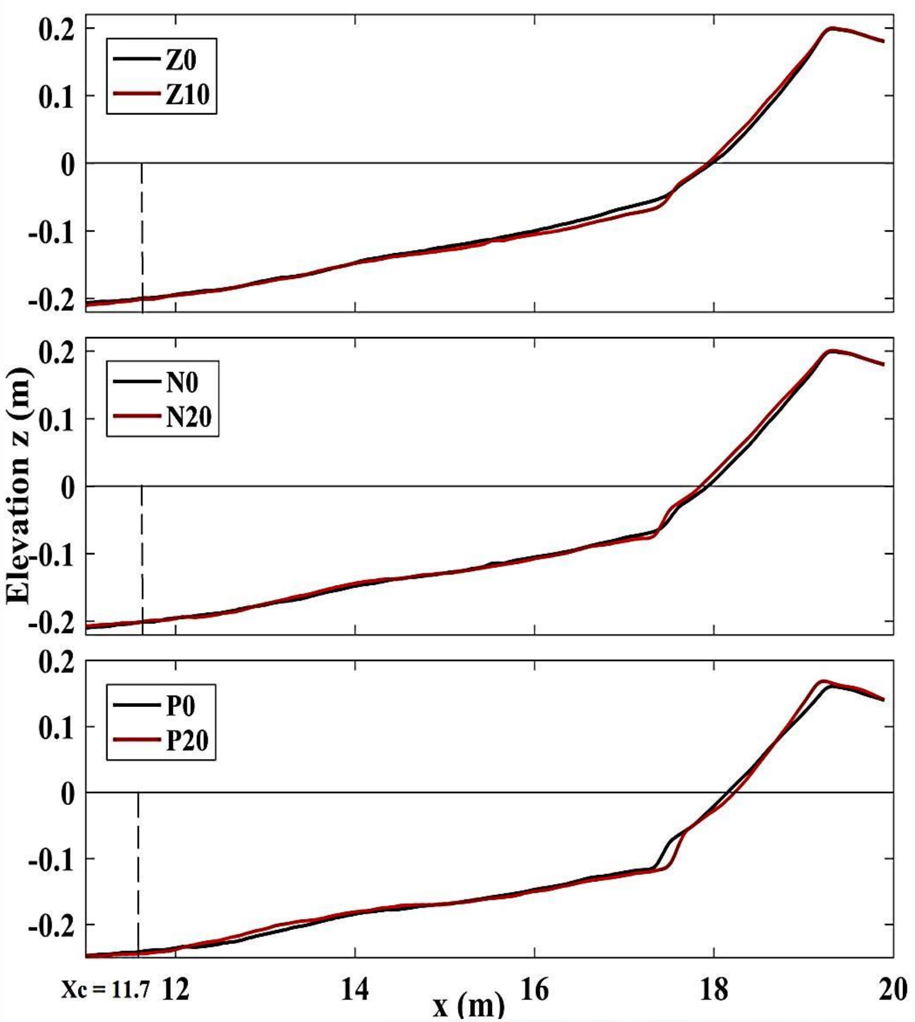
- Initial profile P0 was final profile N20
- 4-cm water level increase
- q_0 and q_{bs} were measured for each 400-s run
- Measured profiles of P5, P10 and P20

3. Data Analysis for Three Tests



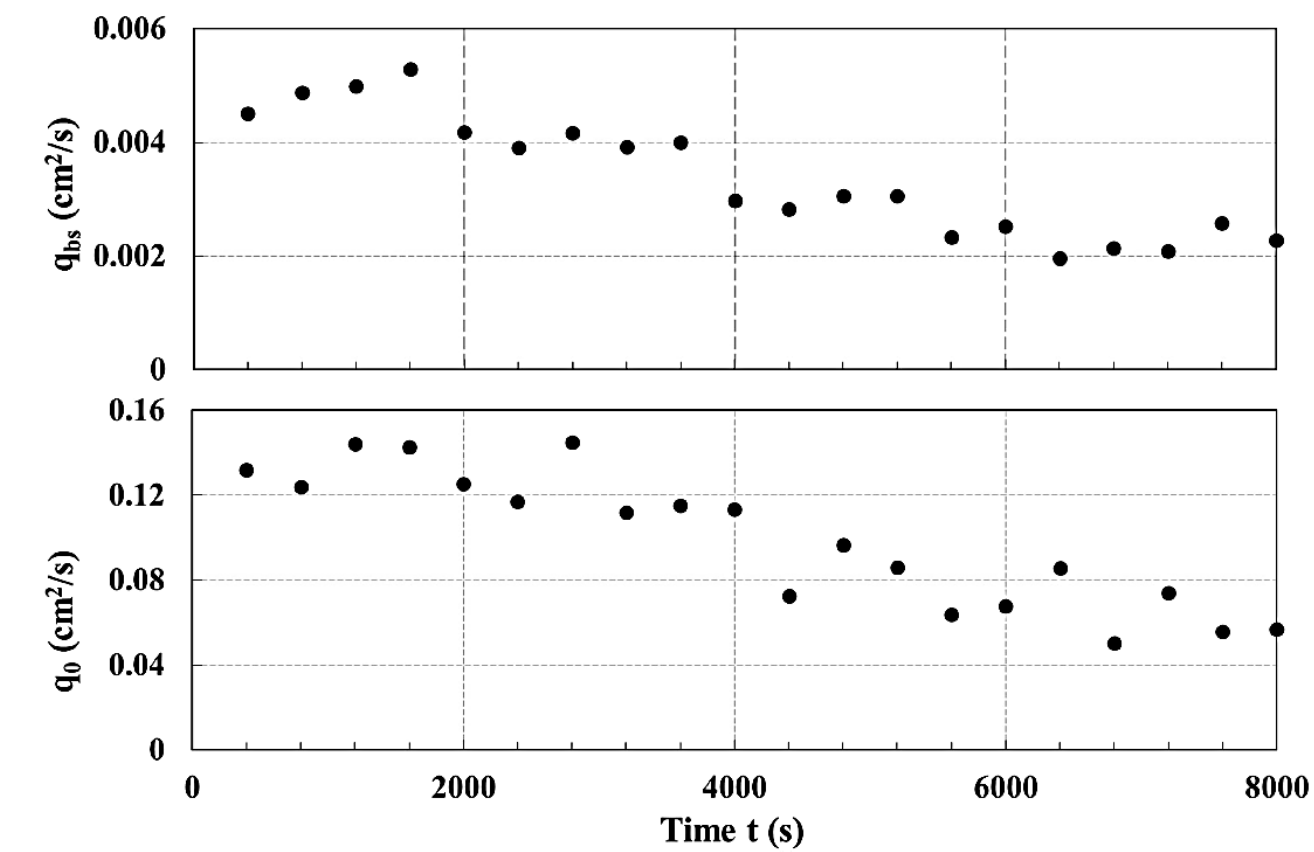
Mean and standard deviation of free surface elevation η and horizontal velocity U together with wet probability Pw for 10 runs during P11 to P20 in Test P

Initial and final beach profiles for Tests Z,N and P



- Profile changes during 5 or 10 runs were about 2 mm for x< 11m and up to 1 cm for x > 17m where a step-like feature developed.
- Minimum (1 mm) profile change at x = 11.7 m.

Sand overwash rate q_{bs} and water overtopping rate q_o during Test P



- q_{bs} and q_o decreased as the foreshore crest became higher
- Ratio of q_{bs}/q_o was about 0.035.
- Overwashed sand volume during Test P was 27 cm^3/cm.

4. Conventional Shoreline Translation Model

- The conservation of sand volume based on net cross-shore sand transport rate q_n and still water shoreline location $x_o(t)$ with t=time.

$$(B+d_c)\frac{dx_o}{dt} = \frac{q_n}{1-n_p}$$

Entire active equilibrium profile translates

- onshore for $q_n > 0$
- offshore for $q_n < 0$

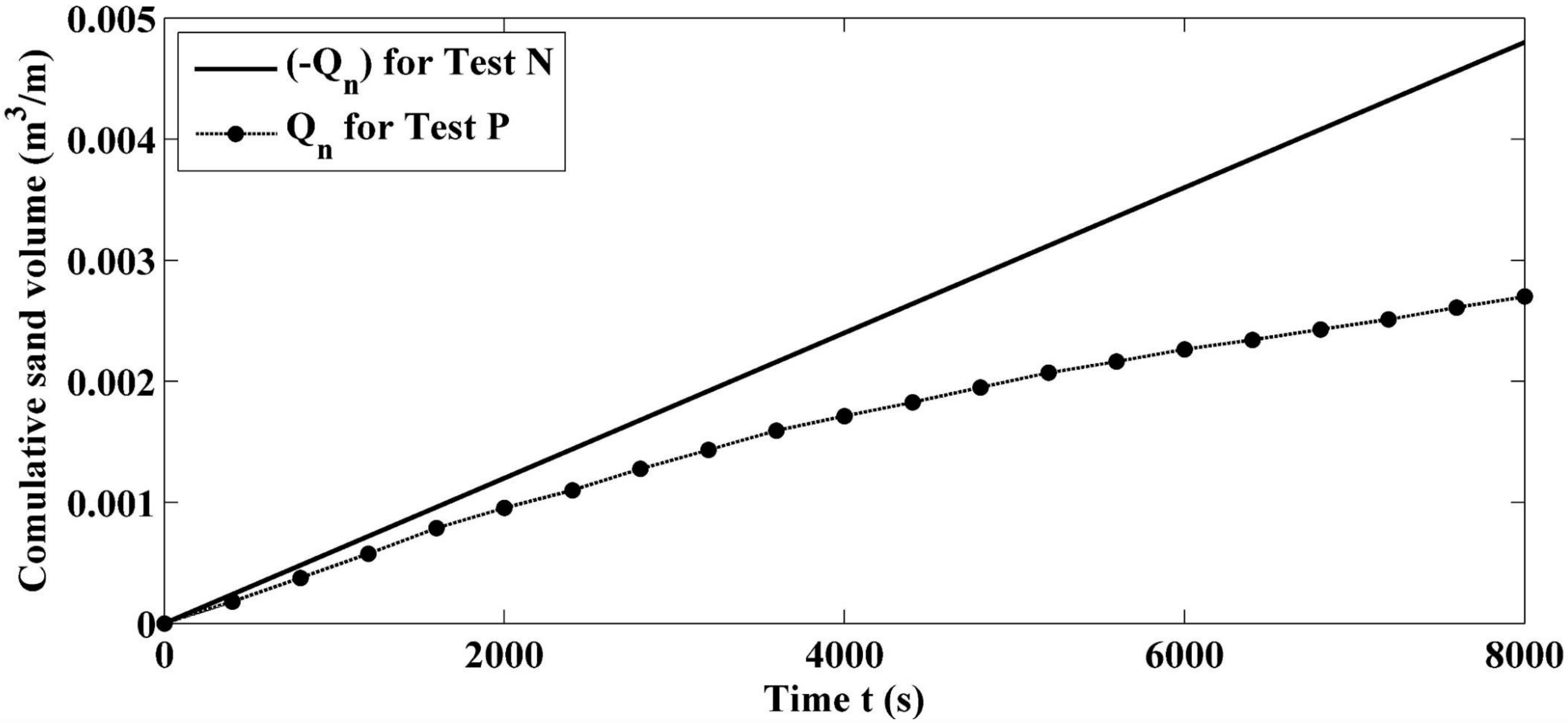
Test	B (m)	dc(m)	(B+dc)
N	0.20	0.20	0.40
P	0.17	0.24	0.41

- Shoreline displacement $\Delta x_0(t)$

$$\Delta x_0(t) = \frac{Q_n(t)}{(B+dc)(1-np)}\;;\; Q_n(t) = \int_0^t q_n dt$$

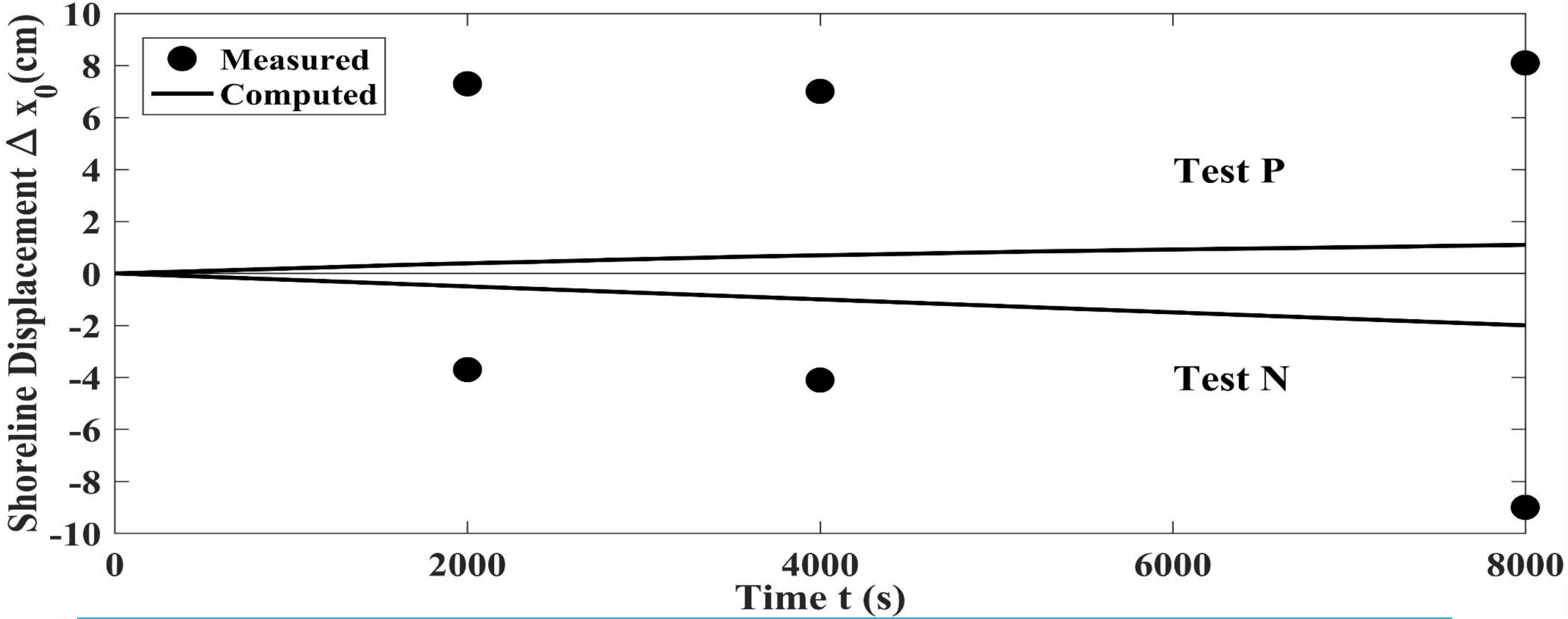
with $Q_n(t)$ = cumulative sand volume per unit width which is added (negative) or removed (positive) from the active profile.

Time series of cumulative sand volume per unit width for Tests N and P



The absolute values of Q_n were similar initially.

Measured and computed shoreline displacement Δx_0 which is negative for Test N and positive for Test P



- ❖ The entire active profile with its height $(B+d_c)$ = 0.4 m did not translate during 8,000s.
- ❖ The measured shoreline shift was less than 0.1m.

5. New Equilibrium Profile Model

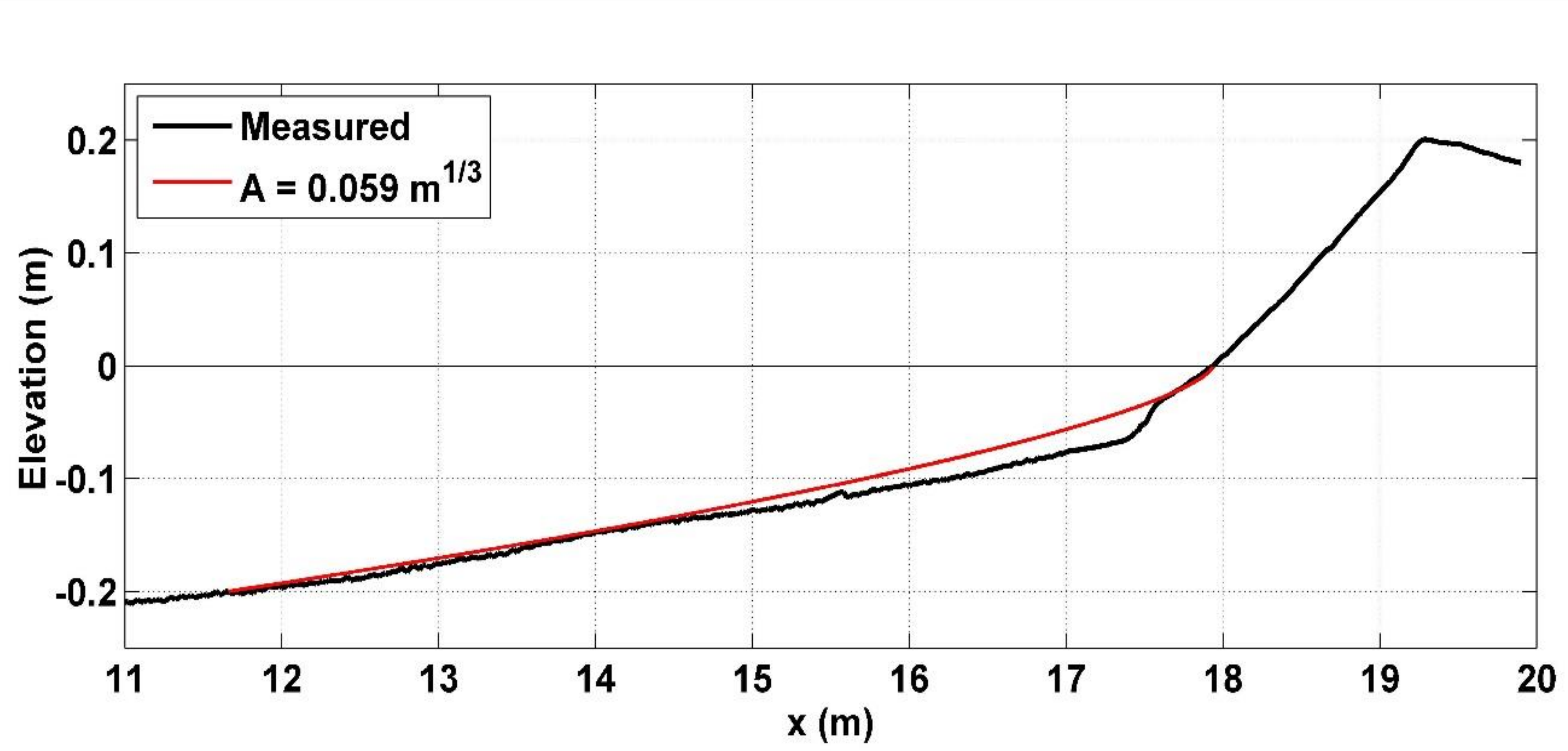
❖ The continuity equation of bottom sediment for an equilibrium profile under the assumption of alongshore uniformity requires no cross-shore gradient of the net rate q_n

$$q_b + q_s = q_n \; ; \; q_n = \text{constant}$$

where q_b and q_s = cross-shore bed load and suspended load transport rates per unit width.

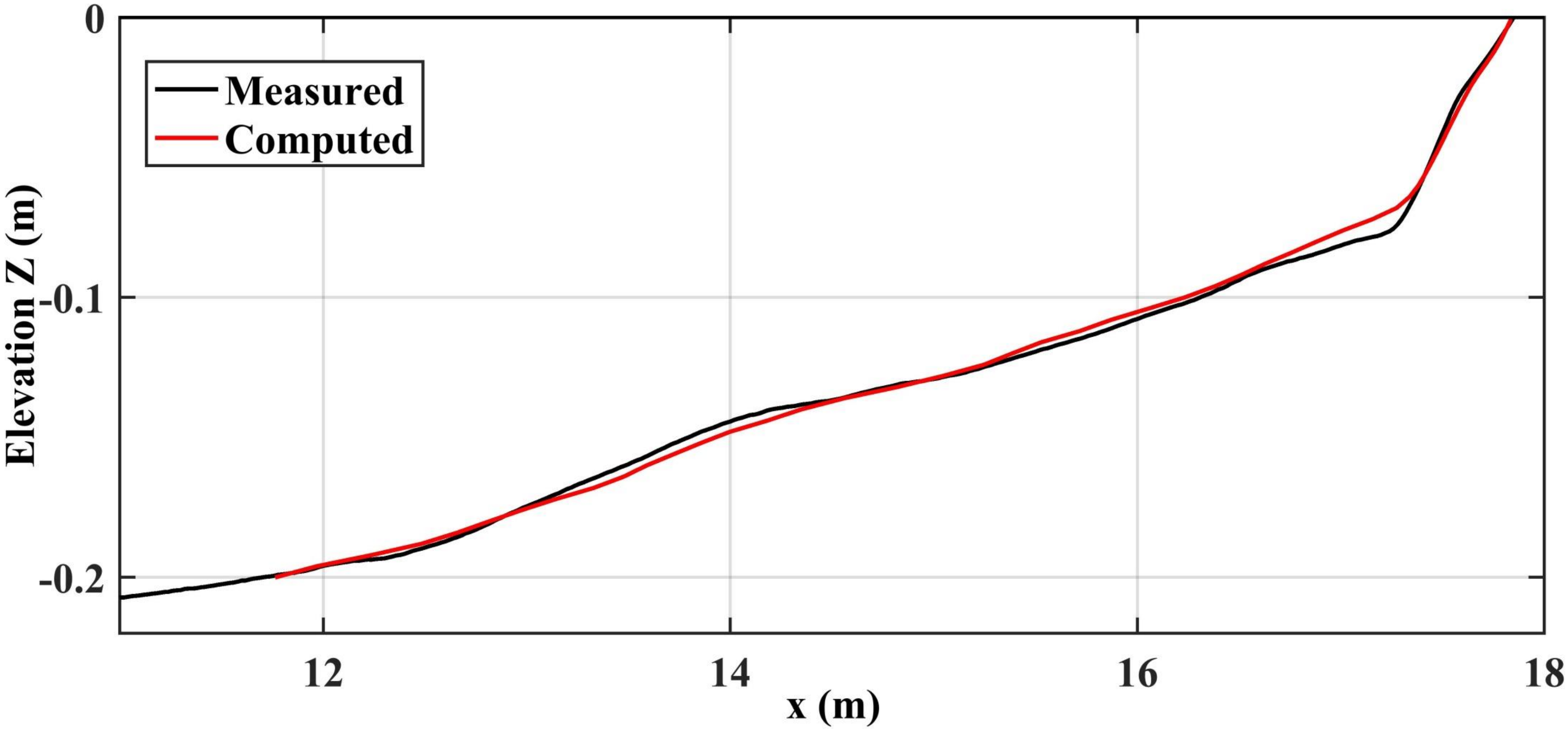
❖ The formulas of q_b and q_s in CSHORE by Kobayashi et.al. (2008) are simplified to derive an analytical equilibrium profile for an arbitrary q_n.

Measured profile fitted with analytical profile for range of 11.7 – 17.9m (closure depth to shoreline) for Test Z



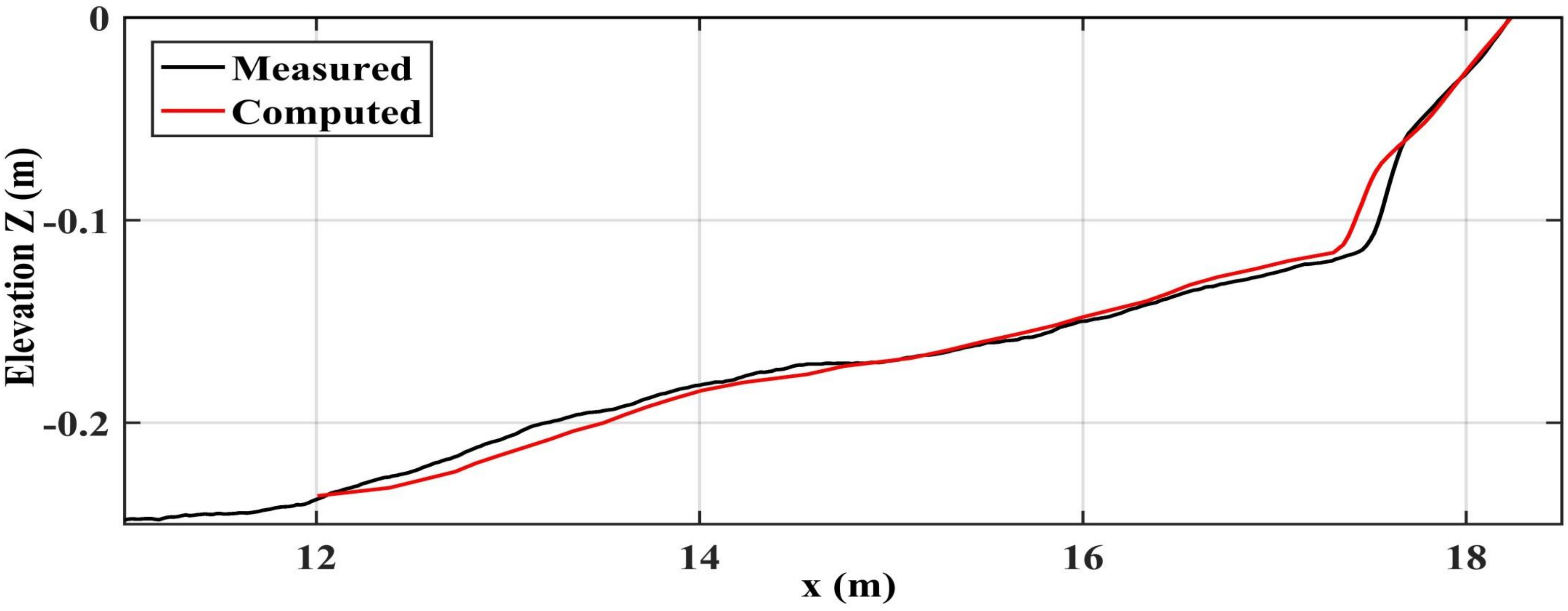
The analytical profile does not include a step formed at the toe of the foreshore.

Measured and computed profile of N20 starting from initial profile of N0



Computed profile is the sum of initial profile N0 and analytical profile shift.

Measured and computed profile of P20 starting from initial profile of P0



- Computed profile is the sum of the initial profile P0 and analytical profile shift.
- The agreement is worse partly because of onshore step migration.

6. Field Applications of New Model

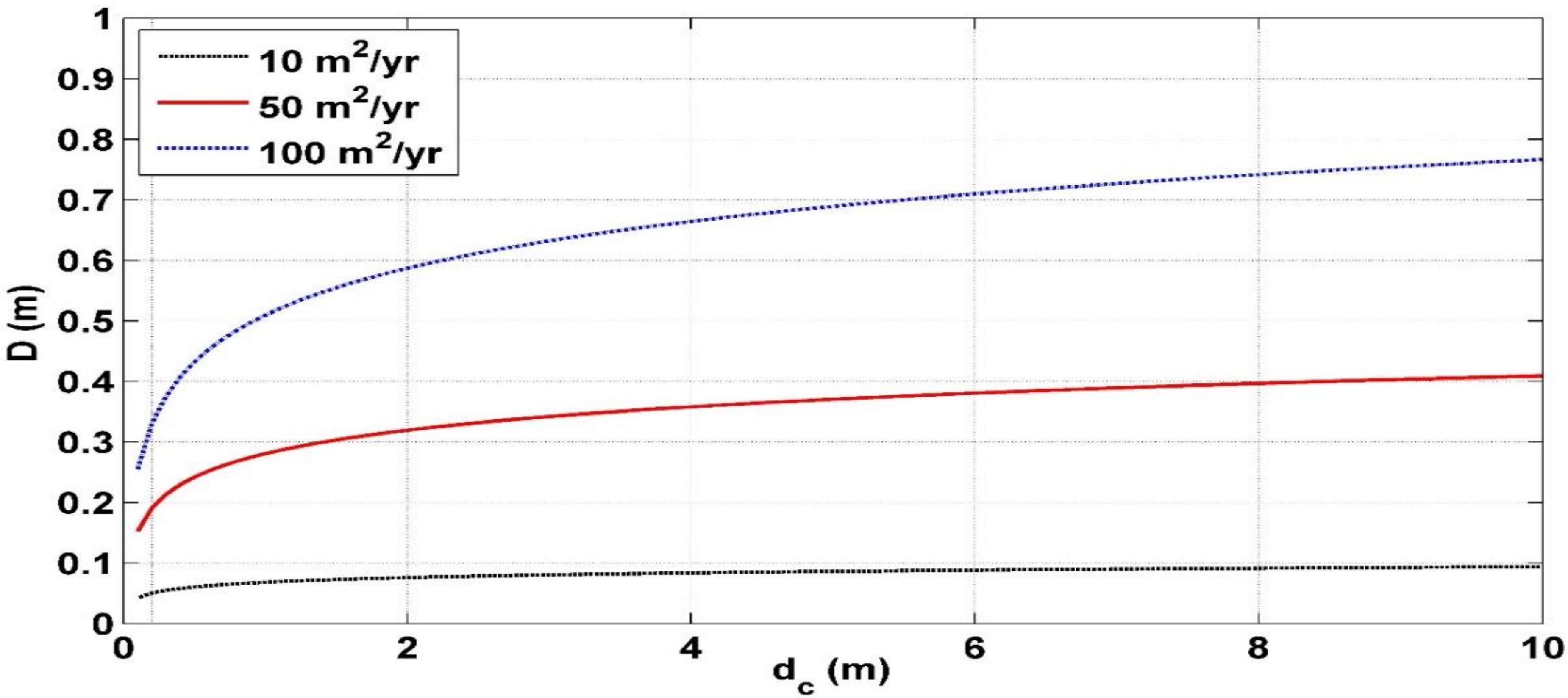
- Present beachfill design does not account for an equilibrium profile modification by periodic beachfill placement (q_n<0).
- Seaward shoreline displacement D

$$D = \frac{-qn}{\propto A^{1.5}} ln \left|\frac{1-q_*}{-q_*}\right| ; q_* = \frac{q_n}{\propto d_c{}^{1.5}}$$

- For Test N; A = 0.059 $m^{1/3}$ (fine sand) ;d_c = 0.2 m ;

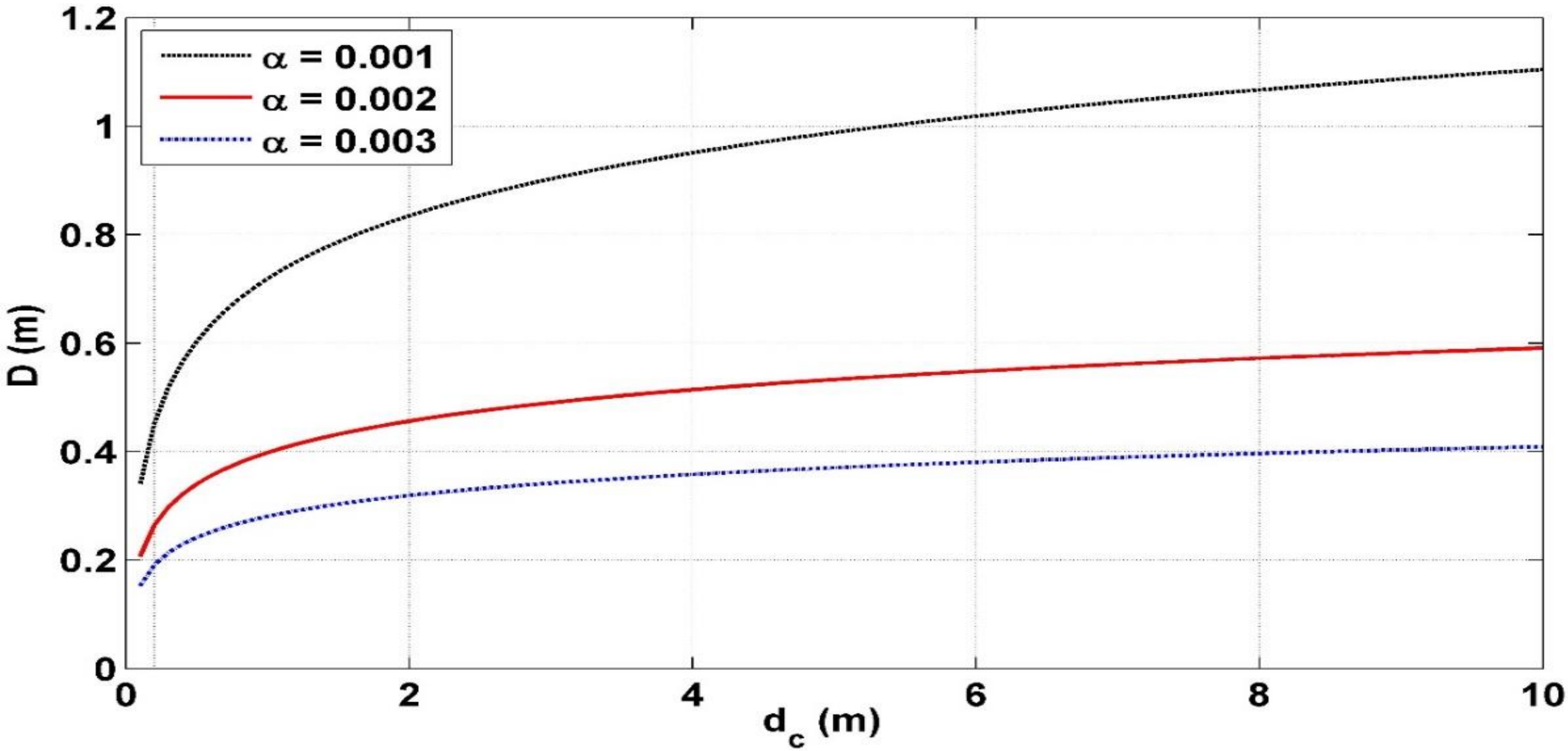
  ($-q_n$) = 0.006 cm^2/s (19 m^2/year)
- Calibrated α = 0.003 $m^{1/2}/s$ but α = 0.0015 $m^{1/2}/s$ for Test P

Seaward shoreline displacement D as a function of closure depth d_c for α=0.003 $m^{1/2}/s$ and $(-q_n)$ = 10 , 50 and 100 m^2/y of fine sand (A = 0.059 $m^{1/3}$)



- The shoreline displacement increases with the increase of $(-q_n)$.

Seaward shoreline displacement D as a function of closure depth d_c for $(-q_n) = 50\ m^2/y$ of fine sand ($A = 0.059\ m^{1/3}$) for α= 0.001,0.002 and 0.003 $m^{1/2}/s$



- The shoreline displacement is sensitive to the bed load parameter α but may not exceed 1 m.

7. Conclusions

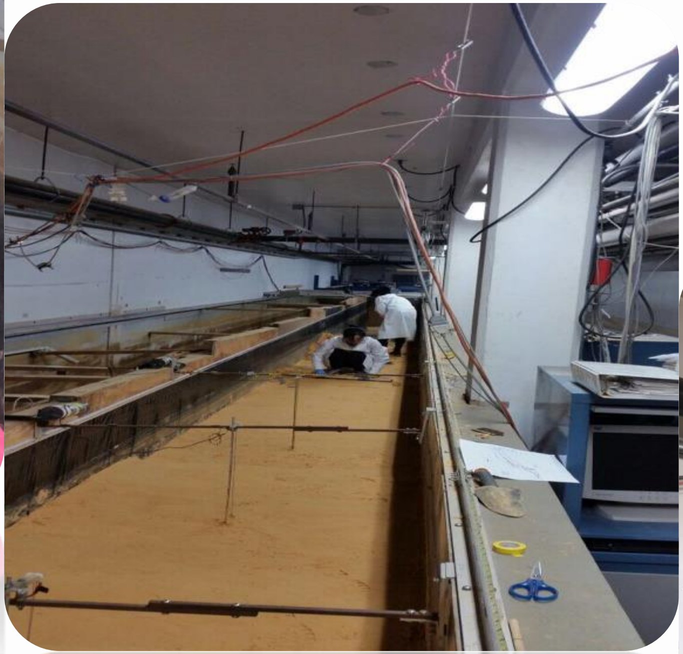
- Three tests consisting of fifty 400-s runs were conducted to quantify the differences among quasi-equilibrium profiles in the inner surf zone under conditions of zero , offshore and onshore net sand transport.
- Periodic sand placement near the shoreline resulted in seaward foreshore slope translation and steeper beach profile.
- Wave overtopping and overwash caused landward shoreline shift and gentler beach profile.
- Profile changes among the three tests were small and shoreline shifts were less than 0.1m.

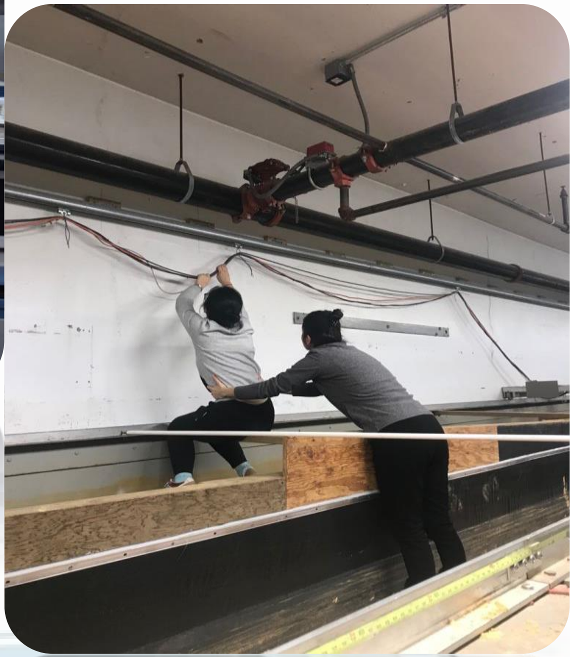
- Analytical model for an equilibrium profile with net cross-shore sand transport is developed and two parameters (A and α) in the model are calibrated using the three tests.

- Calibrated model is used to estimate seaward shoreline shift on periodically nourished beaches, which is of the order 1m or less.

- Analytical model will need to be verified using large-scale laboratory data and field data.

THANK YOU





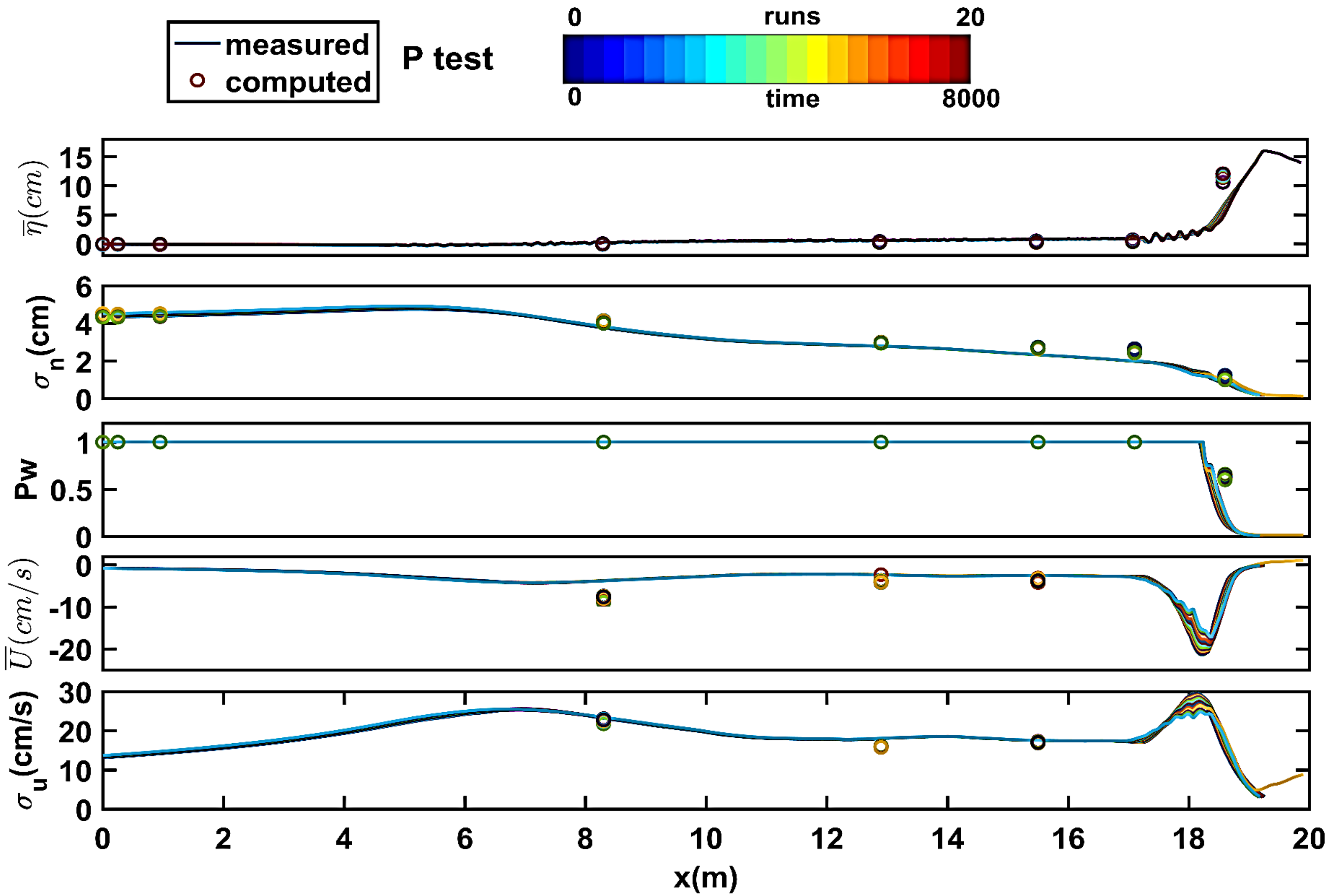
Comparison of CSHORE with Three Tests

The following components of CSHORE for normally incident waves are used:

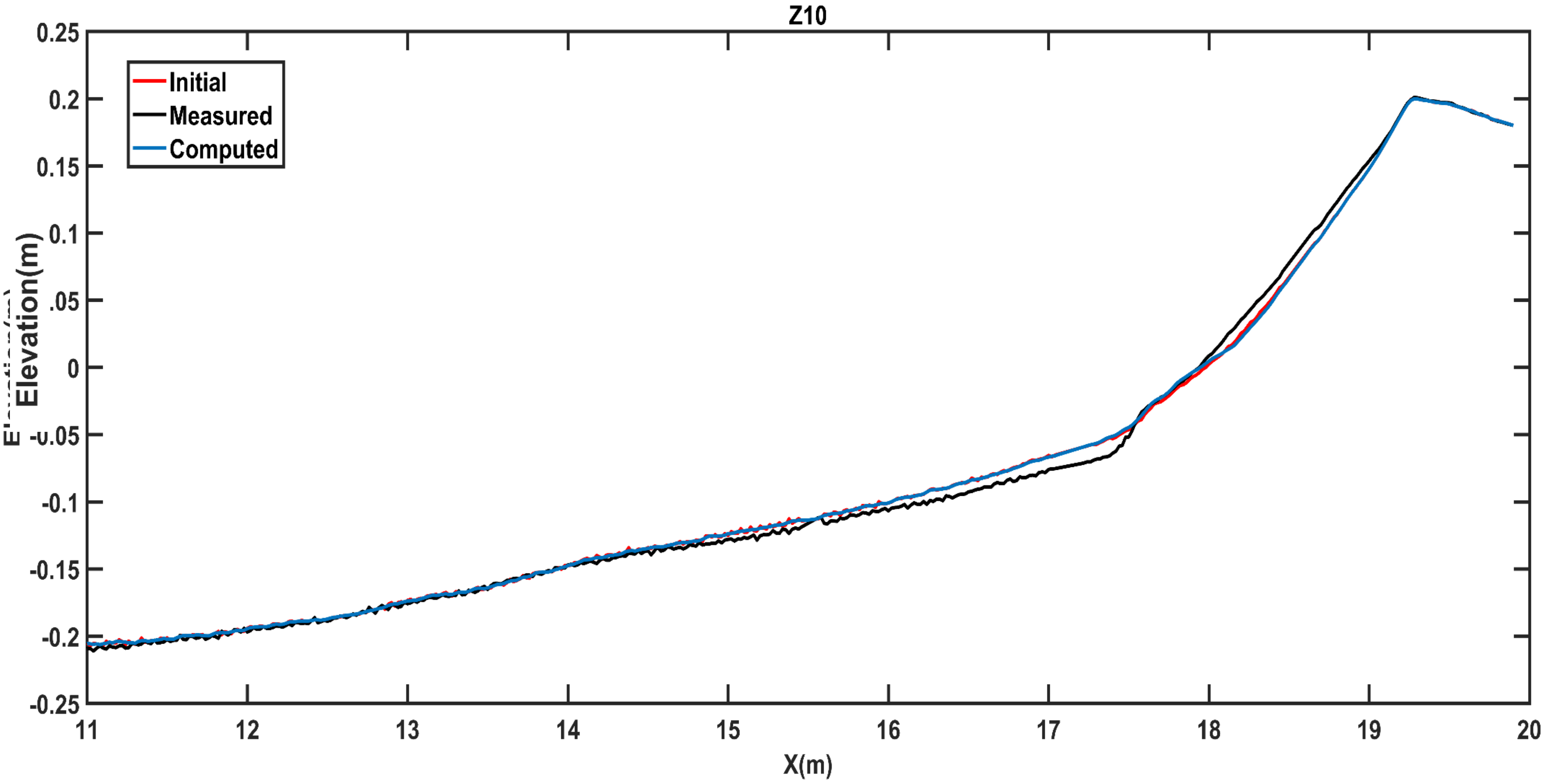
- Combined wave and current model for bed load and suspended load coupled with the continuity equation of bottom sediment.
- Probabilistic swash model on impermeable bottom

Input to CSHORE for each test:

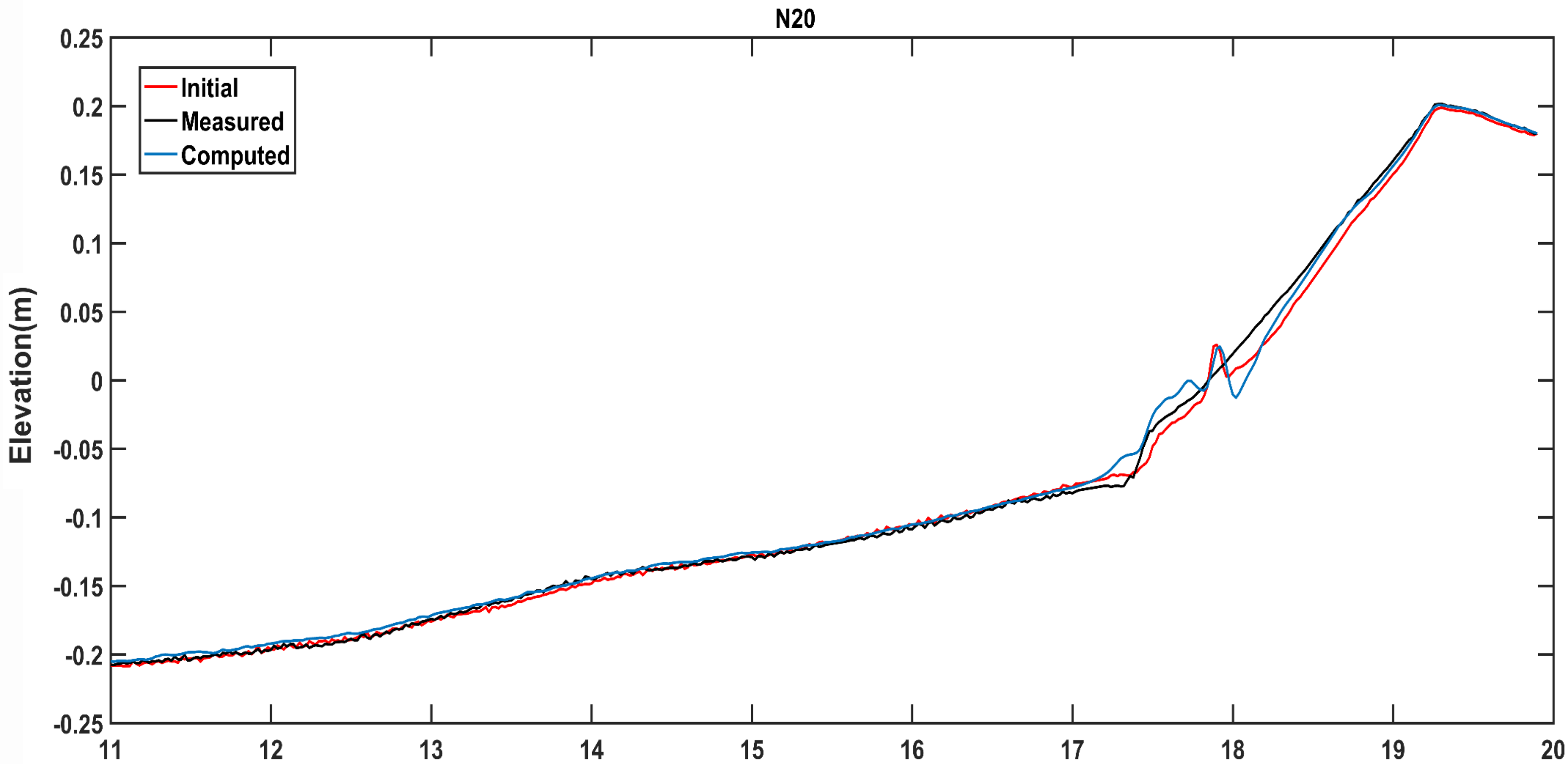
- Measured initial bottom elevation.
- Measured values of $\overline{\eta}$, H_{mo} and T_p at x=0 (WG1).



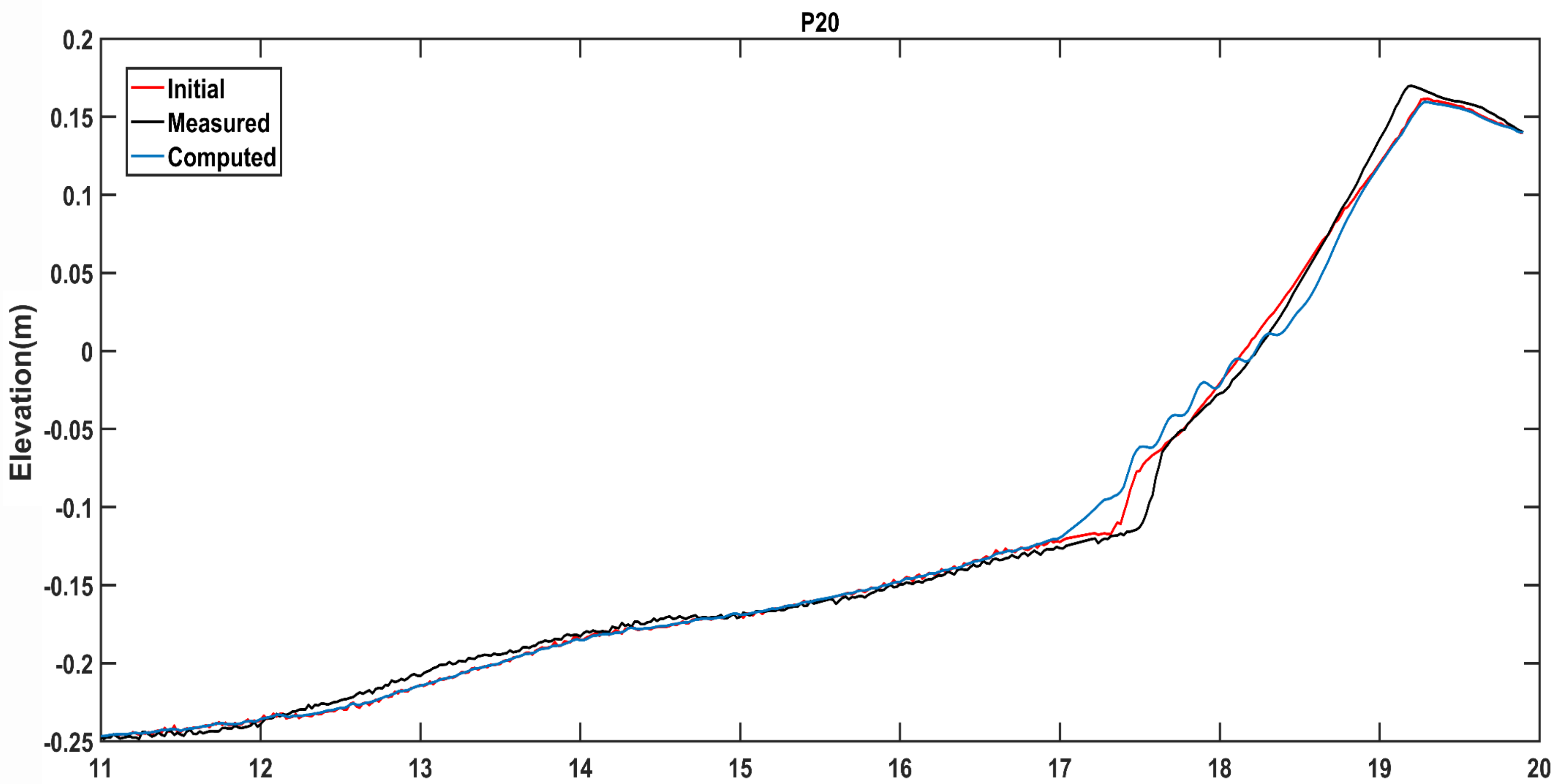
Mean and standard of free surface elevation η and horizontal velocity U together with wet probability P_w for 20 runs during time t = 0 to 8,000 s for Test P.



Measured initial and final profiles and computed final profile for Test Z



Measured initial and final profiles and computed final profiles for Test N



Measured initial and final profiles and computed final profiles for Test P