Coastal Engineering Technical Note

Irregular Wave Runup on Beaches

PURPOSE: The purpose of this technical note is to provide preliminary empirical guidance on estimating wave runup on natural beaches based on field tests conducted by the Coastal Engineering Research Center at the U.S. Army Engineer Waterways Experiment Station.

APPLICABILITY: This technical note applies to all Headquarters, U.S. Army Corps of Engineers (HQUSACE) elements and field operating activities having Civil Works design responsibility.

BACKGROUND: The estimation of wave runup on natural beaches is important to the design of artificial fill beaches as well as to estimation of flood structural damages on existing beaches for "as-is" project conditions. Existing design practice estimation of wave runup in many countries relies on measurement of offshore wave climate at a site and input of such wave climate into a non-distorted physical model. Output water level time series on a beach are then projected from measured water levels in the physical model. At present, the physics of wave runup on beaches is not understood and therefore cannot be numerically modeled. Empirical guidance is utilized for preliminary project estimation of gross wave runup statistics where physical modeling cannot be achieved due to time or money constraints. It should be recognized that present empirical guidance must only be utilized as preliminary guidance due to the limited nature of existing data and the wide scatter provided by such data. For proper design where project design affects either lives and/or property values, laboratory testing is still necessary to assess damage levels due to wave runup and consequent wave overtopping.

DISCUSSION OF THEORETICAL ASPECTS OF WAVE RUNUP: Wave runup is the dynamic elevation of the water level above still-water level due to wave action. Wave runup on a beach for laboratory monochromatic waves is typically defined as the maxima of the dynamic excursion of the water level on a sloping beach (see Figure 1) and consists of two parts, (1) wave setup, which is a

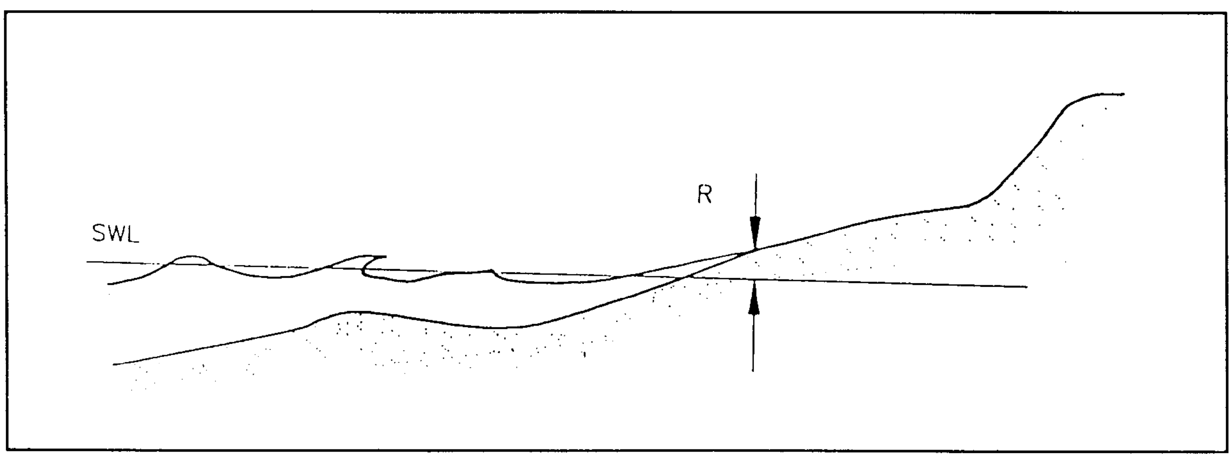

Figure 1. Definition sketch for runup

lower frequency rise in the water level due to dissipative wave action on the beach, and (2) dynamic wave swash, which is the dynamic excursion of the water level from the low-frequency wave setup component believed to be partly due to the non-dissipative portion of the wave action on the beach. Wave runup for monochromatic waves in laboratories is considered to be the combined component of the wave setup and the maxima of the dynamic swash component as shown in Figure 2. In irregular

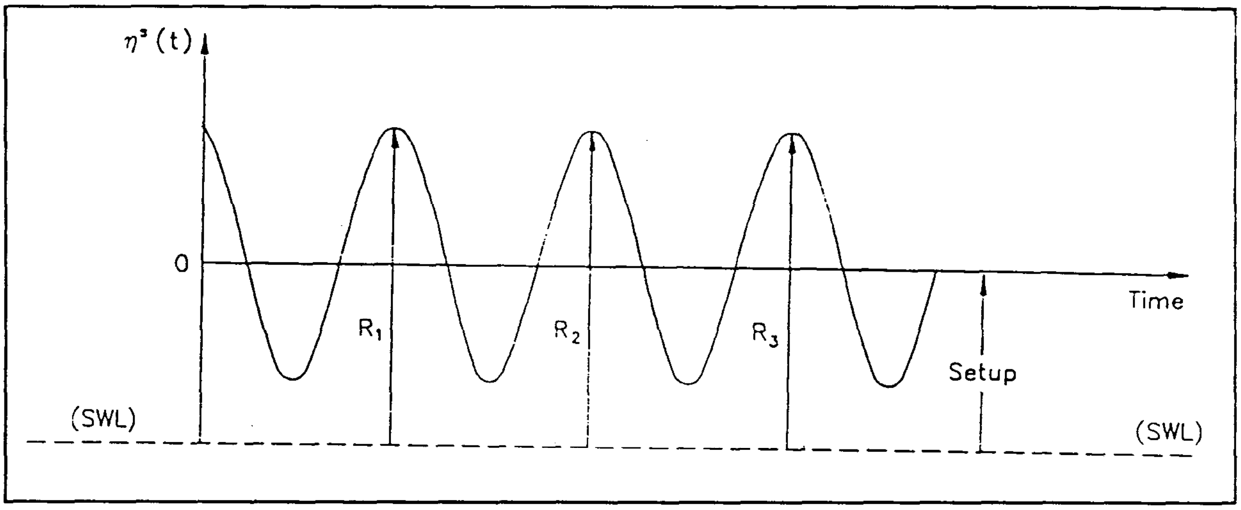

Figure 2. Regular (monochromatic) wave runup

wave runup, the statistics of wave runup must be addressed since runup is different for each different swash maxima deviation from wave setup (see Figure 3). Swash is defined as the difference in elevation between any local crest in the water level on the beach and setup level at the intersection of the still-water level and the beach. Additionally, different averaging time periods will provide different results for averaged setup or swash statistic values.

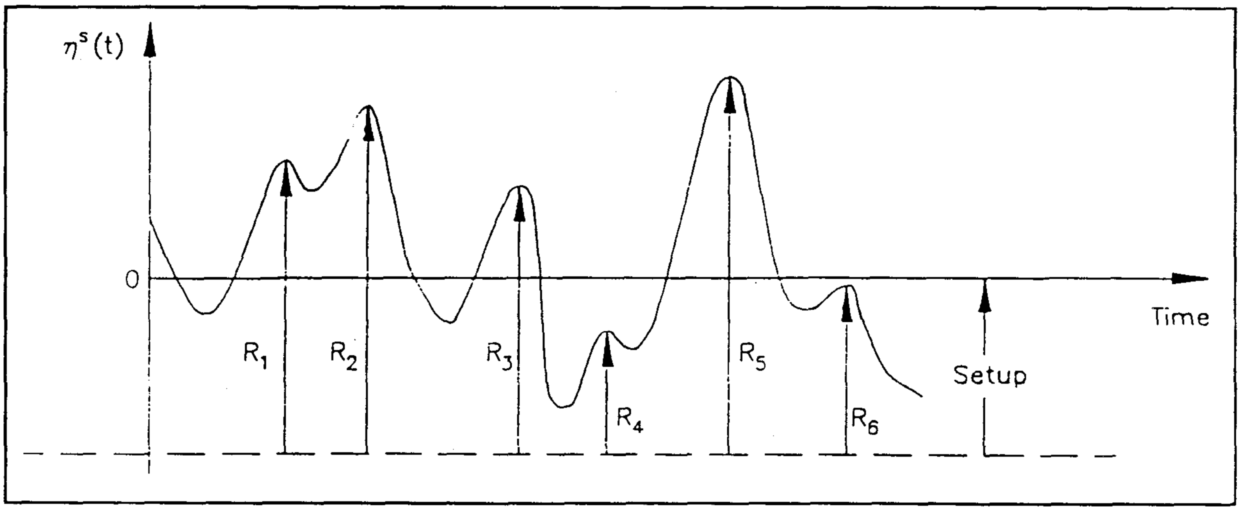

Figure 3. Irregular wave runup

Wave runup for field data is often defined differently from that in the laboratory. Typically prototype runup is defined as the combined effect of wave setup and some statistic/quantile of the swash process in terms of swash level crossing η_s . In this sense, prototype field wave runup is typically defined as $R_p = setup + \eta_{s(p)}$ where $\eta_{s(p)}$ is the swash level crossed by *P* percent of the swash data (i.e. *P* percent of the time the swash is above this level). This is the approach that will be utilized in this guidance.

AUSTRALIAN RESEARCH: Efforts to measure field wave setup and wave runup have been made on a number of Australian beaches (Davis and Nielson 1988; Nielson 1988, Nielson 1990, Nielson and Hanslow 1991). Certain statistical measures of setup and runup were provided but most of the runup data is from visually estimated measurements taken over differing time intervals and offshore data did not come from the beach sites but from some distance away. Additionally, empirical "constants" in measured distributions are not truly constant but change even for the same beach at different times.

UNITED STATES RESEARCH: Research efforts by a number of investigators (Holman(1986), Guza and Thornton (1989), Holman and Sallenger (1985)) provide data from a limited number of west coast sites as well as one east coast site. Data are very scattered and there are questions in some of the data as to conflicting results (Douglass (1992)). Additional problems of concern are that estimation of setup for west coast research results were not surveyed to the same reference as offshore wave gauge elevations.

PRELIMINARY EMPIRICAL GUIDANCE: Preliminary empirical guidance on wave runup presented here is formulated from data sets taken from beaches on the east coast of the United States. In these sets of data, the wave parameters Horms and T (see *Shore Protection Manual* (SPM) 1984 for definitions) were measured by an offshore pressure gauge in approximately 10 m of water and the setup and swash statistics were determined from video camera records via a video imaging system discussed in Coastal Engineering Technical Note (CETN)-II-23 (U.S. Army Engineer Waterways Experiment Station 1990). Results of preliminary analysis of the irregular wave runup data show the swash process to have a typically wide spectral bandwidth. The swash process can be assumed as a first approximation to be of Gaussian form. The standard deviation of the swash can be found to a first approximation as:

$$SD(swash) = C1 * Hmo$$

where $C1 = 0.5$ based on preliminary guidance.

Setup can be found to a first approximation as:

$$Setup = C2 * Hmo$$

where $C2 = 0.4$ based on preliminary guidance. Runup (defined here in terms of beach face water level crossing statistic/quantile) consisting of the combined setup and swash can be approximated based on preliminary findings as

$$Rp = C1 * Hmo + Zp * C2 * Hmo$$

where *Rp* is the beach face water level which would be exceeded P percent of the time, and *Zp* is the standard normal deviate as per the normal distribution. The value of Zp can be found from any standard statistical book (i.e. Rice 1988). As an example, for the runup which would be exceeded for $p=5$ percent of the time , the value of Zp would be $Zp = 1.645$ (see Figure 4). Although beach slope, wave period, and other factors are believed to be important in the estimation of wave runup, the considerable scatter noted in the analysis of presently existing data and the narrow range of wave freqencies observed in data collected to date does not provide substantial evidence for their incorporation at this time.

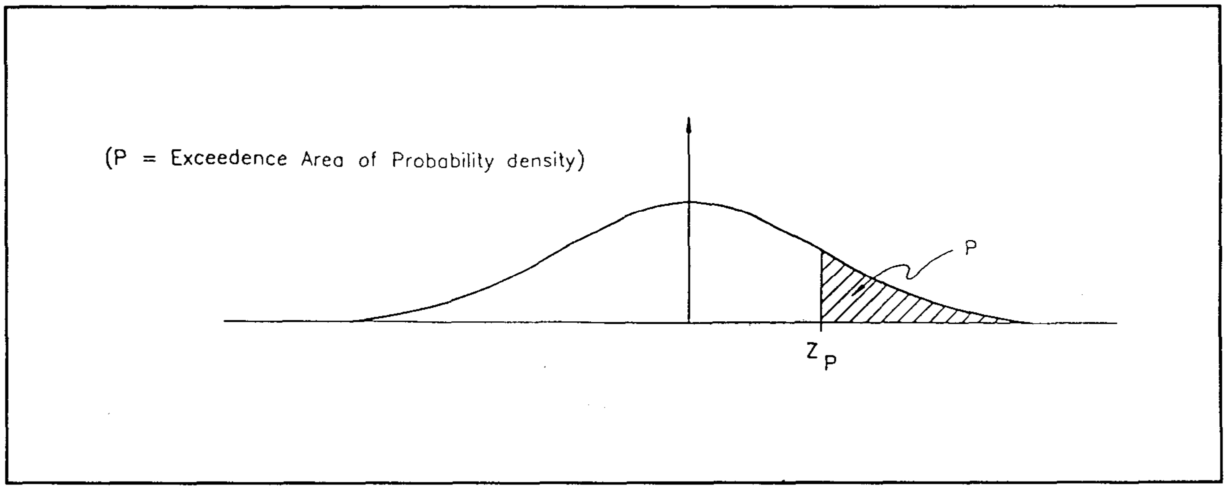

Figure 4. Standardized normal distribution terms

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