Coastal Engineering Technical Note

A REMOTE SENSING SYSTEM FOR MEASURING RUNUP

PURPOSE: This note discusses a technique to remotely measure wave runup using video image processing. The technique permits inexpensive measurements of runup and requires as little as a camcorder and a tripod. A description of the image processing technique, its application, and a field evaluation are presented.

BACKGROUND: Runup is composed of two components, a steady super-elevation from mean sea level called setup, and a fluctuating component called swash. The upward motion of the swash up a beach is termed *up-swash*, and the vertical displacement is the runup. The opposite motion, *down-swash*, has a corresponding vertical displacement called rundown. Runup is of vital interest to the engineer designing coastal structures that must withstand overtopping and erosion.

Traditional methods of measuring runup used capacitive or resistance wires supported above the bed. However, they have several disadvantages. They are prone to fouling and have to be manually adjusted to changes in the sand level (erosion and burial). Moreover, in situ gages can not be used for long-term monitoring or during storms when rapid beach changes are occurring. Another runup measurement technique is to manually survey the maximum extent of each swash. Besides being labor intensive, this method provides only a measure of the upper limit of the up-swash, not a complete swash time series.

Dr. Holman of Oregon State University developed a remote sensing technique for measuring runup; first with time-lapse photography, more recently using a computerized video image processor. Time-lapse photography can produce a time series of wave runup, but only after tedious hand digitization of the film, a process that also requires a degree of subjectivity by the operator. The video technique provides an economic

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **SEP 1990**	2. REPORT TYPE	3. DATES COVERED **00-00-1990 to 00-00-1990**
4. TITLE AND SUBTITLE **A Remote Sensing System For Measuring Runup**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army Engineer Waterways Experiment Station,Coastal Engineermg Research Center,3909 Halls Ferry Road,Vicksburg,MS,39180**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

alternative to the traditional methods of measuring runup and automates the digitization process.

As incident waves break on a beach they produce bubbles and foam that are highly reflective to light, creating a visual contrast with the lower level of reflectance from the beach. The video image processor can track and measure the swash oscillation by detecting the change in contrast between the water/foam line and the beach. Positions of the swash are measured on transects across the beach, normal to the shore (Figure 1). The image processing system presently obtains runup time series at a 1 Hz sampling rate.

APPLICATIONS: The principal application for this video imaging system lies in the ability to measure runup at several alongshore locations simultaneously. This permits the longshore variation in runup to be examined and is useful for detecting and quantifying phenomena such as infragravity edge waves.

The actual vertical runup and rundown can be determined from the video images if the profile of the beach is known. This information can be obtained by surveying the beach cross-section. Methods are being developed that will ultimately allow the image processor to determine the beach profile, permitting daily cross-section measurements and more accurate runup results.

Another potential application for this system is measuring runup on structures. Installing and maintaining gages for measuring wave runup on structures is difficult, or even impossible, due to the extreme forces involved. Making video measurements of runup on structures is even simpler than on a beach, since structures are stationary and will not require repeated surveys to determine the profile.

SYSTEM REQUIREMENTS: The equipment required for data collection is minimal, a black-and-white video camera and recorder, or a camcorder. Typically, 40 minutes of video are sufficient to produce a reasonable length time series for computing runup spectra. However, longer records may be desired for improved resolution of the infragravity wave band, possibly two hours or more.

The camera can be positioned wherever an adequate vantage point of the study area exists. Oblique camera angles are generally used to obtain sufficient coverage of the longshore variations of runup. If measurements are required in a more confined region, with little longshore extent, then positioning the camera so this region fills the field of view will produce improved runup estimates (i.e., better resolution). Increasing the camera elevation results in a less oblique view, which will also reduce errors in determining positions of objects in the image. Best results are achieved when the camera is mounted high above the ground plane and on a stable platform.

Transformation from the three dimensional ground plane to the two dimensional image plane can be determined if the geometry is known. The reverse transformation (called rectification) is required for computing runup positions along transects. This is accomplished by first computing the geometry of the region using a standard cartesian coordinate system, selecting two axes (x and y) in the horizontal plane (e.g., mean sea level) and the third axis (z) positive upwards. In order to perform rectification, the camera position and the ground position coordinate (GPC) of at least two points in the field of view must be known. Additional GPC points will further improve the accuracy of determining the geometry. The imaging system then uses the GPC points and corresponding image coordinate points to compute transformation parameters for mapping from video image positions to ground positions.

The accuracy of determining runup positions on a transect depends on several factors that affect the transformation between the image and ground coordinates. First, errors associated with measurements of the camera height and the position of the GPC points are neglected since these can be surveyed to a high degree of accuracy. Second, the image processing system digitizes the image into a 512-by-512 array of pixels. This quantification of the video determines the fundamental limit on the angular resolution for the system, which in turn sets limits on the accuracy of calculating ground coordinates. Accordingly, reducing the apparent distance between the camera area of interest, either with a telephoto lens or physically moving closer, will improve resolution.

Another limitation on the system resolution is the resolution of the camera and recorder. Several types of cameras are manufactured which have greater resolution than the image processor, and therefore do not limit resolution. Unfortunately, none of the conventional formats for recording video have resolutions that equal or exceed the image processor. However, some video cassette recorders (VCR's) have resolutions sufficient for this application. Both Super-VHS and Hi 8 mm have resolutions exceeding 400 lines (the image processor has 512 lines), and are recommended over standard 8 mm, Beta, or VHS video formats.

Digitization errors associated with measuring runup heights are reduced if vertical runup is computed and accurate beach profiles are known. Transforming the digitized swash motion to vertical runup will produce an error reduction proportional to the beach slope. This can be illustrated with an example; assume a beach with a 1:20 slope and a system with a horizontal pixel accuracy of 1 m (1 pixel). On a beach slope of 1:20, 1 m in the horizontal direction corresponds to 0.05 m in the vertical direction. Thus, accuracy of measuring vertical runup improves with an increase in horizontal pixel resolution and with a decrease in beach slope.

FIELD EVALUATION: The video image processing system was evaluated by comparing a time series plot produced by the system against the results of a hand digitization of video taken during a field evaluation test. The field test was conducted 28-30 November 1989 at the US Army Corps of Engineers, Waterways Experiment Station (WES), Coastal Engineering Research Center's (CERC) Field Research Facility (FRF) in Duck, NC. This test was a preliminary evaluation of the initial algorithms of the image processing system and will aid in improving future algorithms.

Ground truthing was accomplished by placing an arrangement of eight stakes across the beach at 10 foot increments. Their locations and elevations were surveyed using a Zeiss Elta 3 total station. These stakes provided reference points and vertical elevations for hand digitization of runup and also provided the coordinates of the beach profile used with the video image processing system. A Super-VHS camcorder was placed in the FRF tower, approximately 140 feet above sea level, and was aimed at the stakes on the beach. Additionally, a black and white video camera with a telephoto lens was set on the pier to record the runup at the same location.

The video of wave runup taken from the tower was then hand digitized. Several 1 to 2 minute blocks of runup video (averaging about 10-20 swashes each) were digitized by stepping frame-by-frame through the video and recording the time that the swash edge crossed each stake. Determination of runup was relatively simple since a well-defined edge was present. However, rundown measurements were more difficult since the edge is not well defined due to percolation and foam remaining on the beach. The same time blocks of runup video were then analyzed using the image processing system. Because the digitizer would mistake the contrast of the stake as a runup edge, the profile used in the image processor analysis was shifted approximately 1.2 ft towards the camera and parallel with the line of stakes.

Time series of the runup obtained from the image processing system were compared with the hand digitized points (Figure 2). As anticipated, small differences in the runup measurements were observed between the two methods. Some of these differences can be attributed to the measurements being made on profiles slightly offset from each other. Also, the subjectivity of selecting the water edge in the hand digitization would account for some of these differences. Although the two methods showed acceptable agreement, some problems still exist at this stage of the systems development and will be dealt with in future modifications.

From the results of this preliminary field evaluation, the following should be considered when using the image processing system for runup measurements:

a. Anomalous spikes and flat bottoms can occur in the time series plot when the runup goes out of the range of the profile or out of view of the video image. For example, these anomalies can be observed in Figures 2a and 2b around the 20-25 second time intervals. As the digitizer searches for the edge, it may either bounce back and forth along the profile (spikes) or remain at the seaward end of the profile (flat bottoms). Making the profile go beyond the lowest runup/rundown point and aiming the camera so that it includes the entire profile will insure that the runup is always in the field of view.

b. A good quality video should be obtained which accurately focusses in on the full extent of the runup and is free from glare and camera movement. Each time the camera is re-focussed, zoomed in or out, or moved, the geometry will be changed. A separate analysis will be necessary to re-compute the new geometry before processing the runup video.

c. The beach should be relatively clear of debris or large objects since the system might detect them as a change in contrast, causing the digitizer to select then as a swash position. Objects in motion on the profile, such as people or vehicles, cause more problems then stationary objects. Even an object such as a shore bird could cause the digitizer to mistake it as an edge.

d. Although the system will input color video (NTSC format), it strips out the color signal before digitization, and processes only the black and white (luminance) signal. Therefore, improved results are obtained with a high resolution black and white video camera (RS-170 format).

e. At this stage in its development, the image processing system still requires an experienced user to execute the runup program. There are several parameters, such as threshold values, which are not yet automated and are dependent on some subjective analysis by the user.

This field test was conducted to evaluate the initial algorithms used with the image processing system and to aid in the future modifications of the system. Software enhancements are being made that will allow for better recognition of the runup edge and will produce a more automated system.

AVAILABILITY: The Corps' obtained a video image processor in June 1989, which is located at the US Army Corps of Engineers, Engineering Research and Development Center, Coastal and Hydraulics Laboratory (CHL) Field Research Facility (FRF), in Duck, NC. Daily videos are collected at the FRF to monitor longshore variations in runup for detecting the presence of infragravity motions. This system records the videos in Super-VHS format. For further information, contact Mr. Kent K. Hathaway, CHL-Field Research Facility, at (252) 261-6840, ext 224 or Kent.K.Hathaway@erdc.usace.army.mil.

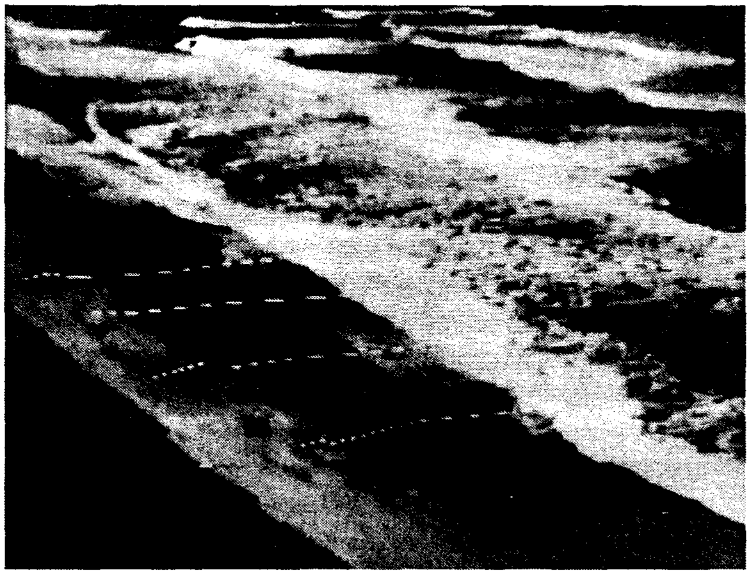
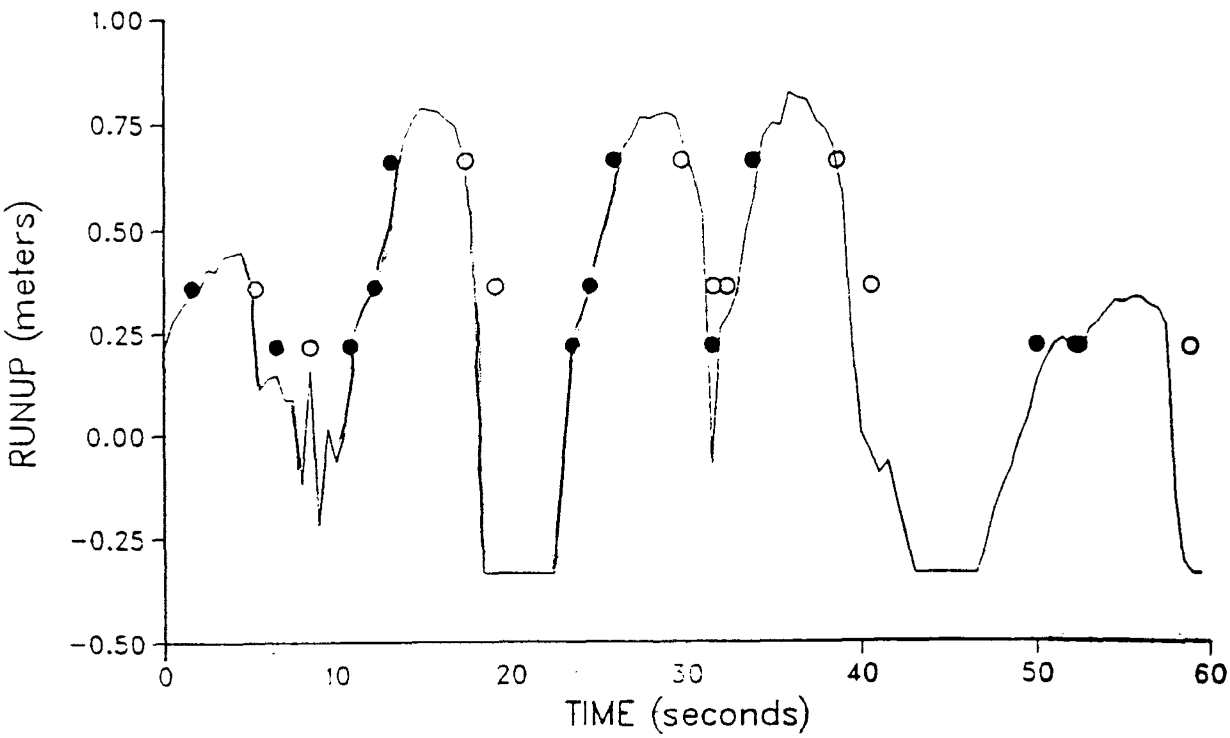
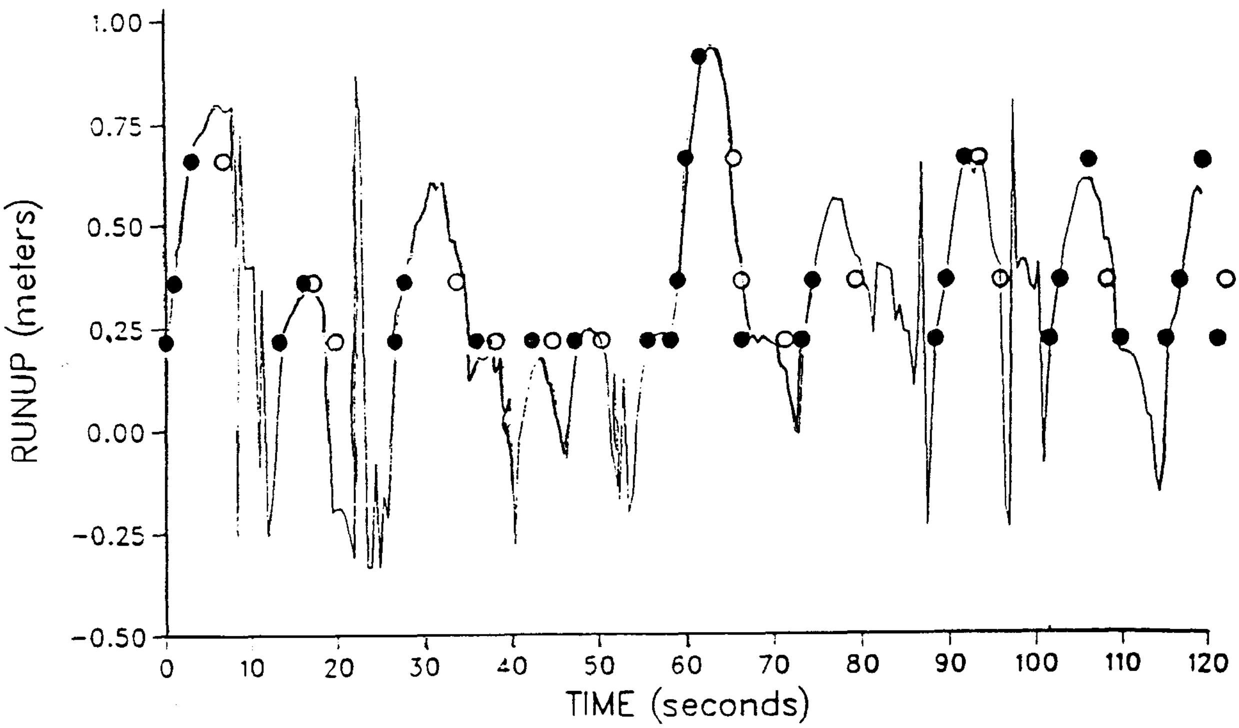


Figure 1. Video image showing four digitization transects. Note the well defined edge between the swash and the beach.



(a)



(b)

Figure 2. Comparison of runup measurements from the video image processor (solid line) to hand digitized runup (solid circles) and run down (open circles) measurements.