LONGSHORE TRANSPORT DETERMINED BY AN EFFICIENT TRAP

by

R. G. Dean[1], M. ASCE, E. P. Berek[2], A.M. ASCE, C. G. Gable[3], and R. J. Seymour[4], M. ASCE

ABSTRACT

The Nearshore Sediment Transport Study (NSTS), sponsored by the National Sea Grant Office included a field component to quantify the total longshore sediment transport relationship. This component was conducted at Santa Barbara, California and encompassed a period of eighteen months during which ten surveys were conducted. To date, eight of these surveys have been analyzed, yielding seven intersurvey periods. A total of 288,600 m^3 of net sediment transport was documented by these eight surveys. The wave characteristics are based on one of two S_{xy} gages located in a water depth of 7 m. The most widely used correlation constant, K, in the relationship $I_\ell = KP_{\ell s}$ is 0.77. The values found from the data were 0.93 and 1.23 for linear and log best-fit values, respectively. The corresponding values of K_* relating I_ℓ and S_{xy} are 2.60 and 2.63 m/s, respectively.

INTRODUCTION

Many coastal engineering projects and interpretation of nearshore phenomena depend on an accurate quantitative relationship between total longshore sediment transport and the wave (and other) characteristics which cause the transport. Although a number of field studies have been carried out, the characteristics of most studies are such that considerable uncertainty exists in either the characterization of the forcing function (i.e. waves) or of the sedimentary response. In particular most of the early data sets

---

[1]Graduate Research Professor, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, FL 32611, Formerly, Professor, Department of Civil Engineering and College of Marine Studies, University of Delaware, Newark, DE 19711.

[2]Research Engineer, Amoco Production Co., Tulsa, OK 74102, Formerly Graduate Assistant, Department of Civil Engineering, University of Delaware, Newark, DE 19711.

[3]Associate Development Engineer, Scripps Institute of Oceanography, University of California, La Jolla, CA 92093.

[4]Associate in Oceanography, Scripps Institute of Oceanography, University of California, La Jolla, CA 92093.

relied on visual observations or hindcasts for wave direction. Additionally a number of the programs were based on tracer studies for determination of sediment transport quantities. In studies of this type, substantial uncertanties exist due to the approximations required to determine the effective vertical and lateral limits of transport.

The present paper describes a field measurement program carried out at Santa Barbara, California. The wave characteristics were determined by an "S_{xy} gage" comprised of four pressure sensors positioned on the bottom at the corners of a 6 m square array in 7 m of water depth. These wave conditions were transformed to the breaker line where both $P_{\ell s}$ and S_{xy} were established for correlation with the sediment transport. The net longshore sediment transport reported herein was established by means of eight surveys, each consisting of 67 beach profiles and 63 survey lines. The "near total" trap is the spit of sand which is attached to the eastern end of the Santa Barbara breakwater and portions of the updrift beaches. The surveys encompassed a period of 13 months during which a total of 288,600 m^3 of net sediment transport was documented. Correlations are presented of the net longshore sediment transport with $P_{\ell s}$, the longshore component of energy flux at breaking and S_{xy}, the flux in the onshore direction of the longshore component of momentum.

PREVIOUS RELATED INVESTIGATIONS

The number of field investigations of longshore transport is very limited. Greer and Madsen (1979) undertook an evaluation of the field data sets available in 1978. These included a sediment trap at South Lake Worth Inlet, Florida, reported by Watts (1953), a study of erosion downdrift of a jetty at Surfside, California, reported by Caldwell (1956), and sand tracer experiments at El Moreno Beach, Mexico, and Silver Strand Beach, California, by Komar (1969). Greer and Madsen find convincing reasons for rejecting all but the Komar results and find that these, at best, are only order of magnitude estimates.

Subsequent to the Greer and Madsen review, three more data sets were reported at the Seventeenth Coastal Engineering Conference that overcame many of their objections to the first three. Seymour et al (1981) describe a sediment trap experiment at Santa Cruz, California, with an adjacent directional wave measurement array. Bruno, Dean and Gable (1981) report a series of experiments with a trap at Channel Islands Harbor, California, with a pair of wave gages nearby providing low resolution wave directional information. Inman et al (1981) describe tracer experiments at Torrey Pines Beach, California, employing a linear wave measurement array. In addition, Kraus et al (1981) report a series of tracer experiments at Ajigaura and Oarai Beaches in Japan.

The most widely used relationship to predict longshore sediment transport was formulated by Bagnold, Inman and Komar and is often referred to as the SPM method because of broad exposure through the Shore Protection Manual, U.S. Army Engineers (1977). The longshore transport rate is given by

$$I_\ell = K\, P_{\ell s} \tag{1}$$

where I_ℓ = immersed weight longshore sediment transport rate
$P_{\ell s}$ = longshore component of wave energy flux at breaking
K = proportionality factor

Values of the coefficient, K, have been established for each of the data sets noted above. The range of these values is shown in Table I. It can be seen that the values of K span over two decades. However, the two trap experiments with direct wave measurements (Seymour et al and Bruno et al) encompass a range of less than a factor of two.

TABLE I

LONGSHORE TRANSPORT COEFFICIENT, K
FOR VARIOUS FIELD DATA SETS

REFERENCE	RANGE OF K VALUES
Watts (1953)	1.0 - 1.2
Caldwell (1956)	0.1 - 2.2
Komar (1969)	0.5 - 1.3
Seymour et al (19B1)	0.5
Bruno et al (19B1)	0.7 - 0.9
Inman et al (19B1)	0.3 - 1.3
Kraus et al (19B1)	0.1 - 0.3

SITE OESCRIPTION

Santa Barbara is located on a sandy lowland on the coast of Southern California approximately 150 km northwest of Los Angeles. It is located on the Santa Barbara Channel which is an elongate marine feature bounded on the north and east by the mainland shoreline of Santa Barbara and Ventura Counties, in the south by the Channel Islands (San Miguel, Santa Rosa, Santa Cruz, and Anacapa) and bordered on the West by the open waters of the Pacific Ocean, Figure 1. The coast in the vicinity of Santa Barbara lies in an east-west direction and is generally rugged. It is characterized by projecting headlands of rock and boulders with intervening coves having cobble covered shores or sandy pocket beaches backed by high bluffs. There are no large rivers, but numerous steep streams, with torrential flow during rainy seasons, that run through arroyos and discharge onto the shore. Santa Barbara is located approximately in the middle of the Santa Barbara littoral cell which extends from Point Conception to Point Mugu. The shoreline between Point Conception and Santa Barbara trends east-west and is composed of sedimentary rocks and shale bluffs

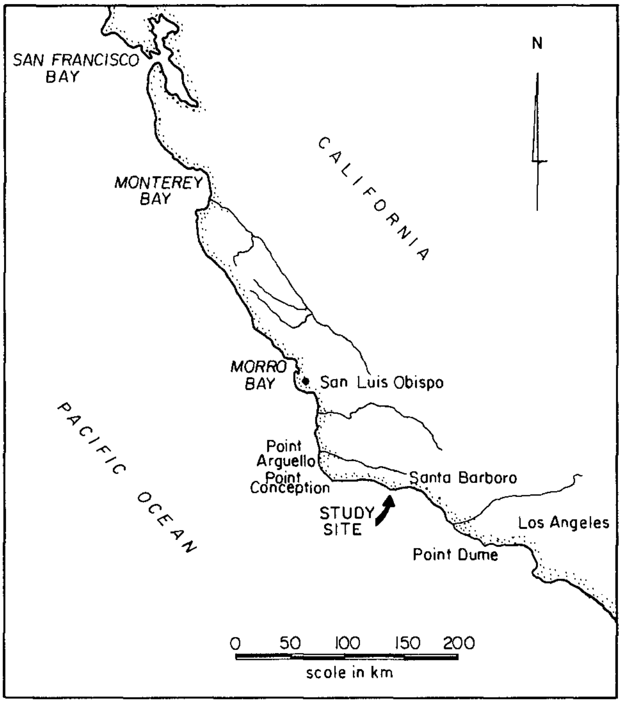

Figure 1 Geographic Location of Santa Barbara (from Trask, 1955).

fronted by sand and cobble beaches. The climate in Santa Barbara is Mediterranean and is controlled primarily by the position and intensity of the semi-permanent Pacific high pressure system over the ocean to the west. During the summer this high pressure feature covers the eastern North Pacific Ocean and deflects eastwardly moving storms to the north. During the winter months this Pacific high migrates southward and weakens, allowing occasional frontal systems that originate in the Aleutians to move through southern California. The most intense extratropical storms are those that develop between Hawaii and the California coast. These storms, because of their southerly position and intensity, often produce large westerly ocean swells which propagate into the Santa Barbara Channel between Point Conception and San Miguel Island.

Before the construction of the Santa Barbara Harbor breakwater the flow of sand was uninterrupted and was transported naturally to the beaches to the east within the Santa Barbara littoral cell. In early 1930 when the harbor breakwater was completed, sand began accumulating west of the shore arm of the breakwater creating what is now known as Leadbetter Beach. Eventually, sand migrated along the breakwater and deposited in the lee or shadow of the structure forming a sand spit in the channel as shown in Figure 2. As a result, the sand spit created a navigation problem as well as stored the sand that was naturally previously transported to the downcoast beaches. Therefore, a dredging program was initiated in 1935 for placing obstructing material within the harbor on the starved downcoast beaches to prevent further erosion. This annual harbor maintenance and beach nourishment program is still in progress. There were two dredging episodes within the time frame of this experiment.

The wave climate at Santa Barbara is generated either between the Channel Islands and the coast (local wind waves) or generated in the ocean seaward of the Islands. The local wind waves from the south are usually insignificant with only choppy seas and small waves. Wiegel (1959) reports that local storms from the southeast have a fetch of 145 km and generate waves toward the Santa Barbara coast with significant wave heights ranging from 244 to 488 cm. The predominant waves are from the southwest and west that enter the Santa Barbara Channel between San Miguel Island and Point Conception. Leadbetter Beach is protected by the Channel Islands and Point Conception from swells generated by distant storms from all other active sectors. Wiegel (1959) reports that waves from the southwest and west range from 30 to 500 cm but average about 91 cm. The average wave period is 12 seconds, but ranges between 8 and 16 seconds. Leadbetter Beach is a feeder beach for the sandspit formed in the shadow of the breakwater. It is characterized by a steep beach slope, narrow surf zone, unique wave climate with a narrow window of approach and high angle of incidence, unique wave refraction effects, and a unidirectional longshore current of high magnitude. The sand is well sorted with a median size of approximately 0.22 mm. Gable (1980) provides a detailed description of the experiment site.

DESCRIPTION OF SURVEYS AND TECHNIQUES

The accumulation of sediment was measured at approximately 6-8 week intervals with profiles extending from the dry beach to a depth of about 10 meters. A total of ten beach and nearshore surveys of the sediment trap at Santa Barbara Harbor and the adjacent updrift "Leadbetter Beach" were completed between 18 October, 1979 and 26 February, 1981. Surveys were scheduled to coincide with days of large tidal ranges. The schedule was modified occasionally according to weather and dredge operations. Each survey required 4-5 days to complete. The starting dates for each survey were: (1979): 18 October, 30 November, (1980): 20 January, 25 February, 10 April, 3 June, 25 August, 22 October, 17 December, (1981): 26 February. The survey plan is shown schematically in Figure 3. A total of 63 nearshore profile lines was surveyed using an Automated Bathymetry System (ABS) on-board a small survey boat provided under contract by Ocean Surveys, Inc. (OSI). Each of these profile lines was surveyed with ABS three times to enable the averaging out of long period ocean swells. The beach surveys were carried out to wading depths, used conventional rod and level techniques and consisted of 67 profile

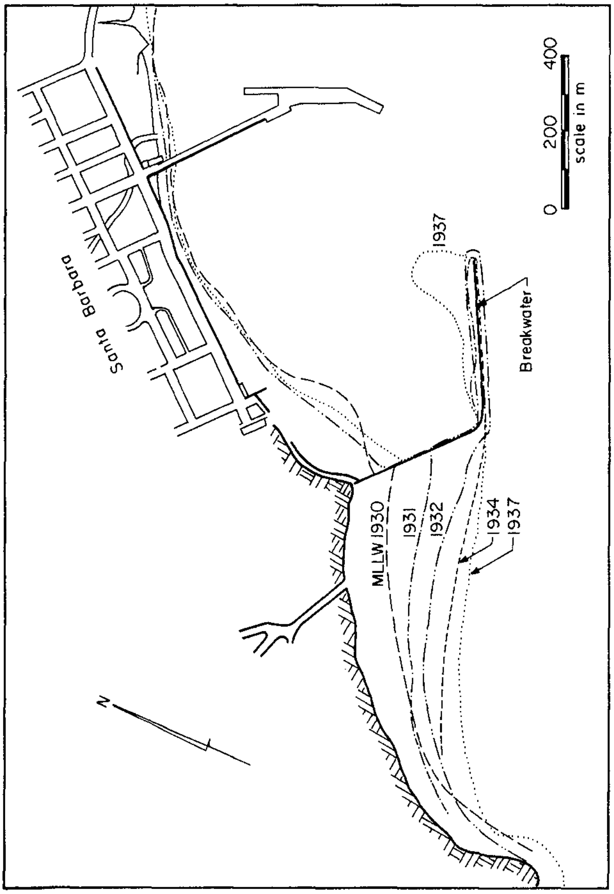

Figure 2 Shoreline Changes Upcoast of the Santa Barbara Breakwater (after Johnson, 1957).

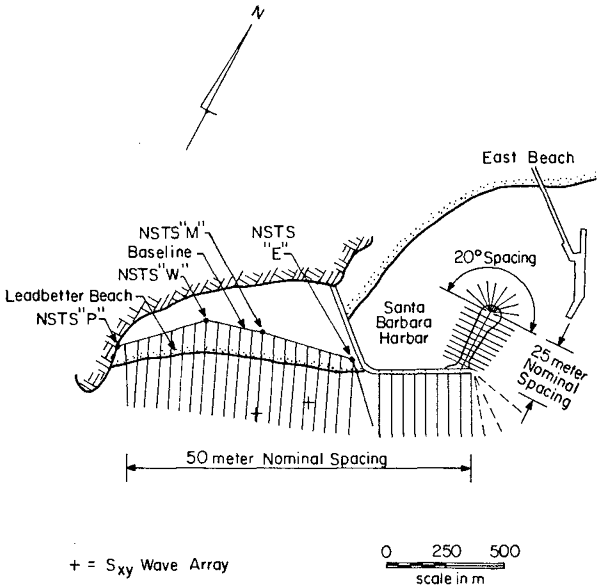

Figure 3 Plan of Sediment Impoundment Study and Location of Directional Wave Gages

lines. The nearshore and beach profiling were conducted over the maxima and minima of large tidal ranges, respectively, to achieve as much overlap as possible. Tide data necessary to reduce depth readings to the MSL datum were collected using a tide staff and a NOAA recording tide station. Range lines were defined by two survey points marked by flags, which a rodman aligned before each survey reading. Rod locations were established rapidly using a specially constructed plastic coated stainless steel survey line marked at 5 meter intervals seaward of the benchmark except where pronounced changes in slope occurred. An engineer's level and rod provided vertical control. Measurements were made out into the water by the tapeman paying out the tape in 5 meter increments from a fixed point on the baseline. The profile was terminated when the water became too deep for the rodman to wade or the breaking waves made it impossible to plumb the rod.

The nearshore bathymetry was measured using an ABS onboard a small survey boat. The "boat" surveys usually took three full days to profile all 63 lines (each three times) and required one boat operator, one field electronics engineer, and a minimum of two experienced surveyors. To assure that the boat remained on the given range azimuth and to assure accurate replication of the survey lines from survey to survey, a transit and Cubic Autotape positioning responder were set up over each of the profile bench marks. The transit operator would turn the proper azimuth from a known backsight and give course corrections to the boat operator via FM radio. Two orange survey cones on-range were placed on the beach to provide the boat operator a visual line. Distance offshore measured from the responder located over the benchmark was continually monitored by the electronics operator on board the boat. This technique ensured that the proper cut-off distance offshore was met. The second responder of the Autotape positioning system was installed over a bench mark a sufficient distance up or down the beach to provide an accurate measure of the distance off-line at each position fix. The ABS consists of the following equipment: a Raytheon DE-719B Fathometer, Innerspace Model 412 Digitizer, Cubic DM-40A Autotape Range-Range Positioning Navigation System, Hewlett Packard Model 5150A Thermal Printer, and a Sea Oata Model 1250 Oata Logger and Cassette Recorder, see Figure 4. This equipment was secured into a 6.7 meter survey boat

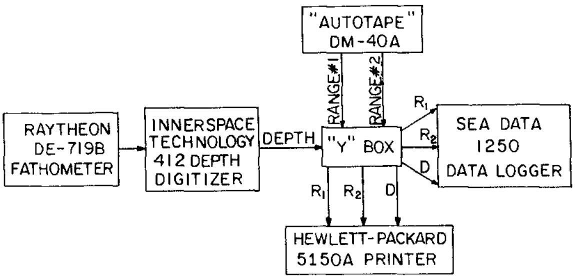

Figure 4 Block Diagram of OSI's Data Acquisition System

(Boston Whaler). The survey boat was conned along each transect by a transit operator on shore. However, boat position was fixed by logging two ranges of the Cubic Autotape positioning system. As the range determinations of the Autotape are updated at approximately one second intervals, the Autotape is designated the master for the automated system. At each update, a print command is sent to a Hewlett Packard Model 5150A thermal printer and a scan command is sent to the Sea Oata Model 1250 digital cassette magnetic tape data logger. The range-range data, in parallel binary coded decimal (BCD), is thus recorded on both printed paper tape (hard copy backup and visual presentation of digital data for field data quality control) and magnetic tape. On command from the Autotape, both the printer and the data logger also record the current depth reading. Depth data are available from the Innerspace Model 412 depth digitizer. The digitizer accepts "start-stop" pulses from the Raytheon Fathometer. The interval of time between the start and stop pulses is directly proportional to depth. The fathometer records on strip chart and provides depth readings to the digitizer nine times per second. Accordingly, the depth data are virtually instantaneously available at each Autotape command. Communication between all components of the system is provided to assure that position and depth data are not being updated at the instant of recording. An automatic "event" is also recorded at every 16th Autotape command on the cassette tape, printer paper tape, and fathometer strip chart. This event mark allows data processors to correlate the three recording media to check accuracy. As a "bookkeeping" function, each sequential event is numbered on the cassette tape. The cassette tape data logger also records times in the "header" for each data record as well as a manually entered run number, set by the operator at the beginning of each run. A "Y" box receives the BCD depth and range data and splits these signals for separate transmission to the printer and data logger allowing continued operation of the system should a failure occur in either of the recording media. A block diagram of the data acquisition system has been presented as Figure 4. The depth sounder and digitizer establish the elapsed time interval between transmission of an acoustic pulse and receipt of a return echo from the seafloor. To precisely relate this time interval to water depth, an adjustment is necessary on both instruments for the speed of sound in the water at the site. This was accomplished by conducting "bar checks", a process of lowering a target "bar" on a calibrated line to known depths below the depth sounder transducer. Both the depth sounder and digitizer are then adjusted to display this depth precisely. Bar checks were performed at nominally three hour intervals and at the beginning and end of each recording period. A more detailed description of the survey system and techniques is provided by Gable (1980).

WAVE ANALYSIS

The incident wave climate was measured using two slope arrays at a depth of approximately 7 m. A description of the hardware and the data retrieval and recording methods for a similar installation is contained in Seymour et al (1981). The location of these arrays is shown in Figure 3. Each array consists of four pressure sensors at the corners of a 6 m square frame. Pressures were sampled at 1 hz and 1024 samples (17+ minutes of data) were obtained at nominal six hour intervals for the duration of the experiment.

Two different approaches were used in analyzing the wave data to allow estimation of the longshore transport. The first method provides input for Equation (1). In this approach, the pressure signal from one of the sensors in each array was Fourier transformed, corrected to surface elevations by application of linear wave theory, and converted to an energy spectrum. A weighted characteristic frequency for this spectrum was then calculated. Using the cospectra of the surface elevation with the sea surface slope components, a characteristic wave approach direction was calculated. Employing the total energy in the spectrum, a singular wave was constructed having the characteristic frequency and direction. This wave was then refracted to the break point using linear shoaling theory. Finally, $P_{\ell s}$ was calculated for this breaking wave.

In the second approach, the longshore component of shoreward directed radiation stress, S_{xy}, was calculated for each array. The slope array facilitates this calculation since, as shown in Higgins, Seymour and Pawka (1981), S_{xy} is proportional to the cross-spectra of the sea surface slopes.

Since the nearshore bathymetry is marked by non-parallel contours, the two arrays produce somewhat different values for either of the two parameters. In this work the data from the east array were employed.

RESULTS

The principal results are the correlations between the immersed weight longshore sediment transport rates, I_ℓ, and measures of the wave forcing as characterized by $P_{\ell s}$ and S_{xy}. For purposes of establishing, I_ℓ, the volume changes were based on the following areas: the spit in the lee of the breakwater, the area fronting the breakwater and the portion of Leadbetter Beach encompassed by the survey lines to the east of the easterly S_{xy} gage, see Figure 3.

Table II presents the characteristics of and results from the seven intersurvey periods. It is seen that there was much more sediment transported during some of the intersurvey periods than during others. For example, during the third intersurvey period the average immersed weight transport rate was almost 300 N/S whereas during the following intersurvey period, the rate was less by more than an order of magnitude. The seventh column of Table II presents the K value calculated from each individual data set and it is seen that these values range from 0.32 to 1.63, a range of approximately five. However the smallest value which exhibits the greatest deviation from the norm is associated with the fourth intersurvey period which is characterized by a very small value of I_ℓ. If this one point is not included, the ratio of the largest to smallest of the remaining individual K values is less than two, which appears reasonable for this type of measurement. Unless stated otherwise, the results presented herein will exclude this one "outlier" value. The I_ℓ vs $P_{\ell s}$ data are plotted in Figure 5 on a log-log scale. Values of K were determined that provided best least squares fits between I_ℓ and $KP_{\ell s}$ and between log I_ℓ and log $KP_{\ell s}$. The corresponding K values were 0.93 and 1.23, respectively. It is noted that a previous study for Santa Barbara by Galvin (1969) had combined sediment accumulation values developed by J. W. Johnson with wave characteristics deduced by Galvin based on wave hindcasts and a wave direction which yielded the maximum $P_{\ell s}$, (i.e. minimum K); Galvin's mean value of K was 1.60. The K value of 1.23 determined from the present study is smaller than that determined by Galvin and larger than the values (0.77) referenced in the Shore Protection Manual (1977) and most often employed. As shown in Figure 6 the value determined herein is in approximate agreement with an earlier correlation of K with sand size developed by Dean (1978), where the characteristics of the other data points presented in Figure 6 are described.

It seems plausible that I_ℓ should correlate reasonably well with the total longshore force, S_{xy}, acting on the surf zone, in the form

TABLE II

SUMMARY OF FIELD RESULTS BY INTERSURVEY PERIOD

Intersurvey Period	No. of Days	Dredging Event	Total Volume Change(m^3)	Immersed Weight Transport Rate I_ℓ(N/S)	Net Longshore Component of Wave Energy Flux at Breaking, $P_{\ell s}$(N/S)	$K = I_\ell/P_{\ell s}$	Net Onshore Flux of Longshore Component of Momentum S_{xy}(N/m)	$K_* = I_\ell/S_{xy}$ (m/s)
10/13/79-11/30/79	48	No	32,820	85.3	52.2	1.63	27.8	3.06
12/1/79-1/20/80	51	Yes, Major	65,070	159.1	101.4	1.57	45.4	3.50
1/21/80-2/25/80	35	Yes, Minor	82,810	295.0	352.4	0.84	119.6	2.47
4/11/80-6/3/80	53	No	10,290	24.2	76.6	0.32	37.9	0.64
6/4/80-8/25/80	82	No	22,220	33.8	31.7	1.07	17.6	1.91
8/26/80-10/23/80	57	No	38,760	84.8	63.8	1.33	32.6	2.60
10/24/80-12/17/80	54	Yes, Major	35,640	84.6	64.4	1.31	34.2	2.47

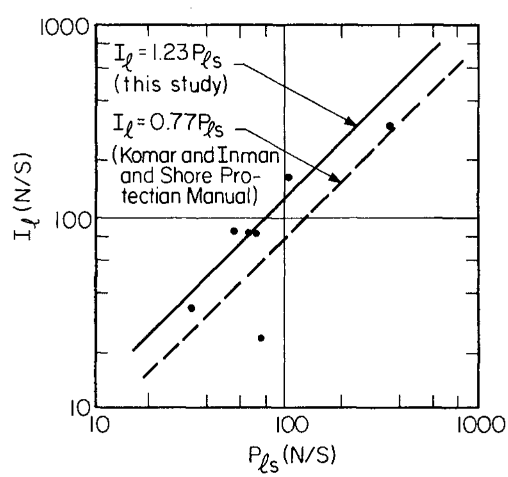

Figure 5 Data From Santa Barbara Field Experiment. I_ℓ vs $P_{\ell s}$, Present and Past Correlations.

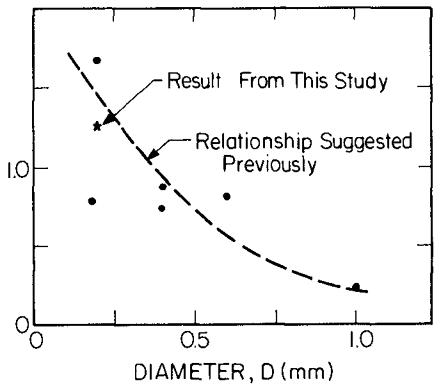

Figure 6 Plot of K vs D. Results of Present and Previous Studies (Modified from Dean, 1978).

$$I_\ell = K_* S_{xy} \quad .$$

One disadvantage of this form is that K_* is dimensional, whereas K (Eq. 1) is dimensionless. The S_{xy} and K_* values for each of the intersurvey periods are presented in Table II where it is seen that if the one "outlier" (small value) is not considered, the ratio of the maximum to minimum values of K_* is 1.83, only slightly less than the corresponding ratio for K. The I_ℓ vs S_{xy} values are plotted in Figure 7. Best fit linear and logarithmic values of K_* are 2.60 and 2.63 m/s, respectively.

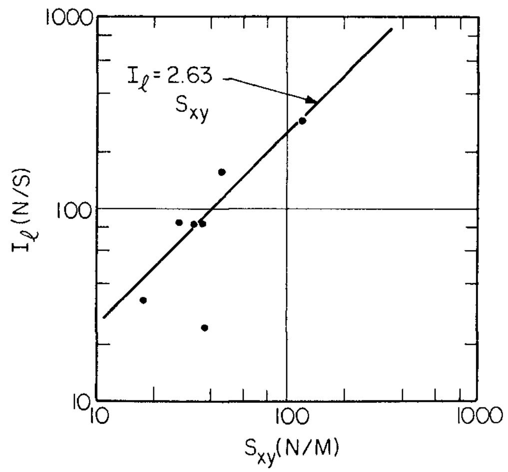

Figure 7 Data From Santa Barbara Field Experiment. I_ℓ vs S_{xy} and Best Least Squares Fit.

The values of K and K_* based on the cumulative I_ℓ, $P_{\ell s}$ and S_{xy} over all seven intersurvey periods are 1.07 and 2.40 m/s. Excluding the one "outlier", the values are 1.17 and 2.67 m/s.

SUMMARY AND CONCLUSIONS

Summary

A field experiment has been carried out with high-quality measurements of directional wave characteristics and the associated sediment transport. The results, documented herein, span approximately 13 months and include surveyed volumes of 288,600 cubic meters of sediment transport. The analysis, based on six intersurvey periods, yield best-fit linear and logarithmic values of K of 0.93 and 1.23, respectively. The corresponding values of K_* relating the immersed weight sediment transport rate, I_ℓ, and S_{xy}, the flux in the onshore direction of the longshore component of momentum, are 2.60 and 2.63 m/s, respectively. While the value of K is somewhat larger than the most-often referenced value of 0.77, it is reasonably consistent with the value (1.6D) determined in an earlier study of Santa Barbara by Galvin and also is consistent with an earlier trend established by Dean of K with sediment diameter, D.

Conclusions

1. The results developed here are supportive of a variation of the sediment transport coefficient, K, with diameter, D. It is likely that K varies with other parameters: beach slope and morphology, wave characteristics, etc. Well documented (waves and sediment transport) field programs at locations with widely different conditions would be valuable in further defining the variation of K with other parameters of importance.

2. Although the two variables $P_{\ell s}$ and S_{xy} are related and appear to provide approximately equally good fits to the longshore sediment transport, investigation should be continued of the relative merits of these two as correlating parameters.

ACKNOWLEDGEMENTS

The financial support provided by the Sea Grant Program to this component of the Nearshore Sediment Transport Program is greatly appreciated. The encouragement and guidance of Dr. David Duane as Technical Monitor of that program was especially valuable. The dedicated and professional efforts of Ocean Surveys, Inc. in the field surveys contributed significantly to the quality of the field data. Finally, the University of California at Santa Barbara was very helpful by providing vessels and highly competent personnel to assist in the field efforts.

REFERENCES

Bruno, R. O., R. G. Dean, and C. G. Gable, "Longshore Transport Evaluations at a Detached Breakwater," Proceedings, Seventeenth Coastal Engineering Conference, ASCE, Sydney, Australia, 1980, p. 1453-1475.

Caldwell, J. M., "Wave Action and Sand Movement Near Anaheim Bay, California," U.S. Army Corps of Engineers, Beach Erosion Board, Technical Memorandum No. 68, Washington, D. C., 1956.

Dean, R. G., "Review of Sediment Transport Relationships and the Data Base," Proceedings, Workshop on Coastal Sediment Transport, University of Delaware Sea Grant Program, 1978, p. 25-39.

Gable, C. G., Ed., "Report on Data from the Nearshore Sediment Transport Study Experiment at Leadbetter Beach, Santa Barbara, California, January-February 1980." University of California, Institute of Marine Resources, IMR Ref. No. 80-5, 1981.

Galvin, C. J., "Comparison of Johnson's Littoral Drift Data for Santa 8arbara with the Empirical Relation of CERC TR 4", Memorandum for Record, Coastal Engineering Research Center, February, 1969.

Greer, M. N. and O. S. Madsen, "Longshore Sediment Transport Data: A Review," Proceedings, Sixteenth Coastal Engineering Conference, ASCE, Honolulu, Hawaii, 1978, p. 1563-1576.

Higgins, A. L., R. J. Seymour and S. S. Pawka, "A Compact Representation of Ocean Wave Directionality," Applied Ocean Research, Vol. 3, No. 3, 1981, p. 105-112.

Inman, D. L., J. A. Zampol, T. E. White, D. M. Hanes, 8. W. Waldorf, and K. A. Kastens, "Field Measurements of Sand Motion in the Surf Zone," Proceedings, Seventeenth Coastal Engineering Conference, ASCE, Sydney, Australia, 1980, p. 1215-1234.

Johnson, J. W., "The Littoral Drift Problem at Shoreline Harbors", ASCE Journal Waterways and Harbors Division, Vol. 83, Paper 1211, April, 1957.

Komar, P. D., "The Longshore Transport of Sand on Beaches," Thesis presented to the University of California, at San Diego, California, in 1969, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, 1969.

Kraus, N. C., R. S. Farinato and K. Horikawa, "Field Experiments on Longshore Sand Transport in the Surf Zone," Coastal Engineering in Japan, Vol. 24, 1981, p. 171-194.

Trask, P. D., "Movement of Sand Around Southern California Promontories," U.S. Army Corps of Engineers, Beach Erosion 8oard, Technical Memorandum No. 76, 1955.

U.S. Army Coastal Engineering Research Center, Shore Protection Manual, U.S. Army Corps of Engineers, Washington, D.C., 1977.

Watts, G. M., "A Study of Sand Movement at Lake Worth Inlet, Florida." U.S. Army Corps of Engineers, Beach Erosion Board, Technical Memorandum No. 42, 1958.

Wiegel, R. L., "Sand 8ypassing at Santa Barbara, California, ASCE Journal Waterways and Harbors Division, Proc. ASCE, 85, WW2, 1959, p. 1-30.