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TRANSPORT OF CONTAMINATED SEDIMENTS OVER A SMALL INDUSTRIALIZED WATERSHED

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ABSTRACT

Nonpoint sources constitute some 65 percent of stream pollution in the United States. One component source that has not been well defined as to its impact on the environment is residues generated during sandblasting operations. This study considers a single case of sandblasting ship components with spent nickel-copper slag abrasives at Naval Shipyard Mare Island near Vallejo, California. Ship parts are cleaned for repainting in a large open area underlain by asphalt. Spent abrasives and associated paint and paint by-products are transported via overland flow during storm events to a beachfront estuary and ultimately into the Napa River (locally called Mare Island Strait).

The research conducted addresses the transport of abrasives and paint products across the watershed and its deposition in the estuary. It also secondarily considers the physical and chemical bonding relationship between abrasives and paint products. Background chemical sampling and sampling within the estuary suggest that elevated levels of heavy metals are caused by the paint products produced during the blasting operations. The mechanisms used for sandblasting, i.e., high-pressure jetting, and the transport phenomena associated with sediment and paint runoff are typical of those found at most operations of this kind.

Hydrologic simulations were performed using the U.S. Army Corps of Engineers HEC-1 model to determine appropriate simulated runoff rates for sediment transport calculations. A sister model, HEC-6, was employed to

estimate sediment transport through and from the operations area. Physical and chemical data were collected for grain size and the presence of five target metals in the area of deposition. Model predictions were verified by an on-site testing program that collected runoff sediment at various flow rates off the operations area.

Results of benchscale chemical partitioning tests suggest that approximately 70 percent of paint materials present are physically bound to the abrasives and the balance are loosely intermixed with the transporting sediments. As such, in this particular case, the majority of the commingled waste was amenable to modeling by HEC-6. Two separate flow rates, 0.5 cfs and 1.0 cfs were chosen for field verification of HEC-6. Results of four 6.5-hour on-site test runs showed that numerical simulations accurately represented actual conditions within 12 percent. Field tests also suggested that HEC-6 may over predict sediment transport for abrasives in shallow flows.

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1.0 INTRODUCTION AND OBJECTIVE

1.1 INTRODUCTION

An unprecedented public awareness of pollution problems in the United States is evident and growing. Until the advent of the U.S. Environmental Protection Agency (EPA) in 1970, only one major law addressing contamination had been passed, the Solid Waste Act in 1965. In 1986, then-EPA-Administrator Lee Thomas commissioned a study by senior staff members to address the question of where America's most pressing pollution concerns stand. One recurring problem that ranked near the top of the study's list was nonpoint source pollution. A separate EPA study (U.S. EPA, 1984) estimates that 65 percent of stream pollution is produced from nonpoint sources. A great amount of information has been gathered pertaining to farmland, feedlot, and industrial runoff pollution. However, one component of nonpoint source pollution has only recently been identified for study; that is pollution caused by abrasives blasting of materials such as bridges, ships, and buildings. This study addresses this issue as it relates to sandblasting ship components and the operations impact on the environment.

On December 16, 1987 the California Regional Water Quality Control Board (CRWQCB) issued a tentative order for Waste Discharge Requirements to Naval Shipyard (NSY) Mare Island. The order identifies several sites where deposition of potentially hazardous compounds may exist. One of the sites referenced is the Building 900 sandblasting area (900 Area). The research presented in this report addresses the issue of environ-

mental contamination and the coincident transport of sandblasting residues produced during sandblasting operations.

Sandblasting of objects is a ubiquitous function of everyday life. The Golden Gate bridge in San Francisco, California is continuously being painted and sandblasted. Sandblasting of painted parts is performed in numerous industries. Often times, like the case of the bridges and with the situation at the 900 Area at NSY Mare Island, these practices are carried out in open areas. Residues from the operations accumulate in sediments near the blasting site and may, as in the case of the 900 Area, be transported by natural forces into estuaries and receiving streams. At present, very little has been done to evaluate the potential impacts of these practices on human health and the environment.

The 900 Area is a relatively small watershed measuring approximately 990 feet long and 500 feet wide at its widest point. It is completely paved with asphalt. The integrity of the asphalt is poor in several places. Sandblasting of large and small ship parts is practiced throughout the entire watershed. An abrasive, actually a nickel-copper slag, called greensand is used to strip paint from metal surfaces. Uncontrolled runoff from the site deposits onto an estuary which comprises the rim of the Mare Island peninsula. Mare Island Strait borders the strip estuary (it occupies less than 2,000 linear feet of coastline).

1.2 OBJECTIVE

The objective of this research is to test the applicability of a universally accepted large-scale predictive model for estimating commingled abrasives/residues transport over a small impervious watershed. The numerical model results were verified with a carefully designed and executed field test. Additional supporting research was conducted to more fully understand the chemical-physical relationships between sandblasting abrasives and paint residues.

Physical and chemical tests were completed both in the field and under laboratory conditions. The study considered five target metals commonly found in paint and abrasives to monitor throughout the lifespan of the investigation. These five metals are copper, chromium, lead, nickel, and zinc. The physical and chemical characteristics of the carrying abrasives were also determined. Environmental fate of each metal was also determined in both solid and liquid states. A geometric sampling grid was established in the area of solids deposition. Background soils sampling was also performed to provide a baseline for interpreting elevated levels of metals in the sampling area.

A wide range of design storm frequencies (1-year to 100-year) were selected for the purpose of estimating the amount of flow which could be expected from the site. Synthetic hydrographs for the drainage basin were developed using the U.S. Army Corps of Engineers (1981) HEC-1 model, one of the most widely employed hydrologic simulation codes. Sediment transport was simulated through the use of the U.S. Army Corps of

Engineers (1977) HEC-6 model. The model, which is well suited for classical river sediment transport, is postulated here to hold promise for estimating sheet flow sediment transport. The HEC-6 model is selected because of its broad acceptability. One of the major objectives of this research study is to demonstrate the applicability of HEC-6 to a unique abrasives transport condition by comparing model results with field simulation of two overland flow rates applied to the watershed.

2.0 LITERATURE REVIEW: SEDIMENT TRANSPORT IN SHALLOW FLOWS

An interest in the transportation of sediment in open channels and fields has been known to exist since at least 4000 B.C. Nevertheless, to this date almost every new theory on the dynamics of sediment transport is typically prefaced by language such as "sediment transport phenomenon is a complex problem for which there are commonly broad differences between predictive models and field-scale studies." Order-of-magnitude differences are often found. In the following review, a summary perspective of sedimentation as it relates to movement in shallow flows is given.

In a broad sense, sediment may be moved along in a flowing column of water by two methods, suspended in the fluid or pushed along the surface as bed load. Generally, when the average flow depth is less than two times the mean bed depth, as in the case of sheet flow, bed load is the dominant mechanism. This condition assumes that the bed material is of a relatively dense and cohesionless nature found in sandy stream channels. The present study at the NSY Mare Island 900 Area is analogous to sheet-type runoff of coarse-grained materials and sediment is transported off the watershed in a bed load form. As such, this discussion is limited to bed load processes. A definitive review of suspended load transport models, techniques, and procedures are found in Graf (1984) and Chow (1959).

In reviewing the wide body of literature on sediment transport one central theme is evident: a tremendous amount of laboratory and field studies have been performed and numerous theoretical hypotheses with wide-ranging differences have been offered. The author believes the problem stems from three core problems: (1) there is no clear understanding of incipient sediment motion, (2) the appropriate single determinant for calculating sediment movement is robustly debated, and (3) applicability of a given hypothesis either scaled up from the laboratory or down from field observations is weak. The first two problems will be discussed explicitly and the third implicitly.

2.1 INCIPIENT MOTION

In general, the transport rate of bed load is a function of low near-bed velocity. There is no effective method to predict or measure velocity near the bed in sediment-transporting flows. Three primary surrogate variables, each described independently in a given theory, are embodied in most sediment transport equations: mean velocity (V_m), tractive stress (τ) stream power ($W = \tau V_m$). Several authors have recently criticized the use of tractive stress, claiming that its performance is markedly inferior to that of velocity (Thompson, 1985) and unit stream power (Yang, 1984) in gravel channels. Each of these concepts is touched upon throughout the course of this discussion.

The transport of sediment mixtures in open channels is complicated because the condition for initiating motion of a given size of sediment, as well as its transport rate, is affected by the presence of the other

sizes in the mixture. The finer fractions moving as bed load are sheltered (or armored) by the coarse fractions, and the coarser particles, in turn, are exposed more to the action of flow past them. As such, the actual force experienced by a certain fraction of sediment mixture at a given average shear stress is different from what it would be at the same shear stress if the material were uniform. Further, this difference in forces is a function of the bed composition and the fluid and flow characteristics. In general, the size distribution of the transported material is dependent on the shear stress and is different from that of the bed material. Therefore, the bed load calculated by making use of any of the methods based on a single representative size may result in large errors in such cases. It is thus necessary to know the transport rate of individual fractions of the bed material if the bed load transport rate and its composition are to be predicted accurately.

Einstein (1985), Proffitt and Sutherland (1983), and Misri et al. (1984) have proposed methods to account for the nonuniformity of sediment in the calculation of bed load transport rates. Misri et al. (1984) emphasized the limitations of Einstein's method. Even though their method gave satisfactory results for laboratory data, the method did not give good results when applied to field data, especially at higher values of dimensionless shear stress for individual sizes. Proffitt and Sutherland's method (1983) also showed poor agreement with field data. Additional experiments using nonuniform sediments of finer sizes so as to obtain higher dimensionless shear stresses are needed. The exhaustive

scope of such a study must include measurements of velocity distribution, concentration distribution of individual fractions, and bed load and total load transport of individual fractions.

In general, recent work is in agreement that relatively smaller sizes in a mixture show greater resistance to movement and a higher critical shear stress than sediment in a unisize bed and that relatively larger sizes show less resistance to movement and a lower critical shear stress in a mixture. However, there is considerable discrepancy in the published results. These discrepancies are not random, but fall into two groups, that may be associated with two broad classes of methods for determining initial motion. The first method involves estimating the critical shear stress for the individual fractions τ_{ci} as the bed shear stress that produces a small transport rate for each fraction. Transport rates of individual fractions are measured for a number of flows and the shear stress that corresponds to a small reference transport rate is determined from a fitted relation between shear stress and transport rate for each fraction (Parker et al., 1982; Day, 1980). The second method involves determining the largest class in a sediment mixture that is moved by a given bed shear stress. This quantity may be measured directly using the largest class found in a transport sample (Andrews, 1983; Carling, 1983) or measured visually by observing the largest grain moving over an area of the bed (Hammond et al., 1984). The largest mobile grain is assumed to represent initial-motion conditions if coarser grains are available in the bed. The two general classes of initial-motion methods will be termed here the reference transport method and the largest-grain

method. When τ_{ci} is measured with the reference transport method, it is found to have little, if any, dependence on the relative size of the fraction that is expressed, for example, as the ratio of the fraction size to the median size of the mixture, D_i/D_{50} (Parker et al., 1982). The largest-grain method typically produces a variation of τ_{ci} with roughly the square root of D_i/D_{50} (Komar, 1987), although Andrews (1983) found only a weak dependence of τ_{ci} on D_i/D_{50} using the largest grain found in transport samples.

Two problems prevent direct comparison of initial-motion results determined by the two different classes of initial-motion methodology. The two initial-motion methods are typically applied to very different portions of a transported sample. A largest-grain τ_{ci} estimate uses only a single grain per sample, typically one in the coarse part of the grain size distribution. A reference shear stress τ_{ci} estimate incorporates the transport rates of all the grains in a sample, as well as the transport rates of other samples that are used to fit an interpolating function between dimensionless forms of the transport rate and bed shear stress for each fraction. The second problem is that in most cases, only one of the two methods can be generally applied to a particular set of transport data. The largest-grain method requires that grains coarser than the largest in the transport sample be available in the bed, a condition often not met by transport samples. On the other hand, a collection of single transport samples from which largest-grain estimates may be made may not be sufficient to adequately define the relation between transport rate and shear stress that is necessary for the

reference transport rate and shear stress that is necessary for the reference transport method. Both the mutually exclusive nature typical of the appropriate data sets and the different portions of the transport size distribution sampled leave open the question of whether in initial-motion results between different sediments and flow conditions are real or merely reflect the different methods used to determine the initial motion.

In field studies the critical shear stress has been estimated from the largest grain observed in motion (Andrews, 1983; Carling, 1983; Hammond et al., 1984). Mixed-size sediment transport rates, from which incipient motion may be estimated, have been measured in several laboratory studies (Day, 1980; Dhamotharan et al., 1980; Misri et al., 1984) and in the field (Milhous, 1973; Parker et al., 1982). Experiments on part of the problem, the pivoting angle of individual size fractions, have been made by Li and Komar (1986). Wiberg and Smith (1987) have used the earlier pivoting angle results of Miller and Byrne (1966) in developing a semianalytical model of critical shear stress. All this work is motivated in part by the importance of the problem: the critical shear stress for individual size fractions is an integral component of mixed-size sediment transport models.

2.2 DETERMINANTS FOR SEDIMENT MOVEMENT

Consider sediment movement within a steady, uniform, open channel flow above a flat bed of loose material. The motion of the sediment particle can be classified as rolling or sliding if the particle is in continuous

contact with the bed, or it can be said to be saltation (hopping) if this support of the particle by the bed is intermittent. These three types of motion are bed load, because the bed supports a part of the net weight of these moving particles. The sediment is considered to move in suspension if the particles hit the bed so infrequently that the particle's net weight is supported by the fluid rather than by the bed.

The trajectory of a sliding or saltating grain is determined by the three forces acting on the particle: the force exerted by the fluid, the force exerted intermittently by the bed, and the particle's weight. The horizontal component of the velocity difference between the saltating particle and the mean fluid flow causes a drag force, which accelerates the particle in the downstream direction and supplies the energy for this transport process. Contacts with the bed initiate and terminate each saltation, support some of the particle's net weight, and absorb some of the particle's horizontal momentum by opposing its downstream motion. The impact at the end of a trajectory either relates the particle velocity and spin of that trajectory to the initialization of the next trajectory or it stops the particle. However, the bed impact force does not influence the trajectories once bed contact is broken. After the initial velocity and spin of a particle are set, the properties of the mean flow determine the resulting trajectory.

White and Schultz (1977) and Murphy and Hooshiari (1982) have shown that saltation trajectories can be calculated from the Lagrangian equations for the dynamics of particle motion by considering just the mean fluid

flow. In particular, the data of Murphy and Hooshiari (1982) show that glass spheres the size of marbles accelerate downward because of their net weight during their entire trajectory, and that, therefore, the net weight of such spheres is not supported by the fluid. Because no random motion was observed, the length and height of the trajectories of these saltating spheres were not affected by the random turbulent fluctuations of the fluid velocity.

A variety of equations have been proposed for describing sheet, rill, and stream sediment transport capacity in terms of a single determinant: either flow velocity (v), slope (s), shear stress (τ), or discharge (Q). In soil erosion research the most common formulations have involved describing sediment transport capacity either in terms of water discharge or effective discharge ($Q - Q_{cr}$) (e.g., Williams, 1975; Meyer et al., 1975) or in terms of an effective shear stress or tractive force ($\tau - \tau_{cr}$) (e.g., Foster and Meyer, 1972; McWhorter et al., 1979; Foster, 1982). In the most recent new theory, Yang (1973) argued that such relationships, when applied to alluvial channels, are nongeneral and often nonunique, particularly at both high and low sediment discharges.

After analyzing a large set of data, Yang (1972, 1973, 1976), Yang and Molinas (1982), and Yang and Stall (1976) concluded that unit stream power is the dominant factor in determining the total sediment concentration of streams with alluvial and gravel beds. Yang (1973) and Yangand Song (1979) defined unit stream power P as the time rate of potential energy dissipation per unit weight of water:

$$P = \frac{dY}{dt} = \frac{dx}{dt}\frac{dY}{dx} = vs \qquad (1)$$

where:

Y = Elevation above a datum (i.e., the potential energy per unit weight of water)

x = Longitudinal distance

t = Time

v = Velocity of flow in the longitudinal direction

s = Energy gradient and can be approximated by the slope of the soil surface or channel bed.

The concept of stream power was first introduced by Bagnold (1960) and was defined in terms of the power per unit area of stream bed (shear stress times flow velocity), whereas Yang (1973) defines unit stream power in terms of the power per unit weight of water.

Unit stream power is a total sediment load formula, whereas stream power was originally developed as a bed load formula. Yang (1984) demonstrated that for gravel size particles sediment concentration is a hysteretic function of both shear stress and stream power, but a nonhysteretic function of dimensionless unit streampower. An earlier evaluation of a number of sediment transport formulas by Alonso et al. (1981) suggests that unit stream power gives reliable predictions of sediment transport in shallow flows and stream flows, particularly for fine to coarse sands. Further elaboration on the stream power technique is presented later in this section.

There is no clear consensus on which approach to sediment transport is the most accurate as evidenced by the aforementioned researchers. It is the author's belief that the stream power theorists remain in the minority at present. Tractive theory as advanced by Einstein (1950) and numerous others remains the dominant pro forma expression used in numerical transport models.

In steady, uniform flow, the downslope force on the water caused by gravity is balanced by resistance from the channel boundary due to roughness. The mean resistance per unit area, boundary shear stress ($\bar{\tau}_s$), is:

$$\bar{\tau}_s = \rho g R s \qquad (2)$$

where:

ρ = Mass density of fluid (M/L^3)

g = Acceleration due to gravity (L/t^2)

R = Hydraulic mean radius (L)

s = Channel slope (L/L).

The mean tractive stress of the water on the boundary is numerically equal to this shear stress, and represents the tangential force per unit area acting downchannel.

The tractive stress on the bed would thus seem to be a logical control of bed load rates. The equation of Meyer-Peter and Muller (1948) is perhaps the most widely used example of the tractive stress approach:

$$q_s = 8(m \setminus K \setminus M_f - 0.047)^{1.5}[(G_s - 1)gd^3]^{0.5}G_s\rho \qquad (3)$$

where:

$q_{s_{unit}}$ = Dry mass transport rate (for particles of diameter d) per width of flow (M/t/L)

G_s = Specific gravity of grains (unitless)

M_f = Shield's shear stress [$M_f = \rho gDs/(G_s - 1)\ \rho gd$]

m and K = Correction factors needed to adjust ρgDS so that it represents stress on the bed (not banks) and on grains (not bedforms), respectively.

A difficulty in using tractive stress in such equations is the computation of the bed stress as distinct from the mean stress acting upon both bed and banks. Another difficulty is calculation of that part of the bed tractive stress acting only upon the bed grains. Recent articles discrediting the tractive stress approach unfortunately overlooked those points, even though they are explicitly recognized in the classical bed load equations. The basic series of equations that forms the foundation of this theory is derived in the following section. Numerical modeling performed in this study also follows the basic concepts of Einstein (1950). It is recognized that other options which include the stream power function are also available in some of the more sophisicated computer models such as HEC-6 (U.S. Army Corps of Engineers, 1977).

2.3 GOVERNING EQUATIONS

The motivation for the present analysis, which treats the bed layer as a continuum bulk flow, is derived from the work of Bagnold (1956), Goodman and Cowin (1972), and Savage (1979). These authors were concerned with the development of certain constitutive relations appropriate for the flow of cohesionless granular materials with finite deformation rates at low stress levels. The theory accounts for the non-Newtonian nature of flow as evidenced by Bagnold's (1956) experiments. Constitutive relations such as Bagnold's are essential for the derivation of a sediment discharge relation.

The motion of sediment as a continuum at the bottom of a stream flow must obey the laws of continuum mechanics. This separated two-phase flow model (Wallis, 1969) should be capable of representing the complete dynamics of the water and sediment flow. Alternatively, water turbulence and bed movement can be predicted by a physical model.

As previously mentioned, to describe the motion of water and sediment in open channels, it is essential that the governing equations be physically based. They must also be capable of accounting for the various dynamic behaviors that water-sediment systems may undergo. The well-established Saint-Venant continuity and momentum equations of water flow possess such properties. These equations as applied to the flow of water in open channels can be stated in the following form for unit width flow:

$$\frac{\partial h}{\partial t} + \frac{\partial (vh)}{\partial x} = 0 \qquad (4)$$

$$\frac{\partial h}{\partial t} + u\frac{\partial v}{\partial x} + g\frac{\partial h}{\partial x} + g\frac{\partial \delta}{\partial x} = gs - C_f\frac{v2}{h} \qquad (5)$$

where:

h = Flow depth (L)

v = Flow velocity (L/t)

δ = Thickness of the movable bed material (L)

s = Channel slope (L/L)

C_f = A dimensionless friction factor

g = Gravitational acceleration (L/t^2).

The first equation is the conservation of mass equation, and the second is the conservation of momentum modified to account for the presence of the movable bed. In the foregoing equations, it is assumed that there is no lateral flow to the unit width channel being considered. The coordinated axes are defined in Figure 2-1, where the x-axis coincides with the rigid bed and is in the direction of the flow. The y-axis is taken normal to the bed of the channel. $H(x,t)$ represents the ordinate of the free surface and $\delta(x,t)$ the ordinate of the bed layer. The flow is considered to be one-dimensional.

The finer particles of sediment are usually transported in suspension, even at low-flow rates. But the transport of larger or less dense sediment, such as sand and aggregates, or both, takes place in the mode of bed load. It is assumed in this analysis that the transport of coarse sediment will occur only as bed load. The sediment in the bed layer is

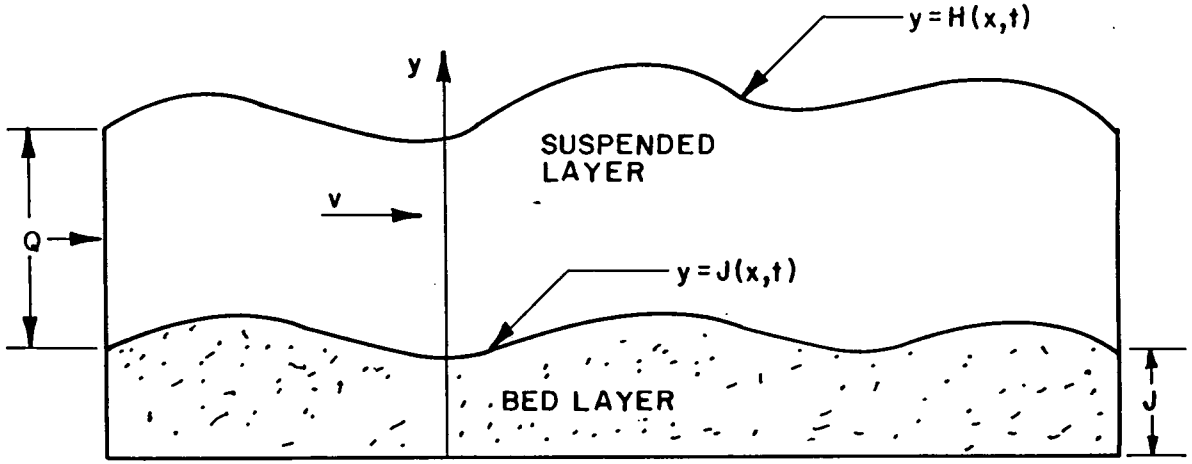


Figure 2-1. Physical Description of Vertical Section of Channel

subjected to shear stresses due to the motion of the fluid. It is assumed that there is no net entrainment of coarse sediment by the turbulent flow and, therefore, coarse sediment particles do not leave the bed layer.

The motion of cohesionless sediment takes place near the bed of the channel, and the uniform grains move by rolling and sliding without leaving the bed. The bed material moves as a bulk flow in closely packed layers. The mass conservation of the sediment layer is:

$$\frac{\partial \delta}{\partial t} + \frac{\partial Q_b}{\partial x} = 0 \qquad (6)$$

in which Q_b = volumetric rate of sediment transport per unit width and is given by:

$$Q_b = \int_o^\delta c u_s dy \qquad (7)$$

where:

c = Volumetric concentration of the solid grains in the bed layer under motion

u_s = Sediment velocity.

Note that there is neither inflow nor outflow of sediment to the bed layer. In other words, grains are neither deposited from nor picked up by the flow of water.

In gravity flow, the hydrodynamic forces of the fluid play an important role in the initiation of sediment motion and in its transport. But as soon as the sediment starts to move in the downstream direction, the dynamics of the sediment will contribute significantly to the momentum

balance of the bed layers. The forces created by the momentum change must be accounted for. These same concepts are revised by the U.S. Corps of Engineers (1977) in their development of one-dimensional transport of sediments using Equations 4 through 7.

The forces acting on the sediment body are composed of inertia forces, intergranular forces, gravity forces, and hydrodynamic forces because of the fluid flow. For a rigorous formulation of the hydrodynamics of sediment transport, all these forces must be considered. The conservation of momentum equation of the sediment layer is written as:

$$\frac{\partial \tau_s}{\partial y} + \frac{\partial P}{\partial x} - c\rho_s \left(\frac{\partial u_s}{\partial t} + u_s \frac{\partial u_s}{\partial x}\right) + c\rho_s b_x = 0 \qquad (8)$$

where:

τ_s = Shear (tractive) stress in the sediment layer

P = Hydrodynamic pressure

ρ_s = Sediment mass density

b_x = Sediment body force in the direction of the flow.

The inclusion of the inertial forces results in a high-order, complicated set of partial differential equations. To keep the analysis simple as a first attempt at this sediment transport problem, the inertia forces are dropped from the sediment momentum equation to yield:

$$\frac{\partial \tau_s}{\partial y} + \frac{\partial P}{\partial x} + c\rho_s b_x = 0 \qquad (9)$$

Assuming a hydrostatic pressure distribution of water and sediment, the pressure at any level $0 \leq y \leq \delta$, (sediment layer thickness) is:

$$P = c\gamma_s(\delta-y) + (1-c)\gamma(\delta-y) + \gamma h \qquad (10)$$

in which γ and γ_s are the specific weights of water and sediment. Taking the partial derivative of equation 10 with respect to x and substituting it in equation 9, one obtains:

$$\frac{\partial \tau_s}{\partial y} + c\gamma_s \frac{\partial \delta}{\partial x} + \gamma(1-c)\frac{\partial \delta}{\partial x} + \gamma\frac{\partial h}{\partial x} + c\gamma_s s = 0 \qquad (11)$$

The last term in equation 11 is the component of the sediment weight in the direction of the flow.

Integrating equation 11 with respect to y leads to an equation for the grain shear stress:

$$\tau_s = -c\gamma_s \frac{\partial \delta}{\partial x} y - \gamma(1-c)\frac{\partial \delta}{\partial x} y - c\gamma_s s y - \gamma \frac{\partial h}{\partial x} y + A \qquad (12)$$

where:

A = An integration constant.

The shear stress at the top of the sediment layer is mainly because of the water flow and is approximated by $\tau = \rho C_f v^2$. Evaluating the constant A in equation 12 by considering the shear stress $\tau_s = \tau$ at $y = \delta$, and then eliminating the higher-order terms, leads to:

$$\tau_s = -c\gamma_s s y + c\gamma_s s \delta + \rho C_f v^2 \qquad (13)$$

which is the shear stress distribution in the sediment. The thickness of the sediment layer, however, is quite small, so that shear stress in the

sediment layer does not vary appreciably along the depth. Therefore, the mean value of the sediment shear stress, $\bar{\tau}_s$, will be considered in the following analysis, so that

$$\bar{\tau}_s = \frac{1}{2} c\gamma_s s\delta + \rho C_f v^2 \qquad (14)$$

In the derivation of a bed load equation, the interaction among the grains must be taken care of for the continuum assumption to hold. The interaction among particles was considered by Einstein (1950) as it affects the probability of individual grains to be picked up or deposited. DuBoys' (1879) sliding layer model only accounts for interlayer shear stress and not for the intergranular friction. Bagnold (1966) derived a bed load equation based on his observations of the upward dispersion of grains caused by turbulent shear stress. His final relations were expressed in terms of the conservation of energy, which equates certain work done.

A bed load equation can be obtained by integrating equation 7. However, assuming a constant volumetric concentration c, the integration of equation 7 requires a knowledge of the sediment velocity distribution. A simplification can be made for very wide rectangular channels, or as it is postulated here, planar beds (parking lots). In wide channels, the hydraulic radius (R) approximates the flow depth (h). The mean bed shear stress may then be approximated by:

$$\bar{\tau}_s = \rho g R s \cong \rho g y s \qquad (15)$$

Equations 4 and 5 represent the motion of fluid and sediment in open channels with a moving sediment bed layer. The motions of fluid and sediment are interdependent, which is reflected by the coupling between the equations through h, δ, and v. Equations 4, 5, and 8 are nonlinear partial differential equations for which analytical solutions are not available. It is argued that one is therefore dependent on numerical techniques to accurately simulate sediment transport in a dynamic state. A widely used computer model HEC-6 (U.S. Army Corps of Engineers, 1977) appears to be a reasonable tool for this study to employ.

2.4 CLASSICAL BED LOAD EQUATIONS

DuBoys was the first to offer a relationship that described bed load sediment transport. Since then, several equations have been proposed for the prediction of the bed load transport rate. A number of the original works are completely empirical in nature; some are obtained from dimensional considerations and the others are based on a semitheoretical approach. A summary of several of these theories is given in the following paragraphs.

DuBoys (1879) assumed that the bed material moves in a series of layers parallel to the bed, the velocity of each layer varying from a maximum for the top layer on the bed surface to zero for the lowest layer at some depth. A number of the early works were based on using tractive force as a determinant of sediment flow. DuBoys' equation may be written as:

$$q_B = A(\tau_s - \tau_o)\tau_s \qquad (16)$$

where:

$$A = \frac{\gamma_s \ \Delta\delta \ \Delta u_s}{2\tau_o^2}$$

Here τ_s represent the average shear stress at the channel boundary and τ_o is the shear stress at incipient motion. Empirical equations are dimensional and the variables used are applicable only for the system of units chosen by the investigator. Several empirical equations that have been published in the literature appear in Table 2-1. A majority of these empirical equations do not include the explicit effect of bed forms on transport rate. One interesting relation is offered by Chang (1939). Note that the bed load rate is a direct function of transport rate rather than an inverse function as it relates to Manning's "n." In all other relationships, bed load rate decreases with increasing "n" values. Of all the empirical relationships the most commonly used is that of Meyer-Peter and Muller (1948) given in Equation 17. A wide range of data have been applied to their formula with only moderate scatter. Chien (1954) has suggested that this relationship predicts the bed load rate better than Einstein's more rational equation.

$$\left[\frac{n_s}{n}\right]^{3/2} \frac{\gamma R_b s}{(\gamma_s - \gamma)da} = 0.47 + 0.25 \left[\frac{\gamma}{g}\right]^{1/3} \left[\frac{q_B}{\gamma_s}\right]^{2/3} \frac{1}{(\gamma_s - \gamma)^{1/3} da} \qquad (17)$$

Table 2-1. Empirical Equations for Bed Load Transport

No.	Investigator (Citation)	Equation	Remarks
1.	Gilbert[a]	$q_B = \frac{a}{d^{0.58}} s^{1.59} q^{1.02} - b$	
2.	MacDougall[b]	$q_B = aS^b(q - q_c)$	q_c is the discharge under critical condition. Data on graded sand used in deriving the equation.
3.	Favre[a]	$q_B = \frac{2.16\, s^{1.5} q}{(\rho_s - \rho)^{1/3}} - 20.7d(\rho_s - \rho)^{7/9}$	Based on experiments with sediments of relative density between 1.25 and 4.0.
4.	O'Brien and Rindlaub[c]	$q_B = A(\tau_s - \tau_o)^m$	
5.	U.S.W.E.S.[a]	$q_B = \frac{A}{n}(\tau_s - \tau_o)^m$	m varies from 1.5 to 1.8 depending on sediment size. Data on graded sand with sediment size varying from 0.31 mm to 4.10 mm used in deriving the equation.
6.	Schoklitsch[d]	$q_B = \frac{As^{3/2}(q - q_c)}{d^{1/2}}$	Equation based on data on uniform sand.

Table 2-1. (Continued)

No.	Investigator (Citation)	Equation	Remarks
7.	O'Brien[b]	$q_B = A(u_s^3/D)^m$	Equation based on data on graded sand.
8.	Chang[a]	$q_B = \frac{A_1 n\,(\tau_s - \tau_o)\tau_s}{\tau_o^2}$	Equation based on data on graded sand.

[a] Y. L. Chang (1939).
[b] H. Rouse (1950).
[c] O'Brien, M. P. and B. O. Rindlaub (1934).
[d] S. Shulits (1935).

Where da is the arithmetic mean grain size, R_b is the roughness factor for sediment and n is the average roughness of the bed. On a dimensional basis, the most prominent equation was presented by Shields (1936). He proposed the following relationship:

$$\frac{qB[(\rho_s/\rho) - 1]}{(q\gamma)s} = 10 \left[\frac{\tau_s - \tau_o}{(\gamma_s - \gamma)d}\right] \qquad (18)$$

Here q is the discharge per unit width of the channel. Equation 17 is based on a range of ρ_s/ρ from 1.06 to 4.2 and sediment size from 1.56 to 2.47 millimeter (mm). Data given by Rouse (1950) indicate errors up to 150 percent in the bed load rate predicted by the Shields equation. This magnitude of error is typical of the equations previously described.

Another set of researchers may be described as theorists. They approached the sediment transport problem from the viewpoint of statistics and fluid mechanics. The notable works of Einstein (1942, 1950) with his probability theory and the stream power function of Yang (1984) fall into this category. Einstein's work is the basis for modeling chosen for this study and is further discussed in Section 3.0 of the main text on materials and methods.

The stream power function theory advanced by Yang (1973) is rooted like many other equations on Manning's formula. The discharge Q or average

flow velocity v across contour element of length b can be represented by Manning's equation if uniform turbulent kinematic sheet flow is assumed.

$$v = \frac{1}{n} s^{1/2} y^{2/3} \qquad Q = vyb - \frac{1}{n} s^{1/2} y^{5/3} b \qquad (19)$$

where:

N = Manning's roughness coefficient

y = Depth of sheet flow at the contour element

s = Slope of the soil surface

Q/b = Discharge per unit width.

Rearranging equation 19 yields:

$$y = \left(\frac{nQ}{s^{\frac{1}{2}} b} \right)^{3/5} \qquad (20)$$

or:

$$v = \left(\frac{Q}{b}\right)^{0.4} \frac{s^{0.3}}{n^{0.6}} \qquad (21)$$

so that the unit stream power for sheet flow is:

$$P = vs = \left(\frac{Q}{b}\right)^{0.4} \frac{s^{1.3}}{n^{0.6}} \qquad (22)$$

Moore and Burch (1986) demonstrated that when steady state runoff was assumed, then theoretical length slope factors equivalent to those empirically developed in the universal soil loss equation could be derived.

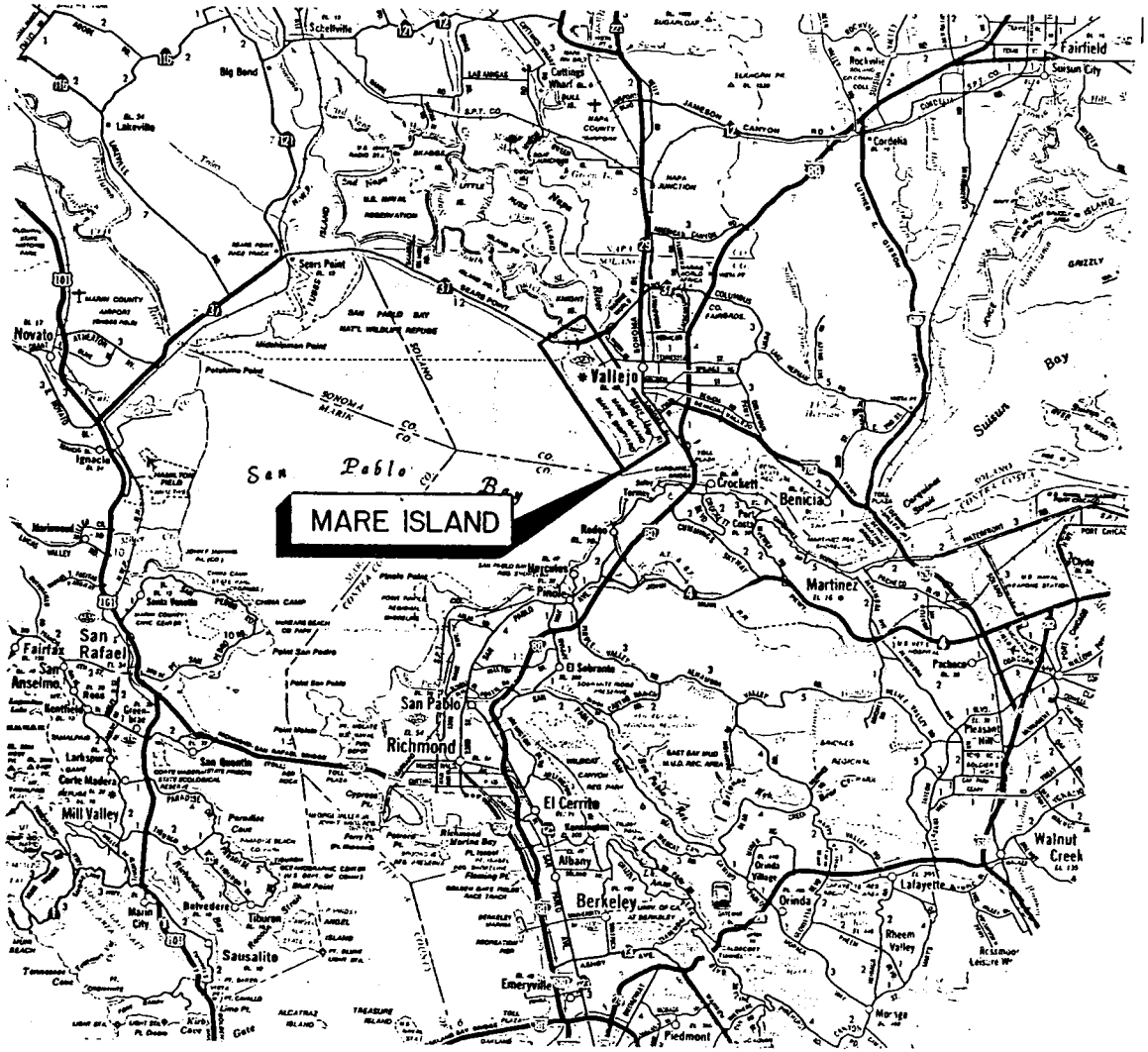
3.0 SITE DESCRIPTION

NSY Mare Island is one the United States military's oldest facilities on the West Coast. Its current mission is submarine overhaul and repair. Located on 5,667 acres of land adjacent to Vallejo, California, the Naval Base lies approximately 30 miles northeast of San Francisco (Figure 3-1). The peninsula may be accessed by land only through a causeway on the northern end of the facility. The remaining three sides of the peninsula are bounded by the Napa River (Mare Island Strait) to the east, Carquinez Strait to the south, and San Pablo Bay to the west.

Mare Island was purchased by the U.S. Government in 1852 for the purpose of constructing a naval shipbuilding yard. Commander David G. Farragut became the inaugural chief and commenced construction in 1854. The first ship was launched in 1858 and a line of combat ships followed through the two world wars and the Korean and Vietnam conflicts. During the 1950s, the base began to change its focus from surface ships to submarines. The nuclear-powered USS Nautilus, America's first submarine to traverse beneath the north pole, was decommissioned at NSY Mare Island, and the first Nautilus-class submarine was built at the shipyard in 1930.

3.1 OPERATIONS IN THE 900 AREA

The 900 Area is an open area near Building 900 and Pier 24 at the southern end of the industrial area as shown in Figure 3-2. The area has been used since about 1952 for the abrasive blasting of a wide variety of submarine parts. Before 1975, the area was an open field. A 15-foot-



SOURCE: AMERICAN AUTOMOBILE ASSOCIATION

Figure 3-1. Map of Mare Island and Vicinity

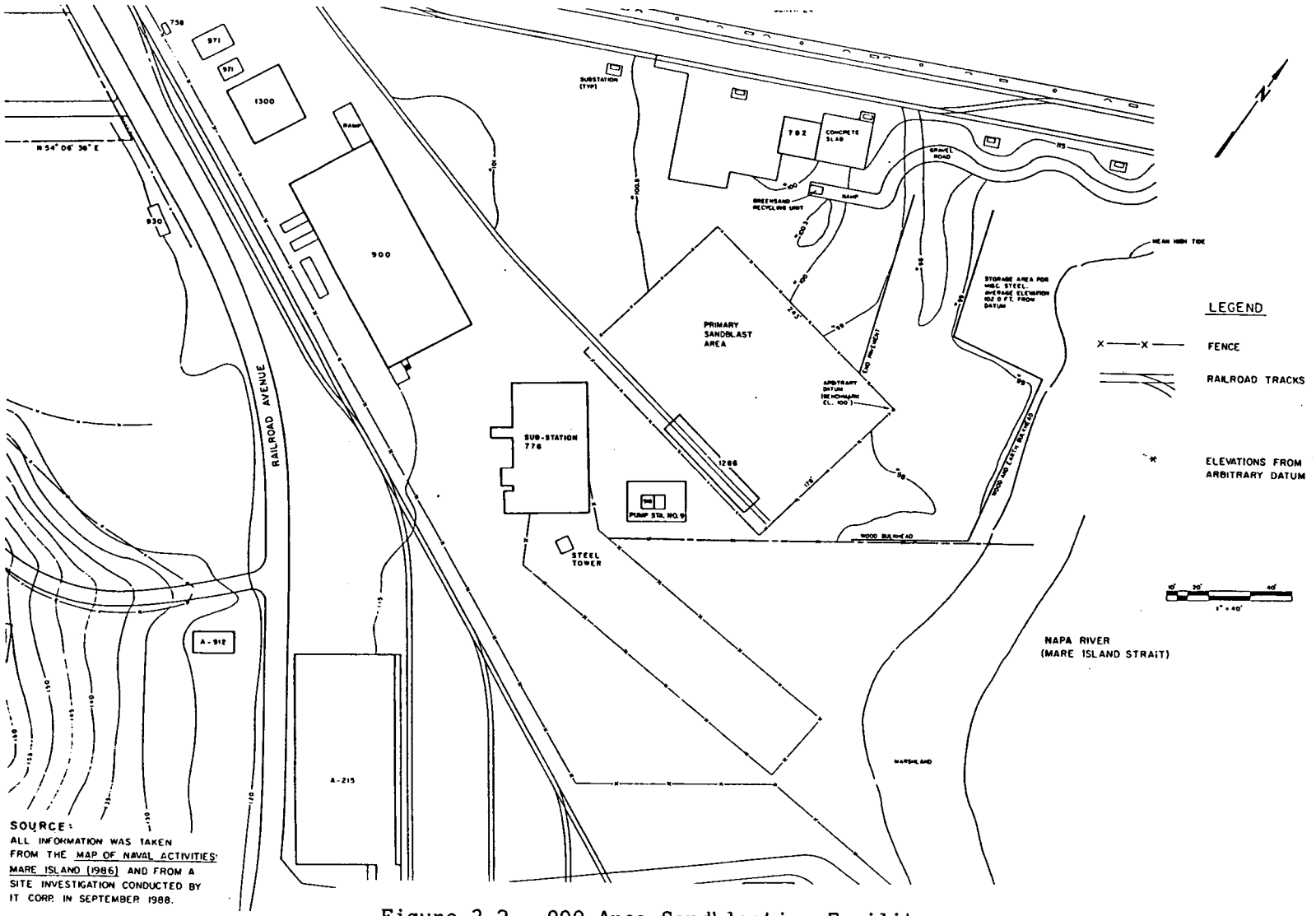


Figure 3-2. 900 Area Sandblasting Facility

high sheet metal fence was installed in 1976 to reduce airborne particulate release and to control runoff. Blasting continues today both inside and outside the fenced-off area. Gaps at the footing of the enclosure also permit spent abrasives to run off into the strait during precipitation. Recent studies by the Navy have shown that approximately 400 cubic yards per year of spent abrasives are created. These materials are collected periodically and placed in 3-cubic-yard containers, either for transport to the station landfill or for screening for recovery and reuse. An estimated 16 percent of the abrasives are reclaimed each year (Ecology & Environment, 1983).

Both virgin and reclaimed blasting sand are stored immediately west of the blasting area in and near Building 215. Piles of sand are present on the north, west, and south sides of the building and adjacent buildings. Varying deposits of this material are also evident throughout the general area (up to and including the marshland border of the Mare Island Strait). Specific distributions of both new and spent abrasives were mapped during September 1988. A detailed description of these findings is presented in Section 4.0.

The only waste generated in the 900 Area is the "Green Diamond" spent nickel and copper slag material abrasive. After use, the abrasive can contain minor amounts of debris associated with paint and varnish removal. The most common elements include paint, organotin, anticorrosion adhesives, marine growth, and metals.

Direct deposition of spent abrasives into the Mare Island Strait was an accepted practice until the mid-1970s when potential adverse environmental impacts were first uncovered. Fugitive runoff through overland sediment transport into the strait is presently the only pathway of significance. A small volume of parent material (less than 50 tons) was still present north of the beach in June 1988 when the sampling program was being performed.

3.2 WATERSHED CHARACTERISTICS

3.2.1 Physiography and Relief

Mare Island is located in the southwest corner of Solano County. The western part of the county consists of hilly to very steep mountainous uplands of the Coast Ranges that have a maximum elevation of 2,819 feet above mean sea level (msl). The rest of the county is on the floor of the Sacramento Valley region. Except for an isolated area of low, rolling hills in the southeast corner of the county, the valley areas of Solano County are either level or gently sloping alluvial plains and marshes. They are near sea level along the eastern and southern borders and rise to an elevation of approximately 100 feet at the foot of the mountains. Predominant physiographic and topographic features of Solano County and Mare Island are presented in Figure 3-3. A large area of tidal flats and marshland is adjacent to Suisun Bay. A portion of these lowlands reside on Mare Island. This entire area has been dissected into a series of islands by a maze of natural drainage channels.

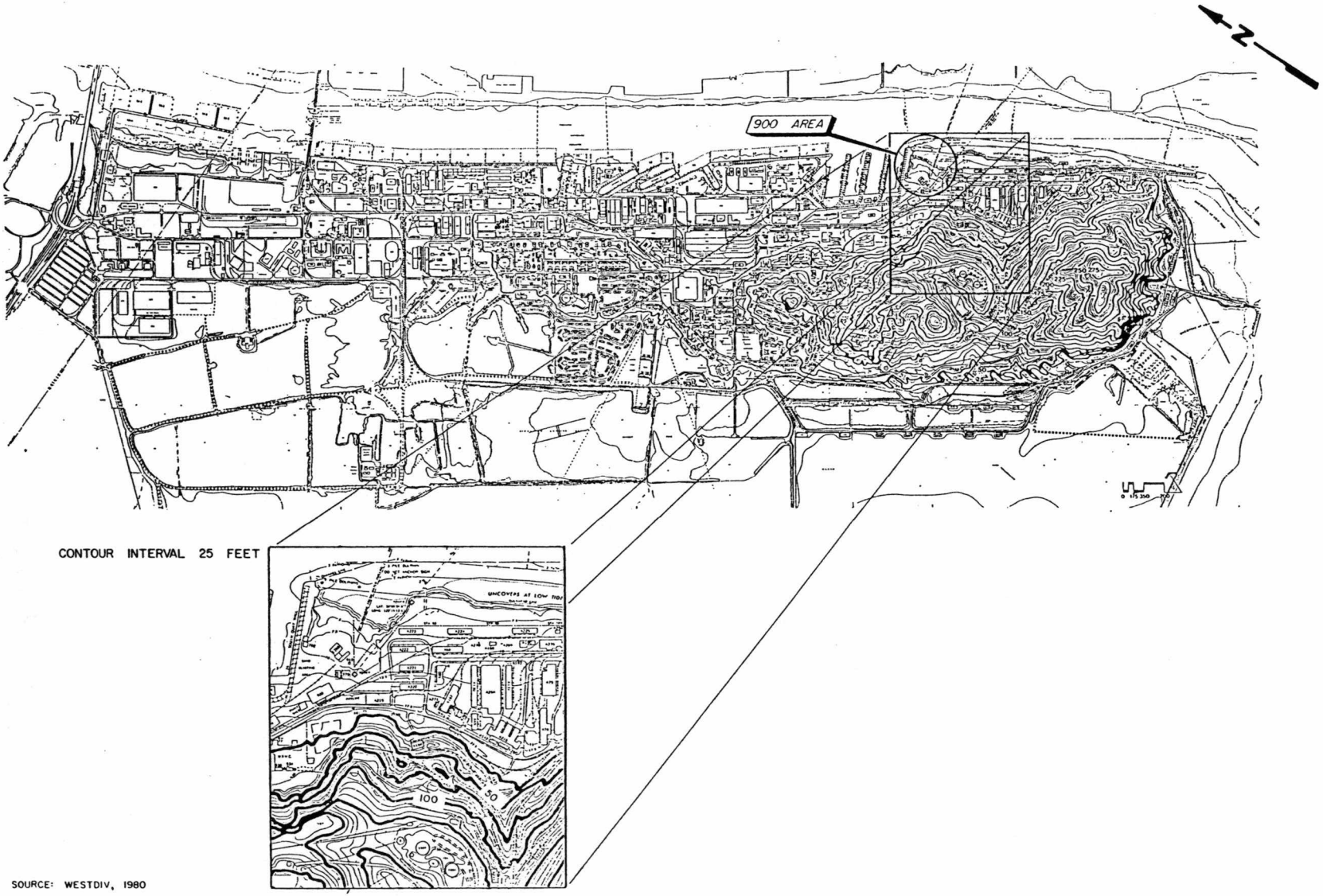


Figure 3-3. Physiography and Topography of Mare Island Area

Mare Island is a predominantly flat peninsula attached to low-lying marshlands and farmlands to the north. Most of Mare Island is relatively flat, ranging from near sea level in elevation at the extreme north end to 40 feet msl in the south-central area. A pronounced feature is the hills at the southern end of the peninsula that rise to a height of 275 feet. Of the 5,667 total acres, 2,582 acres are dry land and 3,085 acres are wetlands, over half of which were created by man-made dredge and fill operations.

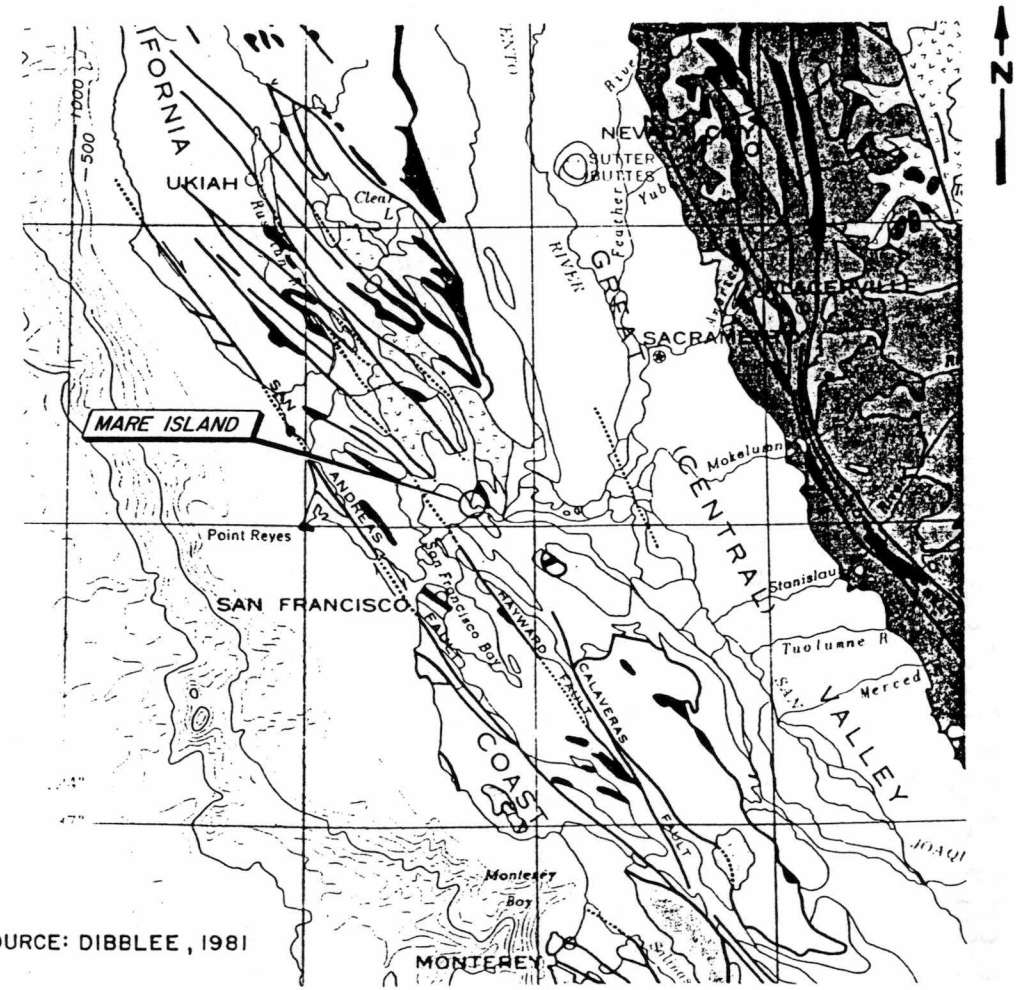
3.2.2 Geology

Mare Island and vicinity lie near the interface of two major geographic provinces: the Coast Range province and the Central Valley province. Mare Island is located where the Sacramento-San Joaquin Delta enters San Pablo Bay, the northern continuation of San Francisco Bay. As such, basement rocks are commonly concealed by thick sequences of bay mud. Rocks exposed at and near Mare Island consist of micaceous shale and arkosic sandstones of the Panoche Formation (Dibblee, 1981), part of the Cretaceous Great Valley Sequence (GVS). Rocks strike to the southeast, but across the Carquinez Strait, also consist of shales and sandstones of the Panoche Formation (Dibblee, 1980). Commonly underlying the GVS is a Jurassic-Cretaceous eugeoclinal assemblage known as the Franciscan Complex. The Franciscan Complex is commonly dominated by graywackes, but also contains substantial quantities of cherts, greenstones, and shales as well as limestones, serpentinites, ultra mafics, and blueschists. Rocks of the Franciscan Complex may be underlying rocks of the Panoche Formation exposed on Mare Island.

The regional geology of the Central Coast Range is very complex and is dominated by the presence of major northwest-trending structural features such as the San Andreas, Hayward, and Calaveras faults as shown in Figure 3-4. These large-scale features and their subsidiary structures have caused extensive shuffling of geologic units, resulting in poorly understood stratigraphic relationships between some units. The age of rocks in the Central Coast Range varies from the Jurassic to the most recent Holocene.

The Central Valley is a large, elongated northwest-trending asymmetric structural trough that has been filled with an extremely thick sequence of sediments. Estuaries and thick alluvial deposits along the western margin of the Central Valley are prominent erosional features of the larger rivers. Suisun and San Pablo bays are included among them. These large rivers excavated canyons that were graded to a sea level about 300 feet below the present level (Louderback, 1951; Higgins, 1952). Upson (1949) showed that along the southern part of the coast these canyons are cut through the lowest marine terrace, making them of Wisconsin Age.

Dibblee (1981) has mapped the surface geologic features of Solano and Contra Costa counties and specifically Mare Island. Over 60 percent of Mare Island is immediately underlain by Quaternary alluvium (Qal). The alluvium, which is more accurately defined in the Section 3.2 on soils, is mainly floodplain deposited sand, silt, gravel, and clay irregularly interstratified. The western border of the peninsula is characterized by



EXPLANATION

SEDIMENTARY AND VOLCANIC ROCKS

Cenozoic nonmarine (continental) sedimentary rocks and alluvial deposits

Cenozoic marine sedimentary rocks

Cenozoic volcanic rocks

Late Mesozoic (latest Jurassic and Cretaceous) shelf and slope sedimentary rocks

Late Mesozoic (latest Jurassic ar Cretaceous) eugeosynclinal rocl of the Franciscan Formation

Mesozoic sedimentary and volcanic rocks older than the Nevadan orogeny; in places strongly metamorphosed

Paleozoic sedimentary and volcanic rocks: in places strongly metamorphosed: includes some rocks of Triassic age in Klamath Mountains: includes some late Precambrian sedimentary rocks in Great Basin

Precambrian rocks of all types including coarse-grained intrusives

Pre-Cenozoic metamorphic rocks of unknown age

INTRUSIVE IGNEOUS ROCKS

Granitic rocks chiefly of Mesozoic age

Ultramafic rocks chiefly of Mesozoic age

Figure 3-4. Regional Geology

younger bay muds (Qbm). These materials are very fine silts and clays admixed with abundant organic material. The pronounced sandstone and claystone formation at the south central portion of Mare Island is of Cretaceous Age but was not named. Dibblee (1981) considered these rocks part of the Panoche Formation. The distribution of surface and near-surface rocks in and around Mare Island is given in Figure 3-5.

One fault is present at Mare Island. It trends southeast to northwest across the eastern side of the peninsula. Named the Franklin Fault, it is thought to be part of the East Bay Hills stepover zone (Aydin and Page, 1984). This structural zone lies between the Hayward and Calaveras faults in the East Bay Hills and is caused by compression between the two faults. This zone of compression has resulted in the upthrusting of the East Bay Hills (Aydin and Page, 1984). The Franklin Fault dips steeply to the southwest and is considered a reverse fault (Aydin and Page, 1984); rocks southwest of the fault are being transported upward with respect to rocks northeast of the fault. The nearby Southhampton Fault, located about 4 miles east of Mare Island (Dibblee, 1980 and 1981) is of the same type as the Franklin Fault; it is a reverse fault dipping to the west-southwest (Aydin and Page, 1984).

3.2.3 Soils

The Mare Island Peninsula has a different appearance now than it did 100 years ago. Many marshlands and lowlands have been landfilled, especially in the northern portion. These landfills, in addition to poor native soils, present several potential engineering problems such as land

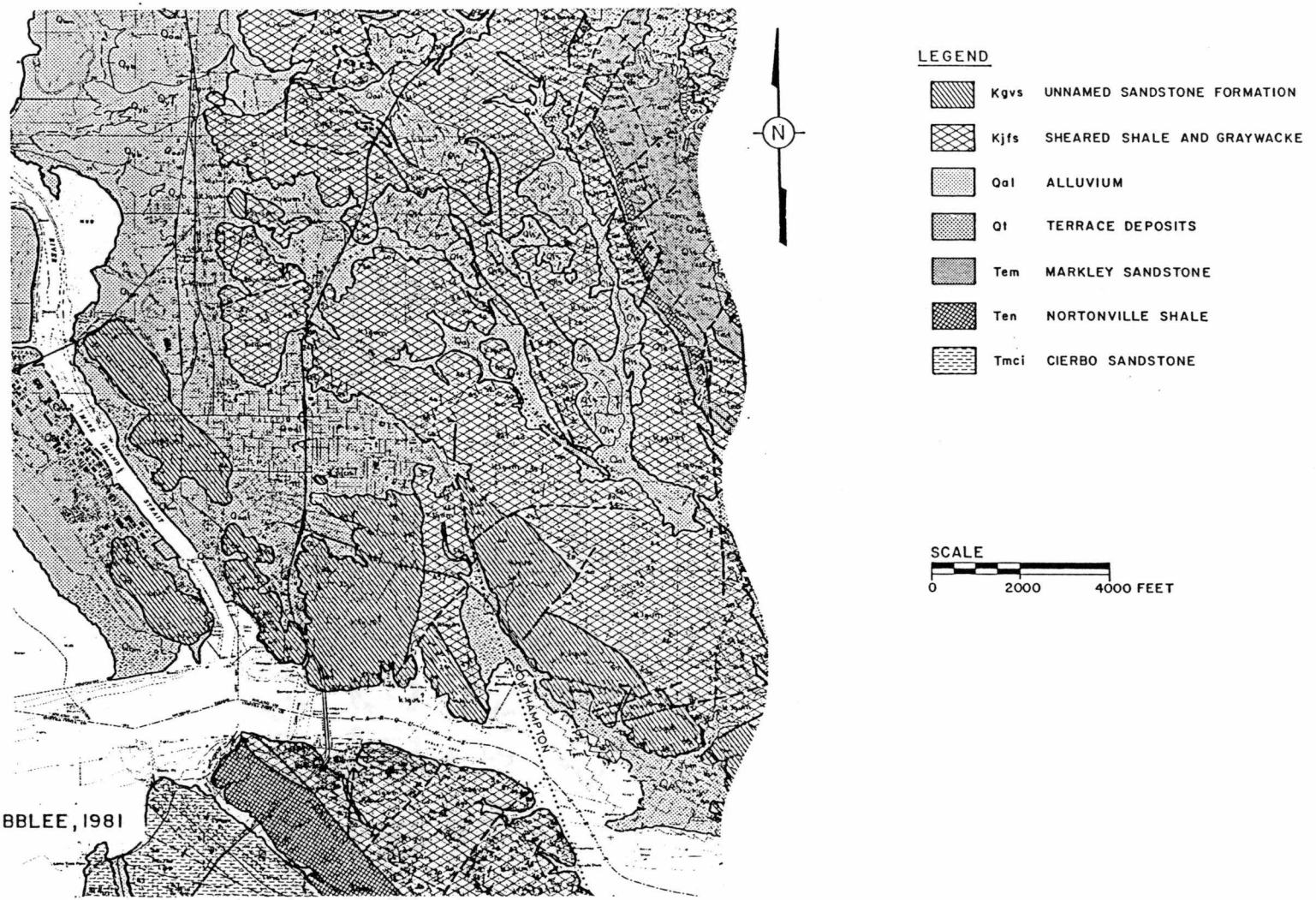


Figure 3-5. Surface Geologic Features - Mare Island and Vicinity

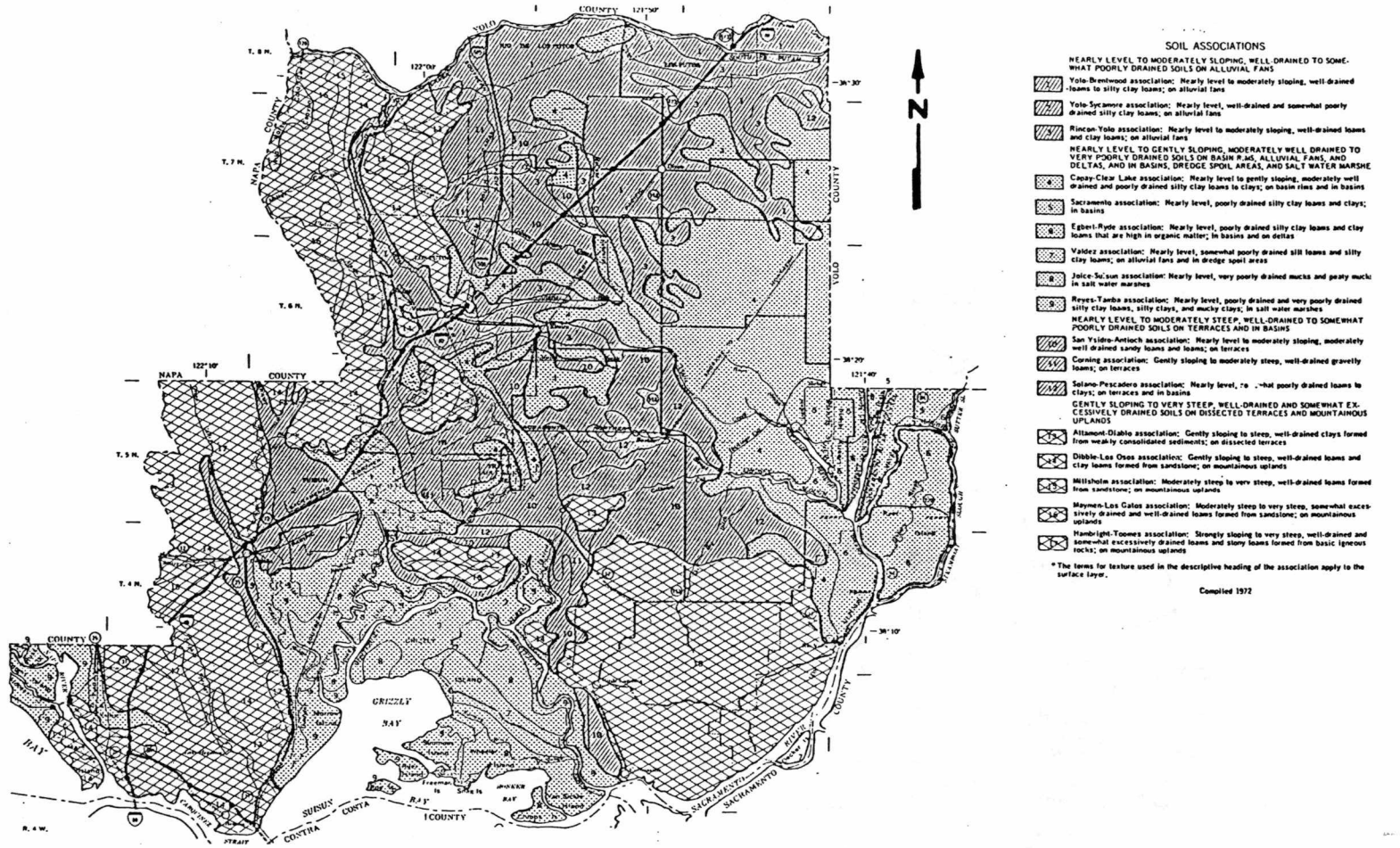
subsidence and erosion. An overview of shallow soils as classified by the U.S. Soil Conservation Service (1977) is provided in Figure 3-6.

3.2.3.1 Soil Morphology

Mare Island and the surrounding Vallejo regional watershed areas may be generally classified into six geomorphic units: delta; floodplains and natural levees; flood basins; low alluvial plains, fans, and low terraces; low hills and dissected terraces; and uplands of the Coast Ranges. Three of these units, delta, floodplains, and uplands of the Coast Ranges, dominate the Mare Island vicinity as evidenced in Figure 3-6.

Delta soils are found at or near sea level along the northern portion of Mare Island, west of Steamboat Slough, and in the Suisun Marsh adjacent to Suisun, Grizzly, and Honker bays. Tidal sloughs form a network of waterways through the delta. A system of artificial levees encloses much of the area. Salinity varies with the distance from the bays and with the seasonal dilution by runoff from the Sacramento River, the San Joaquin River, and tributary streams.

The soils that formed in the delta are mostly mixtures of hydrophytic plant remains and mineral sediments. The poorly drained delta areas support a dense growth of tule and reed plants. Mineral sediments are added to the organic deposits by tidal action and by deposition from turbid water during floods. The resulting soils range from organic soils that contain a small amount of mineral matter, such as thin silt and clay



SOURCE: U.S. SOIL CONSERVATION SERVICE, 1977

Figure 3-6. Shallow Soils in Solano County

lenses, to mineral soils that are low in organic matter content. The U.S. Soil Conservation Service (1977) lists the Reyes silty clay found on Mare Island as a delta soil.

Floodplain-associated alluvium is mostly moderately coarse textured to moderately fine textured. These soils are very recent heterogeneous deposits. Soils of the Valdez and Columbia series once found along the shores of Mare Island have been dredged or overlain by construction fill. This condition is evident at the 900 Area because the U.S. Soil Conservation Service (SCS) mapped the vicinity as man-made fill, but drilling at the site confirms the remnants of alluvium, delta soils, and man-made fill.

A large part of the southern half of Mare Island has been mapped as being a component of the Coast Range Uplands. This geomorphic unit consists of a segment of rugged terrain that parallels the western boundary of Solano County. It consists of several ridges and intervening narrow valleys that trend in a northwestern direction. The Millsholm loam and Los Osos loam soil types on the island are in this geomorphic unit. The Millsholm loam was formed in residuum from sandstone in steep areas such as those found near the base golf course. The Los Osos soils formed from weaker sandstone. Slopes are less steep, erosion is less a hazard, and the soils are deeper. These soils have been subjected to more weathering and translocation of silicate clays and have formed agrilic horizons.

3.2.3.2 Soil Types

Eight different soil types may be found on Mare Island. These are: Reyes silty clay, Reyes silty clay loam, Diablo-Ayar clay, Dibble-Los Osos loam, engineered fill, Tidal marsh, Millsholm loam, and Altmont clay. Exploratory borings taken throughout the island also confirm the presence of Altamont clay and Millsap loams. Columbia loam is believed to be present at depth along the shore of Mare Island Strait. Salient engineering properties of local soils are presented in Table 3-1.

Upland portions of the peninsula are overlain by soils of the Diablo series. These soils are subdivided on Mare Island into the Diablo-Ayar and Diablo-Los Osos classes. Generally, the well-drained Diablo soils are characterized by a dark gray surface layer of clay. The uppermost or A horizon may reach 35 inches in depth. It is underlain by 6 inches of grayish-brown silty clay loam. The C horizon is light yellowish-brown, weakly consolidated sediments that extend to a depth of more than 6 feet. However, the two classes exhibit widely different physical properties. The Diablo-Ayar series is the most plastic soil on the peninsula with a plasticity index exceeding 40. As much as 95 percent of the soil may be classified as clay. It logically transmits water very slowly, having a permeability of less than 1 times 10^{-7} feet per second. Alternatively, the Diablo-Osos soils are very low plastic materials because of their sandstone parent bedrock. These soils are, nevertheless, predominantly clay in content and have a permeability on the order of 10 to 15 times greater than their Diablo-Ayar counterpart.

Table 3-1. Engineering-Related Soil Properties

Soil Map Symbols	Classification		Percentage Passing Sieve				Atterberg Values		Permeability (in./hr)	Available Water Capacity (in./hr of soil)
	USDA Texture	Unified	No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	Liquid Limit	Plastic Index		
Altemont: AcC, AcE,	Clay	CH	100	100	90-100	75-95	50-60	30-40	0.06-0.2	0.14-0.16
A8C, A1E, AmC,	Silty clay loam Siltstone	CL	100	100	95-100	85-95	30-40	15-25	0.06-0.2	0.19-0.21
			100	100	95-100	90-95	30-40	15-25	0.06-0.2	0.07-0.10
			100	100	90-100	60-70	20-30	0-10	0.63-2.0	0.15-0.17
			100	100	95-100	80-90	40-50	20-30	<0.06	0.04-0.06
Ayar	Clay	CH	100	100	90-100	75-95	50-60	30-40	0.06-0.2	0.14-0.16
Mapped with Diablo soils	Clay loam Weakly consolidated sediments	CL	100	100	90-100	70-80	30-40	10-20	0.06-0.2	0.18-0.20
			100	100	95-100	90-100	40-50	15-25	0.2-0.63	0.19-0.21
			100	100	95-100	90-95	30-45	15-25	0.06-0.2	0.16-0.18
			100	100	95-100	80-100	40-55	20-35	0.06-0.2	0.14-0.16
			100	95-100	90-100	80-95	50-70	35-55	0.06-0.20	14-0.16

Table 3-1. (Continued)

Soil Map Symbols	Classification USDA Texture	Unified	Percentage Passing Sieve No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	Atterberg Values Liquid Limit	Plastic Index	Permeability (in./hr)	Available Water Capacity (in./hr of soil)
Columbia: Cm	Fine sandy loam, thin strata of sand to silty clay loam	SM or SC	100	100	70-85	40-50	0-20	0-10	2.0-6.3	0.13-0.15
Diablo: DaC, DaE2	Clay Consolidated sediments	CH	100	100	90-100	75-95	60-70	40-50	0.06-0.200	14-0.16
*Dibble:										
DbC, DbE, DbF2	Loam	ML or CL A-4	100	100	85-95	60-70	20-30	0-10	0.63-2.0	0.16-0.18
	Light clay Sandstone	CH	100	100	95-100	85-95	50-60	30-40	0.06-0.20	0.15-0.17
	Clay loam	CL	100	100	95-100	80-90	30-40	10-20	0.2-0.63	0.18-0.20
DIC, DIE, DIF2	Light clay	CH	100	100	95-100	85-95	50-60	30-40	0.06-0.2	0.15-0.17
			100	100	95-100	90-100	60-80	25-40	0.2-0.63	0.19-0.21

Table 3-1. (Continud)

Soil Map Symbols	Classification USDA Texture	Unified	Percentage Passing Sieve No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	Atterberg Values Liquid Limit	Plastic Index	Permeability (in./hr)	Available Water Capacity (in./hr of soil)
			95-100	90-100	60-70	25-35	b	b	2.0-6.3	0.10-0.12
			90-100	80-90	70-80	55-65	30-40	5-15	0.63-2.0	0.16-0.18
			90-100	90-100	80-90	65-75	25-35	0-15	0.63-2.0	0.08-0.16
Joice: Ja										
	Clayey muck (organic and mineral mixture)	Pt							2.0-6.3	0.23-0.25
Joice, clay subsoil variant: jb	Muck (organic mineral mixture	Pt							2.0-6.3	0.23-0.25
	Clay	CH	100	95-100	90-100	80-95	50-70	35-55	<0.06	0.03-0.05
			100	100	85-95	60-75	20-30	0-10	0.63-2.0	0.14-0.16
			100	100	90-100	70-80	30-40	15-25	0.2-0.63	0.19-0.21
Los Osos	Clay loam	CL	100	100	90-100	80-90	30-40	10-20	0.2-0.63	0.18-0.20
	Light clay	CH or	100	100	95-100	85-95	40-60	30-40	0.06-0.20	0.15-0.17
	Sandstone	CL								

Table 3-1. (Continued)

Soil Map Symbols	Classification USDA Texture	Unified	Percentage Passing Sieve No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	Atterberg Values Liquid Limit	Plastic Index	Permeability (in./hr)	Available Water Capacity (in./hr of soil)
Made land: MA										
Too variable to rate			100	100	85-95	60-75	20-30	0-10	0.63-2.0	0.14-0.16
*Millsap: MkA, M1C	Sandy loam	SM	100	100	60-70	25-35	b	b	2.0-6.3	0.11-0.13
	Clay	CL	100	100	90-100	80-90	30-40	20-30	<0.06	0.05-0.07
Millsholm and Millsholm Variant: MmE, MmG2, MnC, MnE	Loam	SM or ML	100	100	90-100	40-60	15-25	0-15	0.63-2.0	0.16-0.18
	Sandstone		100	100	95-100	90-95	50-60	20-35	0.06-0.2	0.12-0.14
			100	100	95-100	85-95	50-60	35-45	0.06-0.2	0.17-0.19
			100	95-100	90-100	75-85	35-45	20-30	0.06-0.2	0.03-0.05
			100	100	90-100	45-55	20-30	0-15	2.0-6.3	0.13-0.15
Reyes: Rd, Re	Silty clay loam or silty clay	MH or OH	100	90-100	85-95	70-80	50-60	15-25	0.06-0.20	0.12-0.14
Rincon: RnC, RoA, RoC	Clay loam and heavy clay loam loam surface	CL	100	100	90-100	70-90	25-40	10-30	0.06-0.2	0.15-0.17

The 900 Area is underlain by engineered fill to a depth of 2 to 6 feet. This type of land at Mare Island consists of areas that have been filled in with mixed materials. Four shallow borings were taken by Richesin & Associates Inc. (1987) during a preliminary waste characterization study. Sandstone, shale, concrete, and blacktop fragments make up as much as 80 percent of the mass. The soil material in the mixture ranges in texture from sandy loam to clay. The six kinds of material present vary within short distances. The fill material is well-drained but is commonly underlain by poorly drained tidal marsh or saline sediments that are at a depth of more than 3 feet to as much as 7 feet.

The natural soils in the 900 Area, which are to a limited extent still present, are most likely from the Altamont Series. Altamont soils have a dark grayish-brown clay and heavy clay surface layer underlain by light olive-brown silty clay loam. The parent material is light yellowish-brown siltstone at a depth usually greater than 40 inches. The A horizon is 20 to 28 inches in thickness. The profile is weak gradational from the lowermost A to C horizons. The lower portions of the profile exhibit a more dominant loam characteristic. Substratum material is moderately erodible and typical native plant rooting depths extend to 40 inches.

Millsap loam soils, located in the southern portion of Mare Island, have moderate to high erosion characteristics. The topsoil is brown to yellowish-brown silt loam. The substratum is of the same color but differs by virtue of a higher mineral content and a larger percentage of coarser grained materials. It is prevalent on the base golf course.

3.3 STUDY SITE AND SURROUNDING HYDROLOGY

3.3.1 Regional Surface Water

Mare Island is situated at the edge of a complex web of fresh-water drainage ways and salt-water embayments. Two major watersheds drain into surrounding San Pablo Bay. However, effects of the regional hydrology have only minimal impacts and only during flood periods do they effect local watershed. Delineation of the study watershed is discussed in Section 4.2.

The Sacramento and San Joaquin rivers empty into Suisun Bay to the east of Mare Island. The combined flow, in turn, drains westward through Carquinez Strait past Mare Island and into San Pablo Bay. To the north of the peninsula is the watershed of the Napa River. It empties into San Pablo Bay through Mare Island Strait along the east side of the peninsula. About 60 percent of Solano County is drained eastward to the Sacramento River by a number of intermittent streams, such as Putah, Sweeney, and Ulatis creeks. The rest of the county and adjoining Napa and Marin counties are drained southward into Suisun and San Pablo bays by intermittent streams, such as Green Valley, Suisun, and Ledgewood creeks.

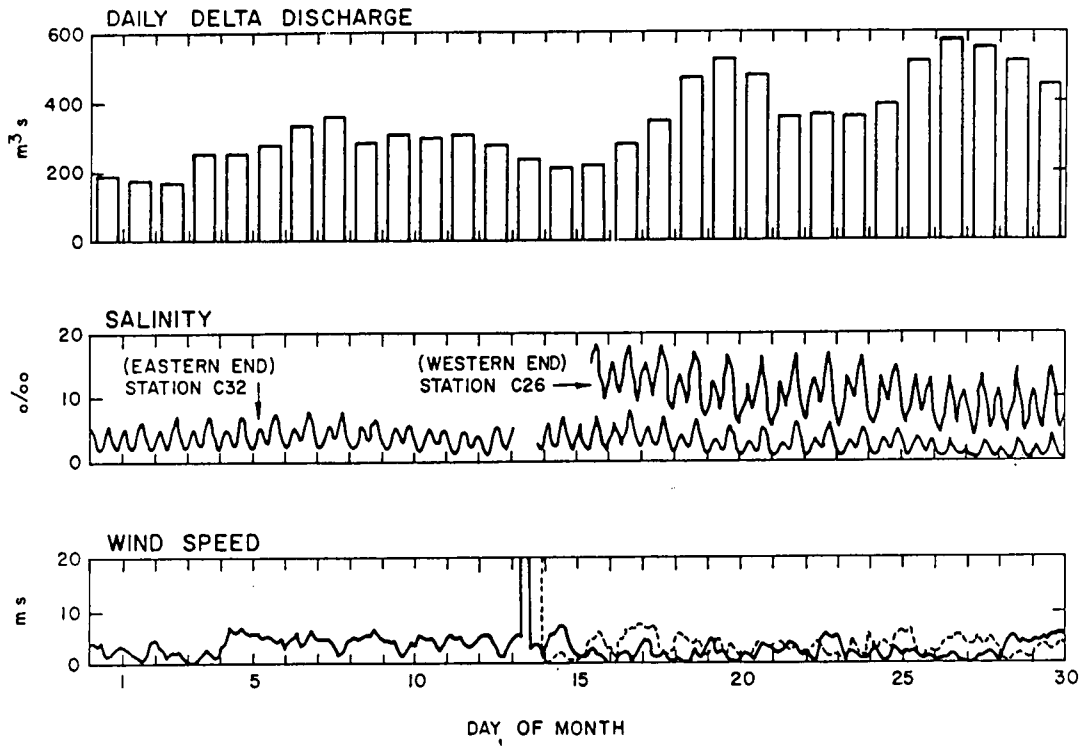
Surface water contributions from Napa, Sonoma, and Solano counties may be subdivided into at least four major watersheds. The smallest is Petaluma Creek, which drains some 41 square miles in Sonoma and Marin counties.

Sonoma Creek, which flows south into San Pablo Bay west of Mare Island, drains 50 square miles in Sonoma County. The Napa River basin, which empties into Mare Island Strait, drains over 230 square miles in Napa and Solano counties. Finally, the largest north bay watershed is found in the Suisun-Fairfield Valley in Solano County. A 260-square-mile basin is drained by Green Valley, Suisun, Ledgewood, and Laurel creeks [California Department of Water Resources (CDWR), 1975].

Suisun and San Pablo bays compose the northernmost portion of the San Francisco Bay system. The eastern reach of the delta encompasses an area of about 738,000 acres separated into 70 islands and tracts by 700 miles of waterways. Tributary streams that supply fresh water to the delta have helped to create and define its unique shape, that of a triangle with its base facing away from tidal waters instead of toward them, as is typical of coastal plain deltas. The Sacramento River provides more than 80 percent of the delta's inflow. San Joaquin River, Middle River, and Old River contribute the remaining 20 percent of inflow. Over 21 million acre-feet of water enters the delta during an average year. Discharge into Suisun Bay can vary from under 10,000 cubic feet per second (cfs) to as much as 600,000 cfs during major runoff events and annually averages 120,000 cfs (CDWR, 1987). Consumptive use averages 1.6 million acre-feet yearly. Water export for the Central Valley Project and the State Water Project consumes another 6.1 to 15.6 million acre-feet annually (CDWR, 1986).

The south channel through Suisun Bay is part of the major shipping channel, connecting the Port of Sacramento to the Pacific Ocean. The rest of the bay area is shallow and is used by fishermen and wildlife. During periods of high delta discharge in winter and spring, Suisun Bay, Carquinez Strait, and the easternmost reaches of San Pablo Bay (including Mare Island) become almost completely fresh. During long periods of relatively steady low delta discharge in summer and fall, stratification and large horizontal salinity gradients develop with little net change in the salinity distribution from tidal cycle. Average daily discharge, salinity, and wind speed during a typical low flow month of November is plotted in Figure 3-7. Low flow values are typically used because they represent a condition of least dilution from a contaminant loading perspective.

Stage data at the mouth of the Carquinez Strait near Vallejo (Smith and Cheng, 1987) show that tides at both the seaward and landward boundaries of Suisun Bay and Carquinez Strait are a mixture of diurnal and semi-diurnal components with a noticeable spring-neap cycle. As the tides propagate through the bay's complex bathymetry, the tidal amplitude of about 4.6 feet at Mare Island is dampened to about 3.4 feet at the eastern boundary. Tides are also being affected by flux in the global climate. The average sea level has risen 0.5 feet in the past 100 years and is continuing at an increasing rate (U.S. EPA, 1983).



LEGEND:

WINDS: 1979 ------
1980 ——

REFERENCES:

CDWE, 1984 (DISCHARGE)
CHENG AND GARTNER, 1984 (SALINITY)
GARTNER AND CHENG, 1983 (WINDS)

Figure 3-7. Northern Bay Delta Region Daily Flow, Salinity, and Wind Speed: Month of November

3.3.2 Regional Ground Water

Ground water in the vicinity of Mare Island is part of the Napa-Sonoma Regional Ground Water Basin. The Napa-Sonoma Valley basins together compose the largest source of ground water in the North Bay with a total storage capacity of over 3,000,000 acre-feet. Sonoma Valley represents 85 percent of the total storage capacity. Napa Valley is composed of a relatively narrow trough of younger alluvium bordered by volcanics and sediments. Well yields can reach 3,000 gallons per minute (gpm) but average about 200 gpm. The Sonoma Valley aquifer also contains some younger alluvium; however, older less permeable alluvium and volcanics dominate. Well yields are appreciably lower, averaging less than 100 gpm with a reported maximum around 400 gpm. Ground water elevations range from 530 feet msl in the northern part of Sonoma Valley to near sea level as Sonoma Creek enters San Pablo Bay. The Napa Valley basin transects a wide alluvial fan east of the Sonoma Valley. Ground water is found at or near 130 feet msl at the outcrop of the basin near the headwaters of the Napa River. Hydraulic head in the aquifer dissipates rapidly to the south and approaches sea level at Mare Island.

3.3.3 General Water Quality

California natural resources agencies currently maintain two programs for measuring surface water quality in the North Bay region. The primary system is part of the CDWR statewide monitoring that has been ongoing for several decades. Stream and bay monitoring locations for this program are shown in Figure 3-8. The five relevant sampling points are located in San Pablo Bay just south of Mare Island, in Suisun Bay, and on the

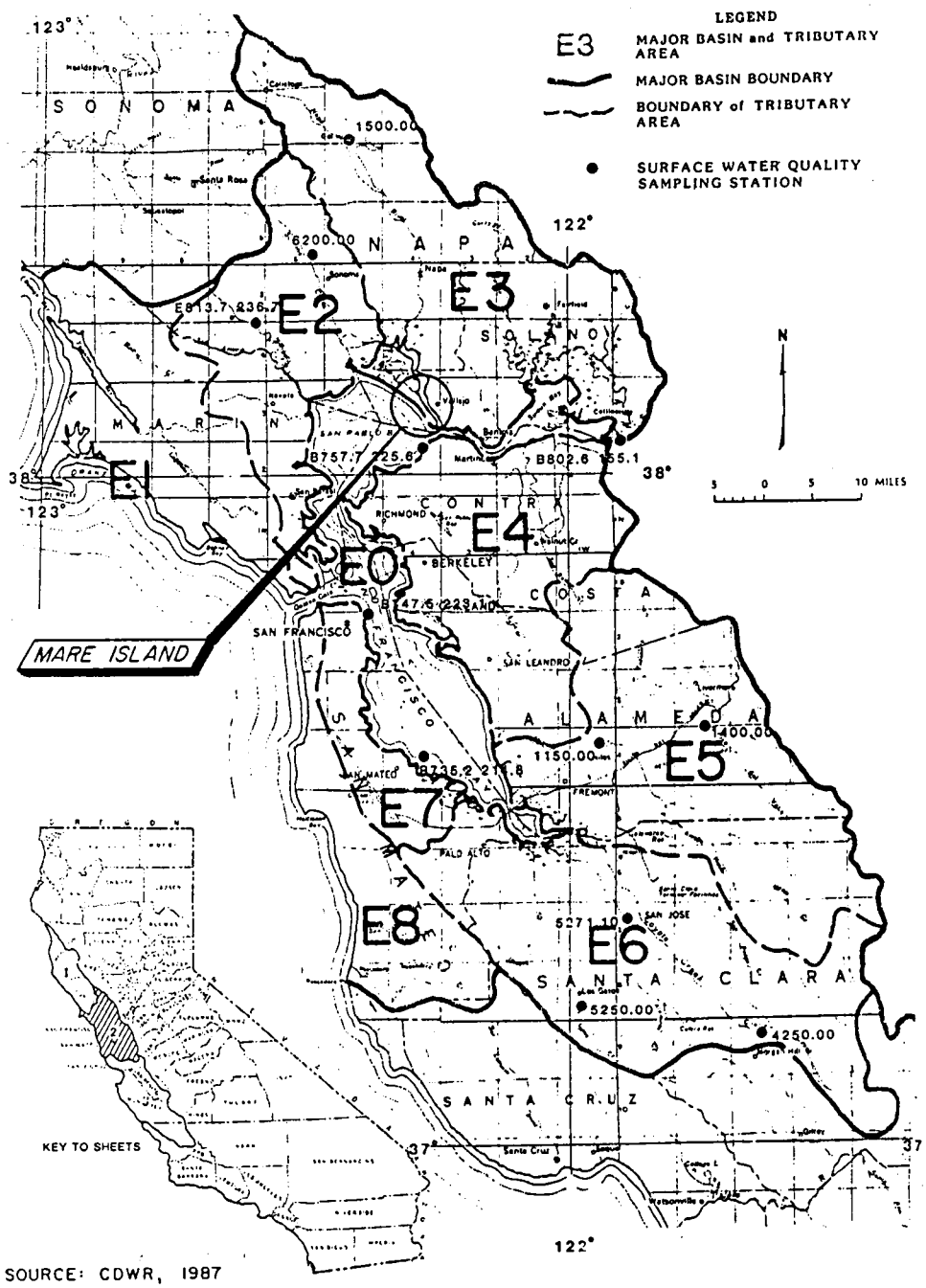


Figure 3-8. Location of Surface Water Quality Stations

Napa, Petaluma, and Sonoma rivers. The second system was established by the State Water Project during the 1970s. It focuses on water quality in the North Bay and Delta region. Twenty-seven sampling stations have been established to monitor chlorophyll distribution, salinity, heavy metals, and benthic biomass. Locations of these sampling points are given in Figure 3-9. The marked influence of sea water is evident in the disparity in electrical conductance in the bay versus the contributing rivers. Influent to the bay through Mare Island Strait contains high levels of dissolved oxygen and is low in total solids and hardness, reflecting a relatively good water source for aquatic life past the 900 Area. Unfortunately, the flow is greatly diluted by bay waters just north of Mare Island. Table 3-2 lists several general water quality parameters for the recording period of 1985 to 1986.

During 1986, heavy metal levels were measured in May and September at 11 representative sites throughout the North Bay and Delta region. Trace amounts of metals were found at some sites, but dissolved concentrations were below California State primary and secondary drinking water standards. All 11 sites showed less than detectable levels of both dissolved and total concentrations for cadmium and lead. Five sites had detectable dissolved concentrations of zinc, all 0.01 mg/l, which is well below the state drinking water standard of 5 mg/l. None of the sites had detectable levels of chromium. It should be noted that none of the locations tested for heavy metals were in San Pablo Bay.

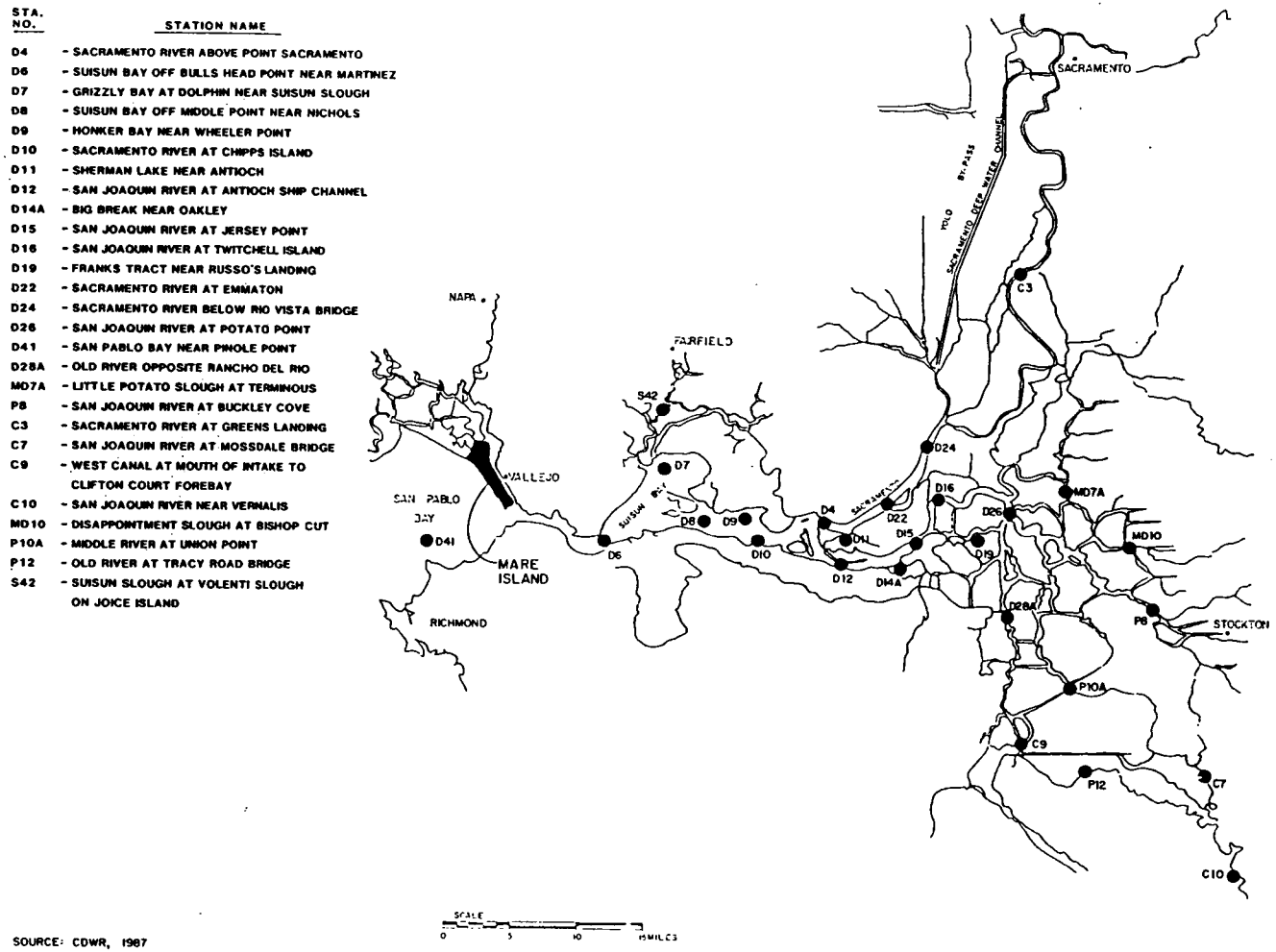


Figure 3-9. 1986 Water Quality Monitoring Sites, Suisun, and San Pablo Bays

Table 3-2. Surface Water Quality, North Bay Drainage Basins

	San Pablo Bay	Petaluma River	Sonoma Creek	Napa River
Identification number	8747.5	E2-813.7	E2-6200	E3-1500
Dissolved oxygen[a]		8.5	11.2	6.4
pH		8.0	8.3	7.2
Temperature (°F)	48 to 62	63	59	63
Electrical conductivity[b]	40,000	7412	300	218
Calcium (mg/l)			19	18
Magnesium (mg/l)			18	9
Nickel (mg/l)			16	15
Potassium (mg/l)			2.1	-
Calcium carbonate (mg/l)			129	74
Sulfate (mg/l)			14	
Chloride (mg/l)	11,000 to 16,000		10	11
Nitrate (mg/l)			2.2	
Turbidity		340	14	
Total dissolved solids (mg/l)	12,000 to 30,000	4580	188	158
Boron (mg/l)			0.4	
SAR[c]			0.6	0.7
NCH[d]			0	8
Total hardness			122	82

[a]Milligram/liter (mg/l).
[b]MicroSiemens.
[c]Sodium adsorption ratio.
[d]Noncarbonate hardness.

Salinity as gauged by electrical conductivity varies widely at Mare Island during the course of any given year. The electrical conductivity may vary from less than 1,000 microSiemens/centimeter in March (high runoff) and over 20,000 microSiemens/centimeter in June (low runoff). This great discrepancy effects a major influence on the partitioning of ionic chemicals in the water and sediment columns. An equally large difference occurs in the stratification of salinity through the bay.

Potable water is provided almost exclusively from surface water sources in the study region. Ground water, conversely, is used extensively for agricultural purposes, mostly for irrigation. Ground water beneath Mare Island has never been developed for consumptive use. Brackish water derived from San Pablo Bay is used to a limited extent in fire water lines. The largest consumers of ground water in the North Bay area are vineyards in Marin, Solano, and Sonoma counties. According to CDWR (1983), projected ground water consumption will increase by some 7 percent over the next 5 years. Overdrafting is not presently a problem in the North Bay but is a significant concern in other areas of the San Francisco Bay region. Salinity is a major concern from an environmental standpoint as well as from the view of water supply. As such, extensive monitoring is performed throughout the North Bay-Delta region.

3.3.4 Meteorology

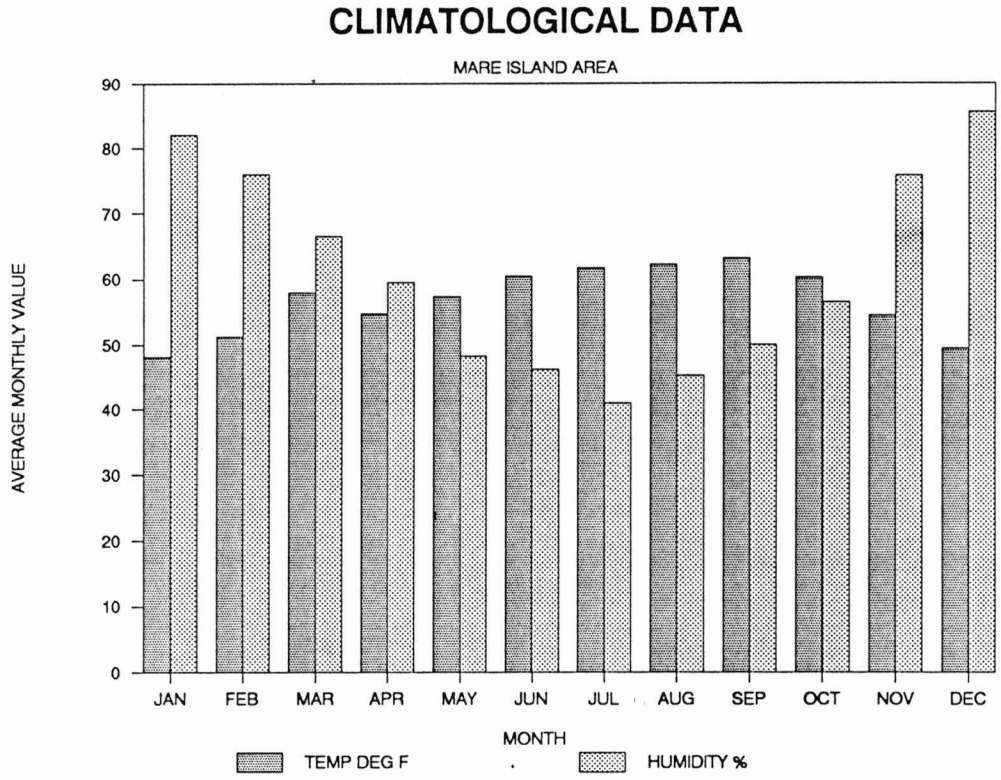
The climate of Solano County and Mare Island is strongly influenced by its location and topography. The Sacramento Valley, to the east and

north, has hot, dry summers and cool winters. The Pacific Ocean, to the south and west, has cool, humid summers and moderate winters.

The moderating influence of the marine air is reflected in the average annual temperature, which is 58°F in the vicinity of the strait, but is 61 degrees or more in the somewhat protected northern parts of the county. The differences are most pronounced in mid-summer. The July average maximum is about 80 degrees in the San Pablo Bay area, but it reaches 96 degrees or more in the Lake Solano-Winters area. Average minimums are more uniform, ranging from 55 degrees in the south to 58 degrees in the northwest. In January, the average maximum temperature is about 53 degrees and the average minimum is about 38 degrees near the water and 36 degrees inland. Mean monthly temperatures recorded at Mare Island are presented in Figure 3-10.

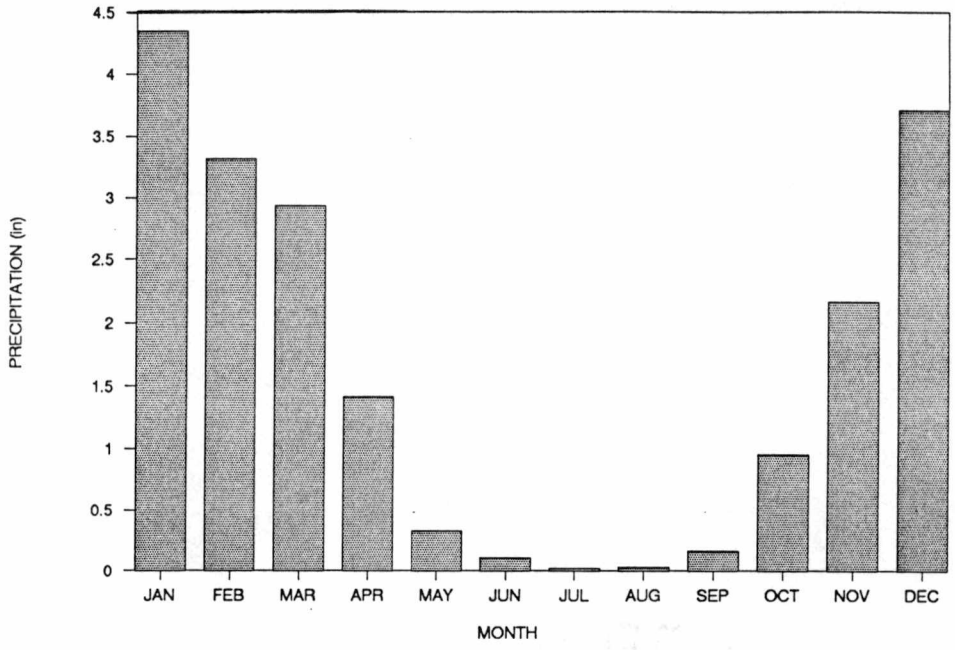
3.3.4.1 Precipitation

Average annual precipitation ranges from 16 inches in some of the southern portions of the county to as much as 30 inches at the top of the Vaca Mountains. Rainfall as measured on Mare Island averages 17.41 inches per year (Ecology & Environment, 1983). Mean monthly precipitation recorded at Mare Island is presented in Figure 3-11. Approximately 17 to 20 inches per year falls on the eastern half of the county. In the driest years (about 1 year in 20), the annual total precipitation is as little as 9 inches in the southeast and 18 inches in the mountains. In the wettest years, 25 to 50 inches of rain falls in the same areas.



PERIOD OF RECORD: 1947-1982
SOURCE: U.S. DEPARTMENT OF COMMERCE, 1984

Figure 3-10. Mean Temperature and Humidity



YEARLY RAINFALL DISTRIBUTION

40 YEAR AVERAGE

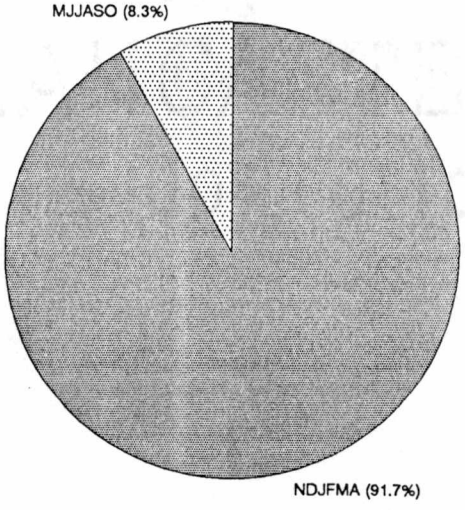


Figure 3-11. Precipitation Data - Mare Island Area

Measurable precipitation falls on 50 to 60 days per year. Approximately 95 percent of the total precipitation falls in October through April.

Sunshine averages about 3,000 hours per year. It varies from 50 percent of the time in January to 75 percent of the time in July. Energy received from the sun averages about 150 langleys per day in January and about 660 langleys per day in July. Snow commonly does not fall on the lowlands. Snow falls at the higher elevations every 2 or 3 years, but it generally lasts only a few hours to a few days. The last day of freezing temperatures in the spring ranges from February 1 in the San Pablo Bay area and at Mare Island to March 10 in the interior. The first day of freezing temperatures in fall ranges from November 20 to December 20. Therefore, the growing season is 240 to 300 days.

3.3.4.2 Humidity, Evaporation, and Soil Temperature

The relative humidity averages about 90 percent at night and near 70 percent in the afternoon in winter. When the humidity is near 100 percent, periods of fog occur and last several days to 2 weeks or more. In July, the relative humidity averages close to 75 percent early in the morning and drops to 55 percent in the afternoon with the influx of marine air, and to about 35 percent in the drier interior. Some dry north winds cause the humidity to drop below 10 percent.

Annual evaporation from ponds or lakes averages 47 to 53 inches, the greater evaporation occurring in inland areas. Approximately 70 percent of the water evaporates during the period of May to October. The

potential evapotranspiration, computed by the Thornthwaite Method, totals 29 inches near Mare Island and about 34 inches near the town of Winters, California. Using a figure of 4 inches as representative of the available moisture stored in the root zone, a computed value of evapotranspiration, as limited by natural precipitation, totals 11 to 13 inches.

Soil temperature recorded at Davis, at a depth of 4 inches, averages 45 degrees in January and 88 degrees in July. The average daily range is 6 degrees in winter and 19 degrees in summer. The annual soil temperature extremes are 30 and 107 degrees, respectively.

4.0 INVESTIGATIVE DESIGN

This study represents research which was conducted in laboratory and field settings. At the heart of this effort is the hypothesis that the HEC-6 model could be used to accurately predict contaminated sediment yield in a shallow flow situation within a small urban watershed. The modeling was performed on IBM-compatible microcomputers. Realistic estimations for runoff volumes that could be anticipated at the study site were simulated on a microcomputer using the HEC-1 model. A detailed discussion of modeling efforts and assumptions is presented in Section 5.0. Field and laboratory tests were performed in support of model input parameter characterization, environmental impact analysis, and model verification. The experimental design, test methods, and analytical procedures for field and laboratory work are described in this chapter. Field verification of the model, techniques employed, and results generated are presented in Section 6.5.

Field investigations at the 900 Area were focused in two categories. The first category considered was chemical analysis of soils, estuarine sediments, and ground water. The second area considered was greensand distribution, local watershed delineation, sediment runoff, and topographic surveying of the site. Chemical analysis of target compounds commonly found in spent abrasives was performed for the purpose of evaluating adverse effects on human health and the environment.

To properly evaluate the long-term impact of the spent abrasives on the estuary, the hydrodynamics of the primary residual transport mechanism (e.g., surface water runoff) must be addressed. Because greensand operations continue, the importance of understanding the volumetric rate at which the abrasives reach the island shore is the paramount issue in the study. The question of whether or not sandblasting presents a potential harm to the environment is exclusively a function of transport rates and chemical concentrations in the runoff stream.

Initial chemical sampling was performed during the month of June 1988. Greensand distribution and watershed delineation data were initially gathered in May and verified, noting any changes during September 1988. Land surveying to determine the slopes and topographic breaks in watershed plots and channels was also accomplished during September. Preliminary setup for on-site sediment runoff tests execution was accomplished between October 1988 and June 1989.

4.1 FIELD CHEMICAL SAMPLING PROGRAM

To maximize sampling at the higher concentration areas and yet define possible concentrations at outlying regions, soil samples were collected in a progressive geometric grid pattern. The most vulnerable area can be determined by review of the runoff pattern from the site. The highest concentrations of spent greensand were observed along the shoreline where bed load transport ceased. It was recognized that tidal action, dispersion of runoff, and local regrading activities promoted additional lateral deposition of spent greensand along this front. To account for

this condition, a sampling grid that addresses these phenomena was developed. If sampling results showed unusual metals concentrations, intermediate sampling points could have been established to confirm trends or outliers.

The sampling grid shown in Figure 4-1 was established on 25-foot centers within the core area. This area was defined by visual observation of spent greensand and lithologic log review from a previous study (SCS Engineers, 1987). The grid began just beyond the edge of the asphalt pavement and continued to a point that allowed two lines of sampling past the average low tide in the strait. Sampling locations were progressively widened in peripheral areas from 25- to 50-, 75-, and finally 100-foot centers. This type of coverage allowed for inclusion of runoff of new greensand mapped from Building 215 to the shore as well. Sixty-three sampling locations were surveyed at the site. In addition, one background location west of Building 900 and one ground water sampling point near the Area 1288 blasting fence were installed.

Shallow borings were advanced to depths of either 3, 4, or 7 feet. Seven of the 63 borings were drilled to a depth of 7 feet. All others were advanced to 4 feet. The rationale for depth selection was twofold. Upon review of data collected by SCS Engineers (1987), the maximum discernable depth of elevated chromium in the core area appeared to be 2 feet. Therefore, it was decided to sample to two times the maximum observed depth. A representative of the CRWQCB (Hoose, 1988) interpreted some of the SCS (1987) lithologic descriptions to be greensand at depths below 4

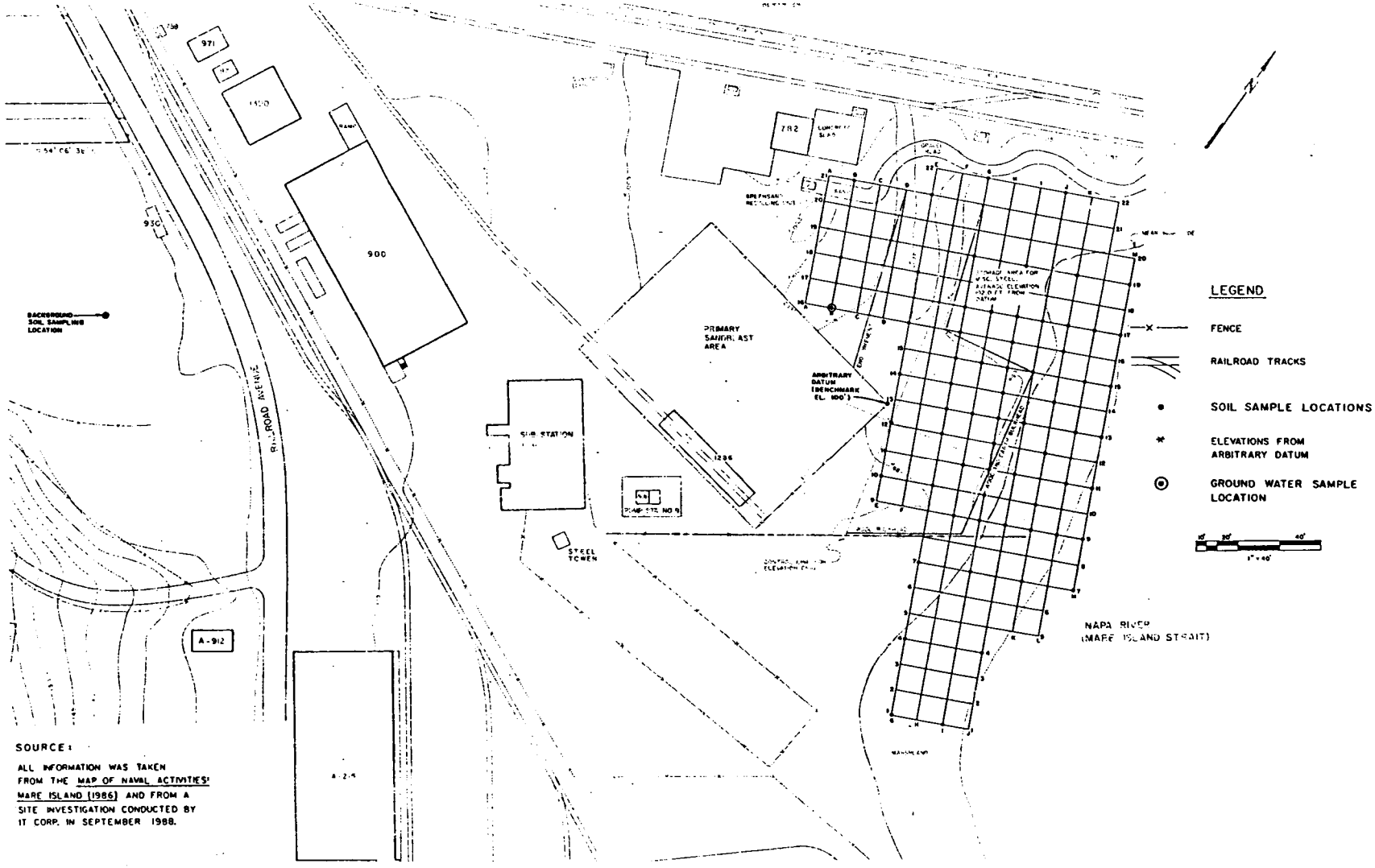


Figure 4-1. 900 Area Sediment Sampling Grid

feet. Therefore, select borings were drilled deeper to confirm this interpretation. In peripheral areas, borings were advanced 3 feet. Deposition in these areas would logically be the result of runoff, dispersion, and tidal action, all of which would result in surficial deposition. Samples drawn from the 3- and 4-foot borings were recovered on 1-foot centers (e.g., 0.5, 1.5, 2.5, and 3.5 feet as appropriate). Sampling interval center points for the 7-foot borings were 1.0, 3.0, 4.5, and 6.5 feet, respectively.

Soil borings were advanced by hand methods on the beach front and in the sediments of the strait. Borings to depths below 4 feet or through dense materials were advanced using a drilling rig equipped with split spoon sampling tubes. Both split spoon samples and hand cores retrieved 2-inch diameter by 6-inch long sample cores. Recovery of sampled material exceeded 80 percent for all samples. Samples were extruded from the sample tubes in the field and were placed in glass jars, sealed with Teflon™-lined lids, labeled, and shipped in Igloo coolers to the analytical laboratory. Meticulous care was given to properly logging each boring. Information documented for each sample included: sample number, date taken, borehole number, sampling interval, weather, field technician, time taken, and lithologic description.

Ground water beneath the 900 Area is a reflection of the Mare Island Strait and, as such, fluctuates with the tides. One temporary drive point was installed at the location shown in Figure 4-1 for the purpose of correlating soluble chemical fraction analysis in sediments with

typical site matrix ground water. A 2-inch diameter stainless steel well point was emplaced in a hole drilled by the on-site drilling rig. The well point was driven to a depth of approximately 8 feet to intercept the uppermost saturated zone. Before sampling, a volume of water equal to five times the submerged well volume was purged from the well point. The well point was allowed to recover to the natural piezometric surface elevation and then sampled. A sample was collected using a Teflon bailer and carefully transferred into glass bottles. The sample bottle cap was lined with Teflon tape, oversealed with duct tape, labeled, and shipped to the laboratory in a cooled ice chest.

Upon completion of the field sampling, lithologic data were reviewed to determine apparent areal and spatial distribution of greensand or greensand by-products. Soils were mapped as black/brown or green/brown, which suggests the presence of greensand. Isopack maps of the upper 2 feet of soil are given in Figures 4-2 and 4-3. Locations may be referenced to Figure 4-1 by use of selected grid marks. From these isopack maps and from similar ones for depths between 3 and 7 feet, it was determined that the spent greensand were present, residing in the upper 2 feet of soil or sediment. On this basis, all samples collected in the upper 2 feet were selected for analysis in the laboratory. The remaining samples would remain in the laboratory archives in case further testing was required.

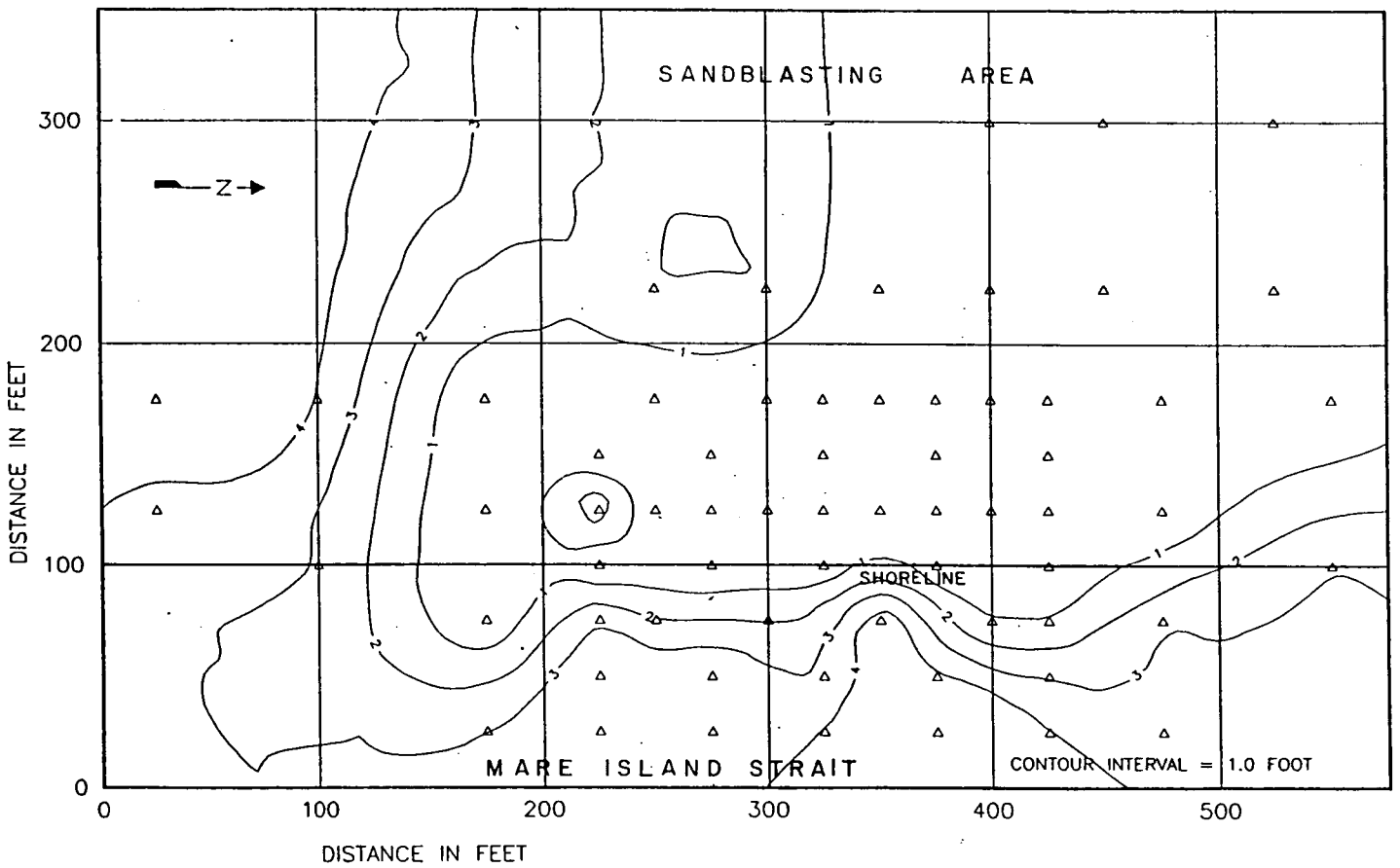


Figure 4-2. Apparent Thickness of Brown-Black/Black Soils

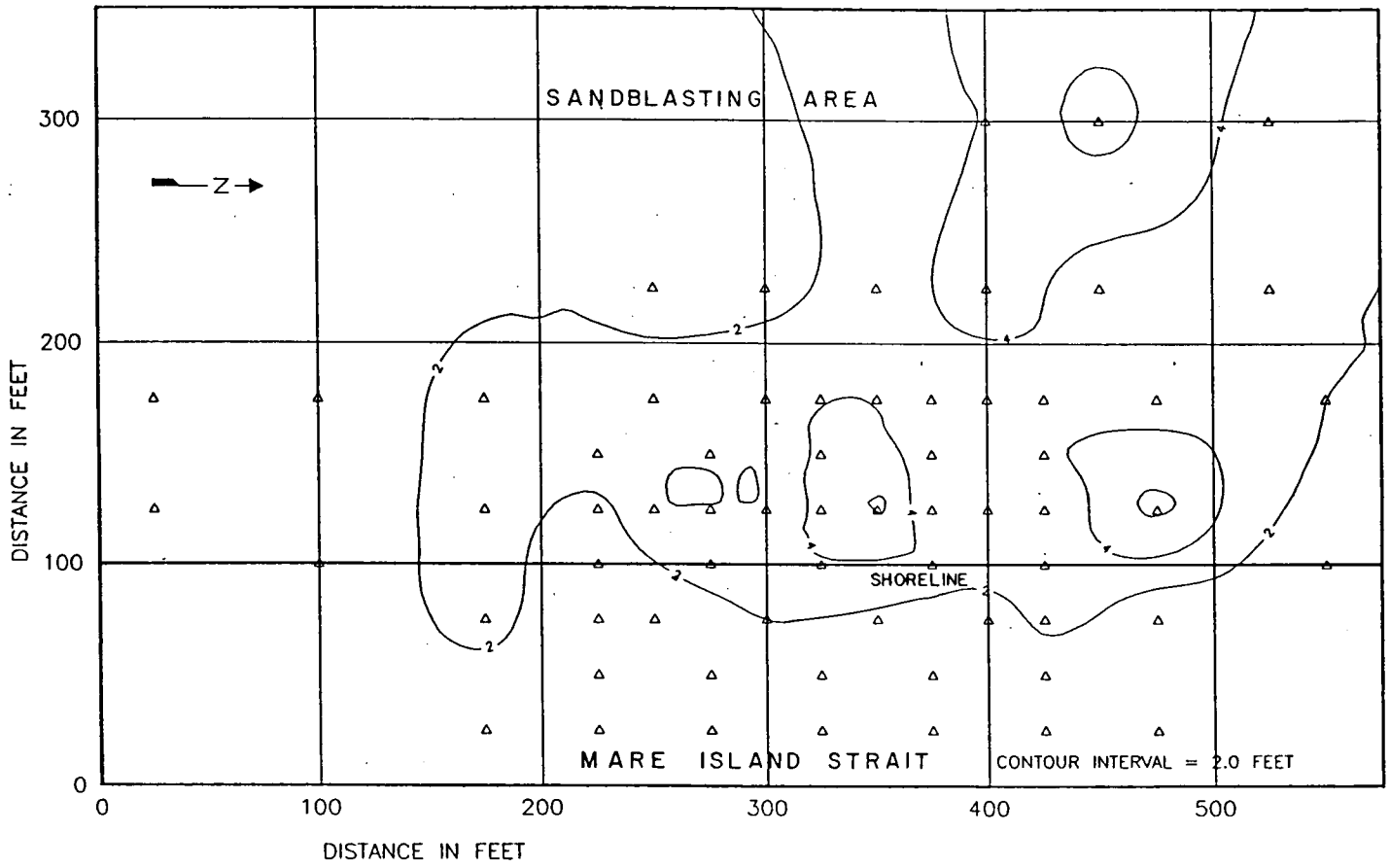


Figure 4-3. Apparent Thickness of Gray/Green Soils

4.2 FIELD HYDROLOGIC INVESTIGATION

Three on-site tasks were completed in conjunction with the original chemical sampling and analysis program. These tasks included:

- Delineation of local watersheds and surface drainage ways
- Mapping of greensand distribution
- Topographic surveying to outline runoff slopes.

To have a basic understanding of how fugitive greensand is transported into the strait, the hydraulics and hydrology of the carrier mechanism, water, must be known. During May 1988, the boundaries of watersheds contributing directly to the 900 Area and neighboring Building 215 area were mapped. The magnitude of surface slopes and man-made and natural diversion features were noted and logged on a U.S. Geological Survey 15-minute topographic map. The preliminary field mapping was confirmed in September 1988 when the area was surveyed using a transit. Three subbasins were identified. The uppermost reach (Subbasin 2) begins at the top of the sandstone hill behind Building 900 and empties into a small channel north of Building 215 as shown in Figure 4-4. A second watershed drains primarily the asphalt paved area around Building 900 and empties onto the sampling grid. It is this subbasin which is modeled in the present study. The third subbasin drains Building 215 and vicinity where the unused greensand is stored. Approximately two-thirds of this basin empties into the 1288 drainage channel. The remainder flows overland into the strait.

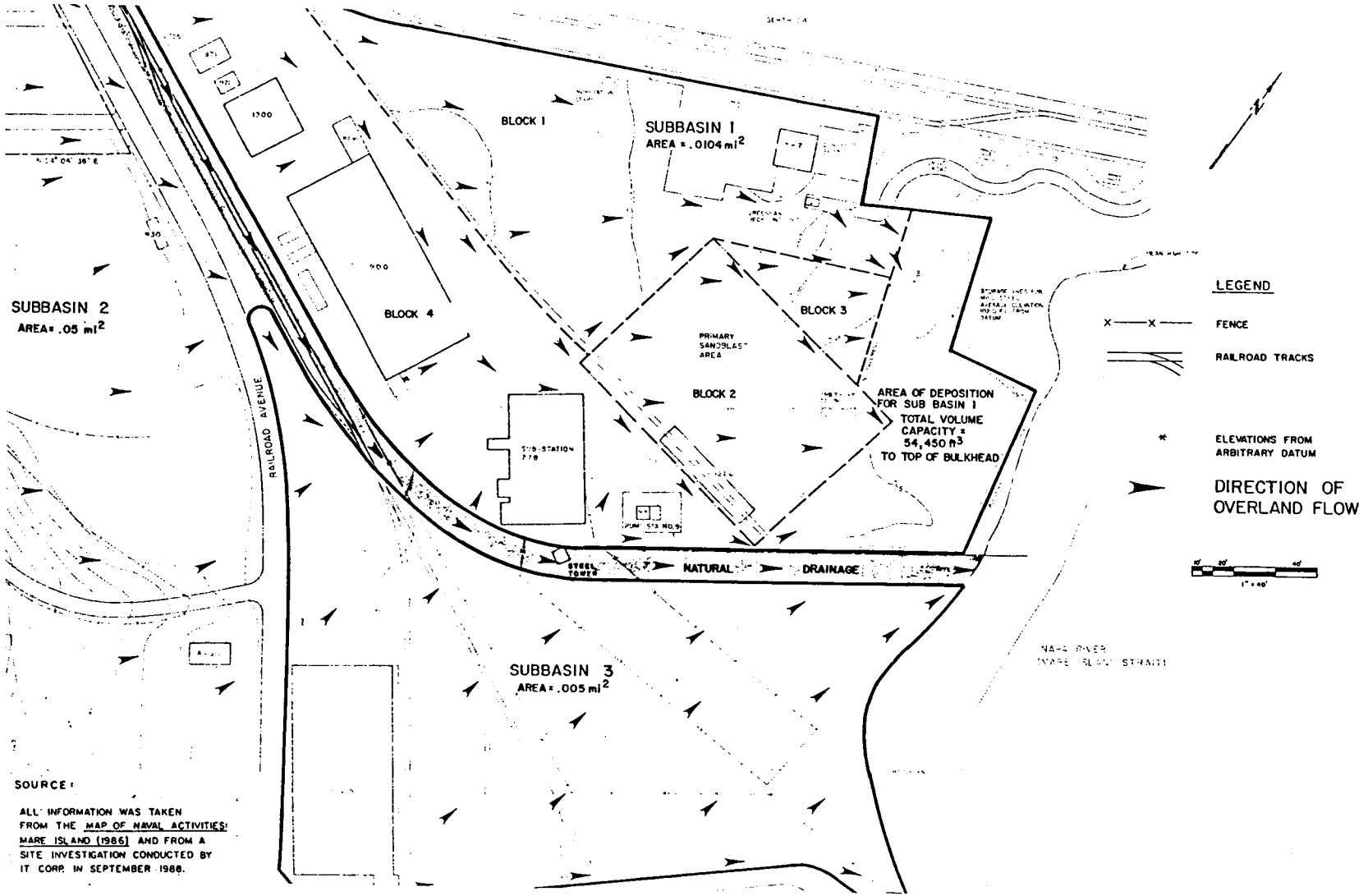


Figure 4-4. 900 Area Subbasin Runoff Patterns

Surface elevations from random locations throughout the three watersheds were surveyed using a Wild Inc. transit. A total of 11 points were shot in Subbasin 2, 14 points in Subbasin 3, and 27 locations in Subbasin 1. Subbasin 1 was determined to be the most critical because it supplies all the runoff, which carries greensand to the sampling grid area. Results of the topographic survey are depicted in Figure 4-1. Elevations in Subbasins 1 and 3 were established using an arbitrary datum with a corner of the 1288 fence designated elevation 100.

Blasting operations continue both inside and outside the 1288 fenced area. As such, a continuing source of new spent greensand is always available. The distribution and depths of both spent and new greensand present in watershed Subbasins 1 and 3 were visually mapped. On the order of 50 to 75 tons of new greensand was found on the ground surface in Subbasin 3, and some 220 tons of spent greensand is present in Subbasin 2. The distribution of greensand outlined in Figure 4-5 was incorporated into sediment transport estimates discussed in Section 5.0. The depth of greensand ranged from less than 0.1 inch to more than 18 inches in piles around Subbasin 3. Most of the greensand appeared to be retarded in the upper reaches of the beach vegetation rather than on the shores of the strait.

4.3 LABORATORY ANALYSES AND PROCEDURES

Five metals were chosen to define the distribution of spent greensand and environmental impacts that the material exhibits. The compounds tested included: copper, zinc, lead, total chromium, and nickel. Tests

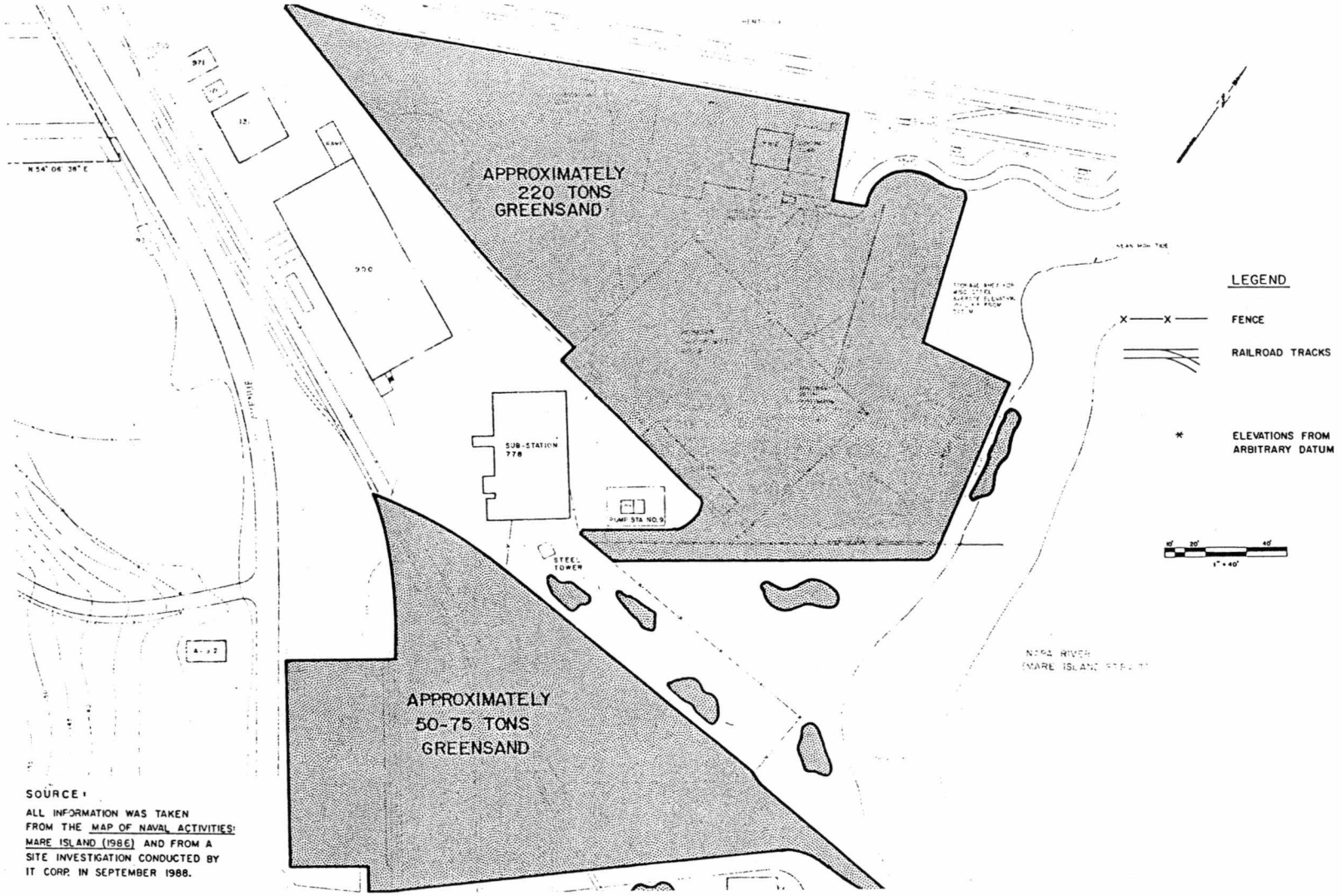


Figure 4-5. 900 Area Greensand Distribution

performed by the Navy and by SCS Engineers (1987) suggested that these five metals, which are major components of abrasives and paint, may produce leachate above state and federal water and wetlands statutes. Laboratory analysis performed by the Navy of both spent and virgin greensand is listed in Table 4-1. Data given in Table 4-1 were obtained from NSY Mare Island, Public Works Office.

As previously stated, all soil samples in the uppermost 2 feet were selected for analysis of total target metals. Once total content data were received, selected samples were analyzed for soluble metals using the California Waste Extraction Test (WET) method. Two criteria were used to determine which samples would be analyzed for soluble metals: (1) the concentration of a given total metal exceeded 10 times the California soluble threshold limit concentration (STLC) value for that chemical or (2) if numerous samples met criterion 1, only sufficient samples would be tested to provide a statistically valid test. Criterion 2 was used for lead where all samples above 75 mg/kg were extracted and analyzed.

Laboratory procedures used for determination of total and soluble metals in soils and ground water were fully consistent with standard methods established by EPA and/or the California Department of Health Services (DHS). Total metals content was performed using methods described in "Test Methods for Evaluating Solid Wastes," SW-846, 3rd edition, Volume 1A, (U.S. EPA, 1986). Methods used for the five metals were:

Table 4-1. Metals Composition in Virgin and Spent Greensand

Chemical	Virgin Abrasive (mg/kg)	Spent Abrasive (mg/kg)
Ag	<0.025	<0.292
As	<6.008	<7.778
Ba	<0.751	<0.972
Be	<0.751	<0.972
Cd	<0.451	<0.583
Co	2.854	4.278
Cr	118.137	131.454
Cu	3.380	4.278
Fe	4881.71	5065.62
Hg	<1.502	<1.945
Mn	64.288	57.365
Mo	<0.751	4.278
Ni	453.023	693.243
Pb	<1.502	<1.945
Sb	<1.502	<1.945
Se	<58.581	<75.839
Sn	<1.502	<1.945
Tl	<3.004	<3.889
V	<0.751	<0.972
Zn	4.281	4.375

- Method 7420: Lead, atomic absorption (AA), direct aspiration
- Method 7190: Total chromium, AA, direct aspiration
- Method 7210: Copper, AA, direct aspiration
- Method 7950: Zinc, AA, direct aspiration
- Method 7520: Nickel, AA, direct aspiration.

Metals in solution may be readily determined by AA spectroscopy. The method is simple, rapid, and applicable to a large number of metals in water and solids after proper digestion. In direct aspiration AA spectroscopy, a sample is aspirated and atomized in a flame. A light beam from a hollow cathode lamp or an electrodeless discharge lamp is directed through the flame into a monochromator, and onto a detector that measures the amount of adsorbed light. Absorption depends upon the presence of free, unexcited ground-state atoms in the metal being determined; the light energy adsorbed by the flame is a measure of the concentration of that metal in the sample.

The single ground water sample collected was also analyzed using AA spectroscopy with direct aspiration. The specific procedures followed are found in "Methods for Chemical Analysis of Water and Wastes" (U.S. EPA, 1983). Specific procedures are:

- Lead: Method 239.1
- Chromium: Method 218.1
- Copper: Method 220.1
- Zinc: Method 289.1
- Nickel: Method 249.1.

For determination of soluble metals content, all samples selected were extracted by the California WET. The extracts were analyzed for copper,

lead, nickel, and zinc using inductively coupled argon plasma spectroscopy according to EPA Method 6010.

All metals analyses were performed at IT's Cerritos laboratory in Cerritos, California. This laboratory participates in the EPA Contract Laboratory Program (CLP) and is certified for metals analysis by DHS.

4.4 MASS FRACTION AND ELEMENTAL ANALYSIS OF FINE SOILS

Because of the important role of particle size plays in sediment transport, an effort to quantify the grain size distribution and mass fraction of fine soils and paint flakes, a technique similar to spectral analysis of clays was performed. Five types of material classes were identified at the site: (1) virgin greensand, (2) spent greensand, (3) surface soils at the edge of the asphalt, (4) mixed greensand and soils at the bulkhead line, and (5) estuarine sediments at the edge of Mare Island Strait. In an effort to retard runoff on the beach front, the U.S. Navy placed railroad ties across a limited portion of the deposition zone. The railroad ties have generally been referenced as the bulkhead line. Computer-controlled scanning electron microscopy (CCSEM) was the analytical technique employed to provide the desired particle information.

Each sample consisted of soil material contained in 1-gallon plastic jars. After the samples were received at the laboratory they were logged in and prepared for CCSEM analysis. The samples were identified in the following manner:

Laboratory Sample Number	Study Sample Identification	Description
26657	Site 1 Surface	Virgin greensand
26658	Site 2 Surface	Spent greensand
26659	Site 3 Surface	Upper grid soils
26660	Site 4 Surface	Mixed greensand soils at bulkhead line
26661	Site 5 Surface	Estuarine sediments below bulkhead line at edge of Mare Island Strait

4.4.1 Sample Preparation

The as received samples consisted of an earth crystal material which ranged in size from fine particulates to rocks [greater than 2 centimeters (cm)]. Because the objective of this study was to analyze the smaller-size fraction of the material using CCSEM, it was necessary to separate this from the larger pieces.

First, moisture was evaporated from the samples by exposing them to heat lamps for several hours. Once the material was dried, it was sieved through various mesh screens to separate the different size fractions. The first mesh served to separate all particles larger than 1/4 inch in diameter from the rest of the material. The material was sieved further

down in size until only particles less than 200 mm remained. This size fraction was then subject to a 400-mesh screening which selected out all particles greater than approximately 50 mm.

After the fine particulate matter was separated for each sample, it could be prepared for the CCSEM analyses. To meet sample preparation requirements for CCSEM, the samples had to be redeposited onto polycarbonate filters. Redeposition involves the removal of a portion of material from the samples, suspension of the particle in a suitable carrier liquid, and subsequent filtering of the carrier liquid using the polycarbonate filter media.

After deposition, each filter was mounted on a CCSEM stud. This mounting was accomplished by removing a 1.5-cm square section of the Nuclepore™ filter and placing the section face up on a polished carbon planchette CCSEM stub. The sample stubs were coated with a thin layer of carbon by evaporative deposition under vacuum. The carbon coating was necessary for conduction of the electrical charge induced by the electron beam of the CCSEM. (The carbon coating does not interfere with the analysis.) After carbon coating, the sample stub was placed in a desiccator until ready to be analyzed.

4.4.2 Soil Sample Analysis Method

The instrumentation used in this study consisted of JEOL JSM-840 CCSEM with a Tracor Northern TN5500 quantitative energy dispersion x-ray analyzer and digital beam controls. The CCSEM system incorporates a

computer-interfaced digital beam control system and a software-based x-ray microanalysis system. Image analysis by this system involves binary coding of the sample image by use of an analog comparator to define a threshold signal level. Picture points with signals above the threshold level were considered on points (points on a particle). All other points are considered off points ignored.

The electron beam of the CCSEM was moved in a stepping motion along a grid network by a digital scan generator (DSG). The dual grid (picture point) density was used to separate the analysis into search and analyze modes. If the signal was below the threshold value, the computer directed the beam to a new (x,y) coordinate. This process was repeated until a particle was located. A low point density was used until the status of the analog comparator indicated the beam was on a particle. The computer program then switched to a subroutine that increased the picture point density and drove the beam in a preset pattern to determine the dimensions and shape of the particle. The sizing pattern consisted of four pairs of rotated diagonals; each diagonal was terminated when the signal fell below the threshold value. This pattern was repeated twice, once to locate the centroid of the feature and once to determine the lengths of the diagonals through the centroid. The maximum, minimum, and average diagonals along with the coordinates of the centroid of the particle were stored. The coordinates of the centroids of the particles were used to prevent counting the particle more than once. Next, a minicomputer positioned the beam at the centroid of the particle and directed the CCSEM system to initiate x-ray analysis of the particle.

Nineteen elements were simultaneously analyzed with the CCSEM system used in this study. The elements included were: carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, and copper. The relative intensities of these elements in the x-ray spectrum were calculated and used by the software-based analyzer to assign each particle to a particle-type category (e.g. silicon-rich, mix-clay, silicon-calcium, etc.). Because these classifications are descriptors of elemental composition, they do not imply positive identification of a specific chemical compound.

4.5 SEDIMENT PARTICLE - PAINT ASSOCIATION TESTING

Early on in the analysis of metals, it was recognized that the relationship between abrasives and paint flakes was key in evaluating environmental impacts. The mechanism by which abrasives and paint are transported onto the waterfront will determine the partitioning of metals with soils and water.

To evaluate if paint flakes are physically attached to the sediment surface, loosely intermixed with sediments, or chemically bound from the heat generated by impaction to sediments, a benchtop test was designed. Two primary variables were chosen, pH adjustment and agitation velocity. The target metals will precipitate at pH levels below 3. Hence a pH of 2 was chosen to effect precipitation of paint flakes from abrasives. A neutral pH of 7 provided a control. To understand the

physical nature of paint and abrasives, solid samples in solution were subjected to quiet stirring and vigorous agitation. It is theorized that paint flakes merely associated with the solid matrix would go into solution without much agitation, but physically impacted flakes would require vigorous shaking to break loose and move into solution.

Select samples were taken from five different regimes in the sampling network:

- Virgin greensand
- Spent greensand near the blasting area
- Soils at the edge of the asphalt pavement
- Soils at the bulkhead
- Soils near the edge of Mare Island Strait.

Each location (except the first one) represents a separate dynamic setting for sediment deposition.

4.5.1 Experimental Design

The five 1-gallon samples were taken at Mare Island on December 19, 1988 and received at the laboratory on December 20, 1988. The samples, in clear plastic 1-gallon containers, were refrigerated upon receipt. A general description of the samples is provided in Table 4-2.

The samples from Sites 3 and 4 were each transferred to clean 2-gallon plastic pails with snap-on covers. The pails were rolled to mix the samples. The samples from Sites 1, 2, and 5 were sufficiently uniform to allow sample aliquot withdrawal from the center of the original clear containers.

Table 4-2. Greensand Sample Description

Grid Location	Sample Number	Site ID	Description
	GG0296	1	Clean greensand, gray in appearance, dusty, uniform
	GG0297	2	Damp greensand, green in appearance, uniform
	GG0298	3	Greensand mixed with soil; some gravel, twigs, grass; not uniform
	GG0299	4	Similar to Site 3, less gravel, mostly dirt, not uniform
	GG0300	5	Similar to Site 2; some dirt, a few twigs, no gravel; fairly uniform

The initial samples were characterized for percent moisture and metals concentration. One hundred grams of each sample was dried in a tared porcelain dish at 100°C for 12 hours, cooled, and reweighed. Percent moisture was calculated as the percentage of weight lost on drying.

Following SW-846 (3rd edition) Method 3050, a 2-gram sample from each site was refluxed with 18 milliliters (ml) of 1:1 70 percent HNO_3, treated with 30 percent H_2O_2, further refluxed with 5 ml of 37 percent HCl, and diluted to 100 ml in volumetric flasks. Triplicate Site 2 samples were digested. A fourth Site 2 sample was spiked with known amounts of copper, zinc, chromium, nickel, and lead. Additionally, a preparation blank (2 ml of deionized water) was digested and analyzed to check for contaminants. The digested 100-ml samples were allowed to settle for 24 hours before aliquots were pipetted out for analysis on an AA analyzer. The AA technique used direct aspiration into an acetylene-air flame and followed SW-846 methods with the exception that no analysis was done with a background correction deuterium lamp.

Fifty grams of each original sample was weighed into a 250-ml flask and 100 ml of deionized water was added. Four flasks were generated for each site sample except for Site 2, which was done in triplicate (12 flasks). Two flasks containing each original sample were adjusted to pH 2, using 1N HCl, and the remaining two flasks were adjusted to pH 7, using 1N HCl. No sample received more than 3 ml of 1N HCl. The stoppered pH 2 samples were agitated as two sets in the gyratory shaker with one set at a low agitation speed (4.5 on dial) and the other set at

a considerably higher speed (8.0 on dial). The pH 7 samples (two sets) were similarly agitated. Each set of samples was agitated for 20 minutes, at which time the shaker was stopped and two "supernatant" samples were quickly taken. Shaking was resumed for 1 minute, and two more samples were taken. This was repeated until all seven flasks in the set had been sampled. Supernatant samples were taken using 10-ml syringes fitted with a plastic snap clamp on the syringe body and set so that each supernatant sample was taken from the same depth and position (center) in each flask. The supernatant samples were transferred to 20-ml scintillation vials. Each vial was labeled with the site number, pH, and agitation speed. For example, a supernatant sample from the flask containing a Site 3 sample at pH 2 and agitated at high speed was labeled "3PH2HI." The triplicate Site 2 samples were labeled as 2A, 2B, and 2C.

Each supernatant sample was shaken to suspend any settled fines. Two ml of sample was pipetted into an all Teflon Parr 43-ml microwave digestion bomb (Model No. 4782) with 8 ml of 70 percent HNO_3 and microwaved for 90 seconds at full power (nameplate rated at 900 watts). After heating, the Teflon bomb and its container required cooling in an ice water bath for 10 minutes before the sample could be removed. The bomb interior and cap was rinsed and the rinses added to the digested sample.

A quality assurance/quality control (QA/QC) blank (2 ml deionized water) was also microwaved and treated as a sample. The microwaved samples were individually filtered through 0.45-micron syringe filters before analysis by AA.

The resulting filtrate was analyzed by AA. For any particular metal, all of the blanks, original samples, and supernatant samples were analyzed during one AA session.

4.5.2 Quality Assurance/Quality Control Protocols and Results

Two experimental/preparation blanks were analyzed. A blank was digested with the total metals (original samples) and is denoted as "Blank-T". The other blank was inserted before the microwave digestion of the supernatants and is denoted as "Blank D." The results of these blanks are shown in Table 4-3.

The sample from Site 2 was digested in triplicate for total metals. The results are shown in Table 4-4. The Site 2 sample was homogeneous for zinc, chromium, and lead. The nonhomogeneity of the sample for Ni and Cu may be caused by the source of the greensand nickel/copper foundry sand. Any modeling effort should be aware of and consider this potential source of "outlier" data for nickel and copper results. The sample from Site 2 was treated in triplicate for the shaker tests at both pH levels and both shaker speeds (see Table 4-5). These data provide an indication of the site-sample homogeneity and of variations resulting from the flask sampling and microwave digestion procedures.

A Site 2 sample for total metals was spiked with known amounts of the metals of interest before digestion. The spike levels were desired to be

Table 4-3. Experimental and Analytical Blanks

	Metals (mg/l)				
	Nickel	Zinc	Copper	Chromium	Lead
Blank-T	0.01	0.03	0.02	0.011	0.025
Blank D	<0.11	0.27	<0.12	<0.11	<0.25

Table 4-4. Replicate Analyses of Site 2 Sample

Sample Identification	Total Metals (mg/kg dry sample)				
	Nickel	Zinc	Copper	Chromium	Lead
2A	3258	332	169	1917	168
2B	1557	344	173	1995	158
2C	1899	349	381	1976	161
Mean	2238	342	241	1963	162
Percent RSD[a]	40	2.6	50	2.1	3.2

[a]Relative standard deviation ÷ mean X 100 percent.

Table 4-5. Site 2 Experimental Runs

Sample Identification	Metals in Supernatant (mg/l)				
	Nickel	Zinc	Copper	Chromium	Lead
APH7LO	3.52	10.26	6.56	3.98	5.28
BPH7LO	3.71	10.93	7.51	4.15	4.55
CPH7LO	3.31	9.70	6.93	3.86	5.05
Mean	3.51	10.3	7.00	4.00	4.96
Percent RSD[a]	5.7	6.0	6.8	3.6	7.5
APH7HI	9.50	42.06	19.95	15.62	14.79
BPH7HI	11.30	45.13	22.99	18.16	15.85
CPH7HI	8.90	38.66	20.35	13.01	12.21
7 Mean	9.90	41.95	21.10	15.60	14.28
Percent RSD	12.6	7.7	7.8	16.5	13.1
APH2LO	2.88	10.36	6.04	3.95	5.28
BPH2LO	3.74	8.36	5.27	3.18	3.76
CPH2LO	2.91	7.94	3.77	2.14	13.1
Mean	3.18	8.89	5.03	3.09	4.19
Percent RSD	15.4	14.5	23.0	29.4	22.8
APH2HI	9.86	40.11	19.29	16.20	12.80
BPH2HI	11.21	41.82	20.63	18.67	13.85
CPH2HI	10.66	46.68	21.27	17.87	15.03
Mean	10.58	42.87	20.40	17.58	13.89
Percent RSD	6.4	7.9	4.9	7.2	8.0

[a]Relative standard deviation ÷ mean X 100 percent.

near 50 to 150 percent of the estimated metals levels in the unspiked original sample. The recovery of each of the metals is shown in Table 4-6.

Table 4-6. Total Metals Recovery From Spiked Site 2 Sample

	Metals				
	Nickel	Zinc	Copper	Chromium	Lead
Recovery	116%	144%	97.5%	141%	98.7%

5.0 PREDICTIVE MODELING

5.1 RUNOFF MODELING

Numerous models exist for estimating runoff hydrographs and peak flow volumes from various watershed types and sizes. Two methods embodied in a single comprehensive numerical model were chosen for use in this project, based on each method's ability to predict runoff from small and urban watersheds, and a third method was used as a check. Each of the models was applied to the subbasin or subbasins within the 900 Area drainage with which they were most suited. The two primary runoff hydrograph methods chosen are the SCS abstraction/dimensionless unit hydrograph Method and the Kinematic Wave Method. In addition, the simple Rational Method was used to verify and compare peak flows. It is accurate for impervious materials such as asphalt and concrete. The comprehensive U.S. Army Corps of Engineers HEC-1 program was employed to generate the Kinematic Wave and SCS hydrographs. HEC-1 is one of the most widely used models for watershed simulation and flood event analysis. HEC-1 uses parameters averaged in space and time to simulate the runoff process. The size of subbasins, routing reaches, or computation interval is selected based on the basin physiography, rainfall data, streamflow data (if appropriate), and required accuracy. A multicomponent watershed such as the one that describes the 900 Area is subdivided into small and relatively homogeneous subbasins called blocks. A rationale for delineation of subbasins and model applications will be presented in the following discussion.

To determine the potential runoff under different conditions, average meteorological conditions were compiled using storm frequency information from 1947 through 1987 (Table 5-1, Figure 5-1) and isohyetal precipitation charts. These data are found in the Rainfall Frequency Atlas of the United States (U.S. Department of Commerce, 1984) compiled for the Engineering Division of the SCS. The storm distribution type for the study area has also been defined by the SCS as type IA.

Three primary subbasin areas were previously defined in Section 4.0 that require independent modeling. They are:

- Subbasin 1 defines the asphalt area which is further subdivided into four blocks for runoff analysis. Two independent models were developed for this area, the Rational Method and the Kinematic Wave Model.
- Subbasin 2 defines the watershed behind the 900 Area site. This is an area of steep grass-covered slopes. A portion of this area is defined as contributing to runoff through the 900 Area by means of channel flow as shown on the site map (Figure 4-4). The model for this area was developed using the HEC-1 program for the SCS using the dimensionless unit hydrograph method (1972).
- Subbasin 3, located south of the containment area (Figures 4-4 and 4-5), was evaluated using the same models as the Subbasin 2 area. However, to achieve the correct peak flow, both areas must be evaluated separately to allow for peak flow development in the channel as a function of the lag time and the distance between the two subbasins.

These basins represent areas that drain to discrete discharge points which are then simulated as catchments in the HEC-1 model. As such, each basin may be described by a unique flow length and time of concentration. Collectively, total runoff may be estimated for the entire study area.

Table 5-1. Storm Frequency Chart

Duration	Rainfall in Inches for Given Return Period Storms						
	1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR
30-Minutes	0.8	1.0	1.2	1.4	1.6	1.8	2.0
60-Minutes	1.0	1.2	1.4	1.6	1.8	2.2	2.5
2-Hour	1.4	1.6	2.0	2.5	2.8	3.0	3.2
3-Hour	1.8	2.0	2.5	3.0	3.0	3.5	4.0
6-Hour	2.5	3.0	3.5	4.0	4.0	5.0	5.5
12-Hour	3.0	3.5	4.0	5.0	6.0	6.5	8.0
24-Hour	4.0	6.0	6.5	6.5	7.0	8.0	8.0

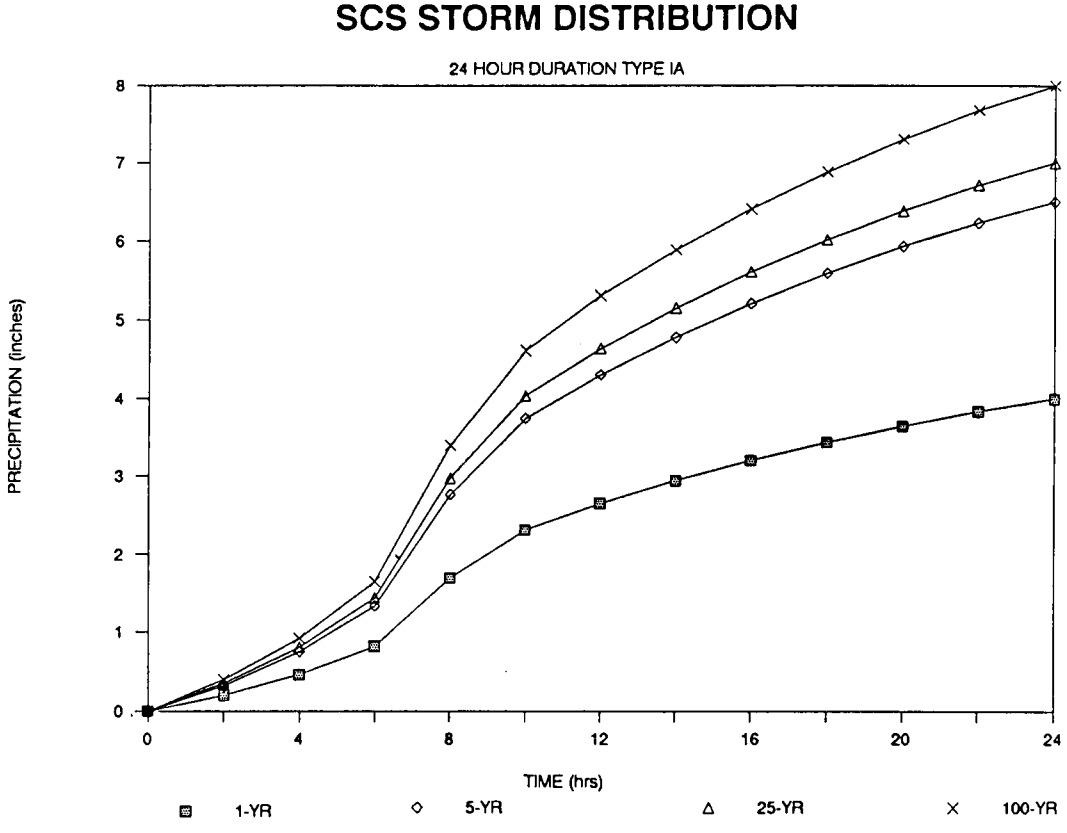


Figure 5-1. Storm Frequency - Precipitation/Duration

5.1.1 Rational Method

One of the simplest peak flow formulas is called the Rational Method, which allows for the prediction of peak flow (Qp) (in cfs) from:

$$Qp = CIA \tag{23}$$

where:

C = runoff coefficient; variable with land use
I = intensity of rainfall of chosen frequency for a duration, equal to time of concentration (inch/hour)
A = area of watershed (acres).

The concept behind the method lies in the assumption that a steady, uniform rainfall rate will produce maximum runoff when all parts of a watershed are contributing to outflow, a condition that is met on impervious areas and for $t_R \geq t_c$ after the time of concentration has elapsed.

The assumptions that are applicable to the Rational Method apply to this site, i.e., uniform intensity for the area, duration is $\geq t_c$, and small draining areas. The Rational method was used for Subbasin 1 to determine the peak runoff for an assumed storm frequency. A rainfall rate of 1 inch/hour was selected as a unit value to model runoff from the asphalt area because the Rational method assumes a linear increase in runoff with a corresponding increase in rainfall. This will facilitate analysis of the impact on runoff from any return-period storm on sediment transport in the Subbasin 1 area. This will also allow comparison with any return-period storm with the SCS unit hydrograph or Kinematic Wave models by

interpolation. For a given storm that exceeds the infiltration capacity of the asphalt, the surface runoff would eventually reach a rate equal to the rate of rainfall. The time required to reach this equilibrium is the time of concentration. From the law of mass conservation, for a small, near-impervious area, one may assume that if rain persists at a uniform rate (steady state) for a period at least as long as the time of concentration, the peak of runoff will equal the product of the runoff and the area because input must equal output given no abstractions. Equation 24 may be rearranged as:

$$Qe = IA_d/43560 \quad (24)$$

$$qe = iL/43560 \text{ (for unit width)} \quad (25)$$

where:

qe = incremental peak runoff rate (ft^3/s)
A_d = basin area (ft^2)
L = distance of overland flow (ft)
I = rain intensity (inch/hour).

Time of concentration for a small basin is equal to the sum of travel times from the uppermost reaches of the basin to the basin outlet and consists of combinations of overland or sheet flow; shallow concentration flow, and open channel flow. The discussion of this is well documented in the literature (U.S. Soil Conservation Services R-55, 1972). Cumulative runoff from the four blocks using the Rational Method was estimated at approximately 5.0 cfs.

5.1.2 HEC-1 Modeling

HEC-1 is a two-dimensional surface water flow model that can simulate runoff from a given watershed, flood routing, dam safety, and flood damage analysis. The model can utilize several types of empirical and theoretical equations for calculating volumetric runoff from an observed storm or from a synthetic storm. As previously mentioned, two methods for runoff calculation were chosen for this study, the SCS method and the kinematic wave method.

HEC-1 is organized into two general types of data records, input control, and river basin simulation data. The input controls diagnostic output and tells the program the format of the river basin data. Input cards are identified by an asterisk in the first column, followed by a command.

River basin simulation cards are identified by two character alphabetic code in the first two columns. The codes have a dual purpose. They identify the data to be read from the record and they also activate simulation options. The sequence of input data cards determines how the river basin will be simulated. There are three general subdivisions of simulation data cards: job control, hydrology/hydraulics, and economics. Economics cards are not used in this study. A list of the job control and hydrology/hydraulics cards is given in Table 5-2. The data model of a river basin can be visualized as a series of building blocks, each beginning with a KK record. The form of the storm distribution is generated on PC cards. Sheet flow conditions in Subbasin

Table 5-2. HEC-1 Input Data Identification

DATA CATEGORY	RECORD IDENTIFICATION	DESCRIPTION OF DATA
JOB	ID	JOB IDENTIFICATION
INITIALIZATION	IT	JOB TIME CONTROL
	IO	GENERAL OUTPUT CONTROLS
	IN	TIME CONTROL FOR INPUT DATA ARRAYS
JOB STEP	KK	STREAM STATION IDENTIFICATION
CONTROL	KM	ALPHANUMERIC MESSAGE RECORD
PRECIPITATION	PB	BASIN AVERAGE TOTAL PRECIPITATION
DATA	PC	CUMMULATIVE PRECIPITATION TIME SERIES
LOSS RATE	LS	SCS CURVE NUMBER
BASIN DATA	BA	BASIN AREA
UNITGRAPH DATA	UK	KINEMATIC OVERLAND
ROUTING DATA	RK	KINEMATIC WAVE CHANNEL
HYDROGRAPH TRANSFORMATION	HC	COMBINE HYDROGRAPHS

Note: Record identification codes are further identified in the following tables

1 are simulated by the kinematic wave equation through the use of UK cards. A description of each card used in hydrologic modeling is shown in Table 5-3.

Subbasins 2 and 3 were modeled collectively using the SCS curve number technique. Subbasin 1, which is the subbasin of greatest interest, was subdivided into five separate blocks to facilitate more accurate sediment transport calculations. The kinematic wave equation was employed on this subbasin. A schematic of the overland flow patterns as modeled by HEC-1 and HEC-6 is shown in Figure 5-2.

5.1.3 Kinematic Wave

The kinematic wave process was adapted from the Massachusetts Institute of Technology catchment model (Harley, 1975). It represents a nonlinear runoff response compared with linear unit hydrograph methods. The Kinematic Wave Model relies on parameters that are generally measurable from a basin, such as slope, land use, lengths, channel shape, roughness, and area. Overland flow, collector, and main channel elements are used to represent the characteristics of a drainage basin.

The kinematic wave assumption is that inertial and pressure effects are unimportant and that the weight or gravity force of fluid is approximately balanced by the resistive forces of bed friction (ie, $S_f=S_o$). The main equations are Manning's equations of flow and continuity:

$$Qc = FcAc^{mc} \quad \text{(flow)} \tag{26}$$

Table 5-3. HEC-1 Input Logic for the 900 Area

RECORD IDENTIFICATION	DATA INPUT FIELD
	ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
*DIAGRAM	This causes a logic diagram of the stream network to be printed Results are presented at the beginning of the output information sheet under the heading SCHEMATIC DIAGRAM OF STREAM NETWORK. The diagram shows how the runoff from specific divisions is routed, combined and presented.
ID	Four identification cards are used for this model. The first three provide information regarding the model type, storm type, and basin characteristics. The fourth field is used as a divider between job ID and other Job control information
IT	This card defines the time control which will be used in the model Field 1: Integer number of minutes in the time step. Fifteen was used to insure that the peak flow was not missed. Field 2: Starting date for the hypothetical storm which can be used to show discharge date relationships. The date the program was run is the date used for this model. Field 3: Starting time of storm with a twenty four hour duration which is used to show time discharge relationships. Field 4: Determines the number of hydrograph ordinates to be computed. At 15 minute intervals 96 points are required to plot the outflow hydrograph A minimum of 120 ordinates were required to show storm discharge as it approached zero.
IO	This card controls output for the entire job. Field 1: Five was used to provide printouts of the job specification and master summary sheets. Field 2: Two was used to provide printouts for all the hydrographs calculated.
IN	This card indicates the time interval for specific data read into the program Field 1: A tabulation interval of 15 minutes was used to match the precipitation input data.
KK	This is a station computation identifier (This job card is used with each task performed). All fields are used to provide a text identification of each station such as Sub A, Sub B, Comb 1, ETC...
KM	All fields are used to provide a text description of the job specified on the above KK card.

Table 5-3. (Continued)

RECORD IDENTIFICATION	DATA INPUT FIELD
	ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
PB	This card is used if the basin average and total storm distribution is known. If no value is entered a default value of "0" ensures that the storm distribution provided on the following PC cards is used.
PC	The cummulative distribution of storm precipitation is provided on these cards. The total precipitation expected for a 25-yr and 100-yr return period storm of 24 hour duration was determined using the TP-40 data for th Marc Island area. A Type 1A distribution was used to determine and input the 96 values required.
LS	This card was used to input information on each basin regarding the SCS CURVE NUMBER LOSS RATES. Field 1: A value of zero was used so that initial abstraction would be computed as a function of the curve numbers. Field 2: The SCS Curve Number value of 98 was used to represent a paved area which is nearly impervious. Field 3: This field is used to specify the percentage of the basin considered to be representative of the curve number. Fields 4-6: Is used to input the same information as fields 1-3 if field three is not equal to 100 percent. For this model 20 percent of the area was considered to have a curve number of 85 which is representative of porous ground caused by cracks in the asphalt, areas not covered with asphalt, and as a result of sand.
BA	This record is required to compute runoff from precipitation on the subbasin. Field 1: Drainage area in square miles. This was determined using figure 4-? for each of 5 subbasins withis Subbasin 1.
UK	This card is required to determine the overland flow aspects of the kinematic wave routing. Field 1: For each of five subbasins, the longest overland flow distance was used. Field 2: A representative slope for each of the subbasins was provided in this field. Field 3: Roughness coefficients representative of the surface conditions were provided in this field. Field 4: The percentage of the subbasin that the pervious and impervious sections represent were provided in this field for each subbasin. To account for cracks, changes in slope, areas of no asphalt, and sand, the two different roughness coefficients were used.

Table 5-3. (Continued)

RECORD IDENTIFICATION	DATA INPUT FIELD ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
RK	This card is used for the channel routing of runoff from overland flow. Field 1: This field is used to input the length of the collector channel. appropriate values for each subbasin were determined using Figure 4-?. Field 2: A representative slope for each channel was determined and entered in this field. Field 3: The roughness coefficient for each channel was determined to be the same as that for the asphalt areas. Field 4: not used for this model Field 5: This field is used to specifiy the geometric characteristics of the collector channel. Trapazoidal was selected which includes triangular shapes. Field 6: For a triangular channel a value of "0" was selected for each subbasin channel and main channel. SEVEN EIGHT Field 7: A side slope value of 20 was selected for each subbasin channel to represent a shallow "V" shaped channel through the center of each subbasin. Field 8: Each collector channel was also considered a main channel for routing runoff from previous basins. On a second UK card provided for each subbasin, The channel length, slope, roughness, and geometry was described. If runoff from a preceding subbasin was routed through the next basin a YES was entered in the seventh field to specify routing and combing of a previous subbasin.
HC	This card is used to combine hydrographs routed from upstream. Field 1: Denotes the number of hydrographs to be combined at this point. All previous hydrographs were combined as a function of the UK field 7 entry. Combining the final subbasin with all previous subbasins was accomplished using this card.
ZZ	This card is used to specify the end of a data input record.

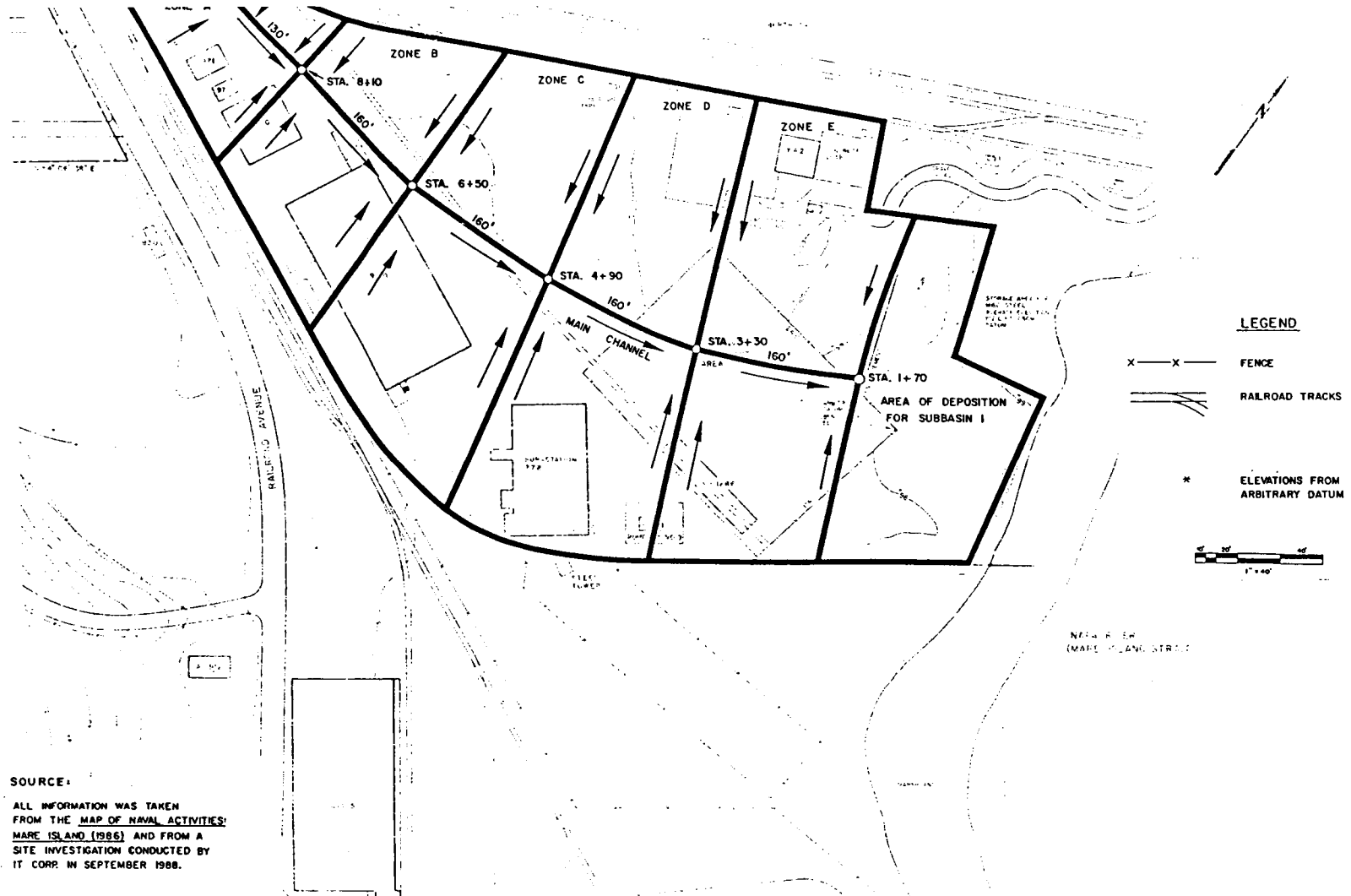


Figure 5-2. 900 Area Subbasin I Water and Sediment Transport Model

$$dAc/dt + dQc/dx = qo \quad \text{(continuity)} \qquad (27)$$

These are solved numerically in the HEC-1 program to produce Q as a function of time and space.

Physically, rain falling on the watershed is carried to a collecting stream channel, or in the case of Subbasin, to a simulated central gutter. Flow from the uppermost reach is then routed through the next subbasin and combined with the downgradient subbasin's overland flow. The recombining and flow routing continues until the stream intersects a river or, in this case, ends as the flow enters Mare Island Strait.

A total of six separate simulations were developed and executed. In Subbasins 2 and 3, 1-year, 5-year, 25-year, and 100-year return period storms were considered. Two return period storms, 25 year and 100 year, were simulated for Subbasin 1. Unrefined input and output data for each of these cases appears in Appendix B.

To establish a relationship between the independent blocks used in the Rational Method evaluation, the same area was studied using the Kinematic Wave Model in the HEC-1 program. The 24-hour duration, 1-year, 5-year, and 100-year return-period storms were modeled. The purpose in using a 24-hour duration storm for analysis is twofold:

- HEC-1 uses a storm distribution breakdown (24 hours) for program input data. This provides the greatest range of analysis possibilities for various storms.

- It has been established that rainfall intensity varies throughout a storm. The various changes in intensity over the 24-hour duration period includes the maximum intensities resulting from 5-minute, 30-minute, 1-hour, 6-hour, and 12-hour storms.

The rainfall intensity has been previously established to be Type IA (Figure 5-3 and Table 5-4). The sand area near the bay water was modeled as a channel area for collection of runoff. The total area was estimated at 0.0104 square miles. The overland flow element of this model assumes a rectangular channel of unit width to simplify modeling of runoff. This implies a unit form of Manning's equation:

$$Q = 1.49/n \quad S^{1/2} \quad R^{2/3} \text{ X } A \qquad (28)$$

where:

Q = the flow in cubic feet per second
S = the channel bed slope in foot/foot
R = the hydraulic radius (area /wetted perimeter)
A = the cross-sectional area in square feet
n = Manning's resistance factor.

This equation can be simplified to:

$$Q = 1.49 \quad S^{1/2} \quad N \qquad (29)$$

where:

S = the slope of the channel
N = the Manning's coefficient of roughness (for overland flow).

This replacement N for n roughness factor for channel flow was determined by Crawford and Linsley (1966) to be between 0.05 and 0.10 inclusive. When applying equations to an overland flow element, the lateral inflow is rainfall excess and the outflow is a flow per unit width. HEC-1 output for Kinematic Wave Modeling of 25-year and 100-year return-period storms, respectively, with a 24-hour duration is graphed in Figure 5-4.

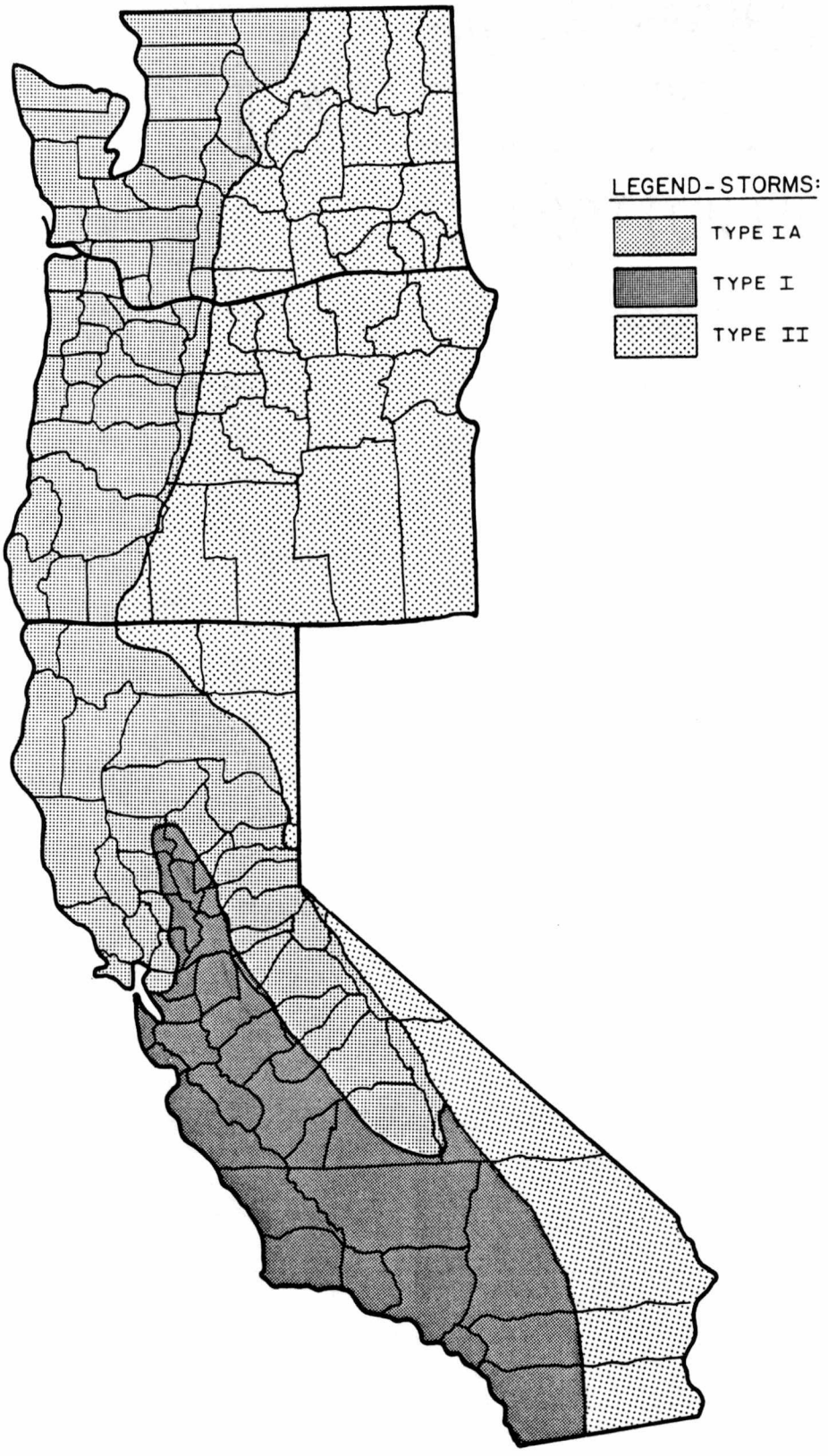


Figure 5-3. SCS Storm Type Distribution - Pacific Coast States

Table 5-4. Type IA Storm Distribution

TYPE IA DISTRIBUTION											
24-HR DURATION		1-YR	5-YR	25-YR	100-YR	24-HR DURATION		1-YR	5-YR	25-YR	100-YR
TIME (min)	DIST	PRECIP (in)	PRECIP (in)	PRECIP (in)	PRECIP (in)	TIME (min)	DIST	PRECIP (in)	PRECIP (in)	PRECIP (in)	PRECIP (in)
15	0.00432	0.0173	0.0281	0.0302	0.0346	735	0.67089	2.6836	4.3608	4.6962	5.3671
30	0.00816	0.0326	0.0530	0.0571	0.0653	750	0.67847	2.7139	4.4101	4.7493	5.4278
45	0.01372	0.0549	0.0892	0.0960	0.1098	765	0.69027	2.7611	4.4868	4.8319	5.5222
60	0.01776	0.0710	0.1154	0.1243	0.1421	780	0.69744	2.7898	4.5334	4.8821	5.5795
75	0.02568	0.1027	0.1669	0.1798	0.2054	795	0.70838	2.8335	4.6045	4.9587	5.6670
90	0.03184	0.1274	0.2070	0.2229	0.2547	810	0.71551	2.8620	4.6508	5.0086	5.7241
105	0.04095	0.1638	0.2662	0.2867	0.3276	825	0.72586	2.9034	4.7181	5.0810	5.8069
120	0.04695	0.1878	0.3052	0.3287	0.3756	840	0.73263	2.9305	4.7621	5.1284	5.8610
135	0.05633	0.2253	0.3661	0.3943	0.4506	855	0.74277	2.9711	4.8280	5.1994	5.9422
150	0.06276	0.2510	0.4079	0.4393	0.5021	870	0.74948	2.9979	4.8716	5.2464	5.9958
165	0.07240	0.2896	0.4706	0.5068	0.5792	885	0.75943	3.0377	4.9363	5.3160	6.0754
180	0.07880	0.3152	0.5122	0.5516	0.6304	900	0.76598	3.0639	4.9789	5.3619	6.1278
195	0.08829	0.3532	0.5739	0.6180	0.7063	915	0.77571	3.1028	5.0421	5.4300	6.2057
210	0.09471	0.3788	0.6156	0.6630	0.7577	930	0.78211	3.1284	5.0837	5.4748	6.2569
225	0.10502	0.4201	0.6826	0.7351	0.8402	945	0.79160	3.1664	5.1454	5.5412	6.3328
240	0.11229	0.4492	0.7299	0.7860	0.8983	960	0.79786	3.1914	5.1861	5.5850	6.3829
255	0.12342	0.4937	0.8022	0.8639	0.9874	975	0.80712	3.2285	5.2463	5.6498	6.4570
270	0.13107	0.5243	0.8520	0.9175	1.0486	990	0.81322	3.2529	5.2859	5.6925	6.5058
285	0.14310	0.5724	0.9302	1.0017	1.1448	1005	0.82226	3.2890	5.3447	5.7558	6.5781
300	0.15159	0.6064	0.9853	1.0611	1.2127	1020	0.82821	3.3128	5.3834	5.7975	6.6257
315	0.16530	0.6612	1.0745	1.1571	1.3224	1035	0.83702	3.3481	5.4406	5.8591	6.6962
330	0.17501	0.7000	1.1376	1.2251	1.4001	1050	0.84281	3.3712	5.4783	5.8997	6.7425
345	0.18999	0.7600	1.2349	1.3299	1.5199	1065	0.85140	3.4056	5.5341	5.9598	6.8112
360	0.20049	0.8020	1.3032	1.4034	1.6039	1080	0.85704	3.4282	5.5708	5.9993	6.8563
375	0.21808	0.8723	1.4175	1.5266	1.7446	1095	0.86539	3.4616	5.6250	6.0577	6.9231
390	0.23064	0.9226	1.4992	1.6145	1.8451	1110	0.87089	3.4836	5.6608	6.0962	6.9671
405	0.24878	0.9951	1.6171	1.7415	1.9902	1125	0.87901	3.5160	5.7136	6.1531	7.0321
420	0.26127	1.0451	1.6983	1.8289	2.0902	1140	0.89435	3.5774	5.8133	6.2605	7.1548
435	0.28287	1.1315	1.8387	1.9801	2.2630	1155	0.89555	3.5822	5.8211	6.2689	7.1644
450	0.30019	1.2008	1.9512	2.1013	2.4015	1170	0.89744	3.5898	5.8334	6.2821	7.1795
465	0.35469	1.4188	2.3055	2.4828	2.8375	1185	0.90511	3.6204	5.8832	6.3358	7.2409
480	0.40255	1.6102	2.6166	2.8179	3.2204	1200	0.91014	3.6406	5.9159	6.3710	7.2811
495	0.45168	1.8067	2.9359	3.1618	3.6134	1215	0.91759	3.6704	5.9643	6.4231	7.3407
510	0.47164	1.8866	3.0657	3.3015	3.7731	1230	0.92247	3.6899	5.9961	6.4573	7.3798
525	0.49752	1.9901	3.2339	3.4826	3.9802	1245	0.92968	3.7187	6.0429	6.5078	7.4374
540	0.51296	2.0518	3.3342	3.5907	4.1037	1260	0.93442	3.7377	6.0737	6.5409	7.4754
555	0.53292	2.1317	3.4640	3.7304	4.2634	1275	0.94140	3.7656	6.1191	6.5898	7.5312
570	0.54456	2.1782	3.5396	3.8119	4.3565	1290	0.94598	3.7839	6.1489	6.6219	7.5678
585	0.56116	2.2446	3.6475	3.9281	4.4893	1305	0.95274	3.8110	6.1928	6.6692	7.6219
600	0.57184	2.2874	3.7170	4.0029	4.5747	1320	0.95717	3.8287	6.2216	6.7002	7.6574
615	0.58685	2.3474	3.8145	4.1080	4.6948	1335	0.96370	3.8548	6.2641	6.7459	7.7096
630	0.59635	2.3854	3.8763	4.1745	4.7708	1350	0.96797	3.8719	6.2918	6.7758	7.7438
645	0.61044	2.4418	3.9679	4.2731	4.8835	1365	0.97428	3.8971	6.3328	6.8200	7.7942
660	0.61956	2.4782	4.0271	4.3369	4.9565	1380	0.97840	3.9136	6.3596	6.8488	7.8272
675	0.63264	2.5306	4.1122	4.4285	5.0611	1395	0.98447	3.9379	6.3991	6.8913	7.8758
690	0.64096	2.5638	4.1662	4.4867	5.1277	1410	0.98845	3.9538	6.4249	6.9192	7.9076
705	0.65220	2.6088	4.2393	4.5654	5.2176	1425	0.99429	3.9772	6.4629	6.9600	7.9543
720	0.65970	2.6388	4.2881	4.6179	5.2776	1440	1.00000	4.0000	6.5000	7.0000	8.0000

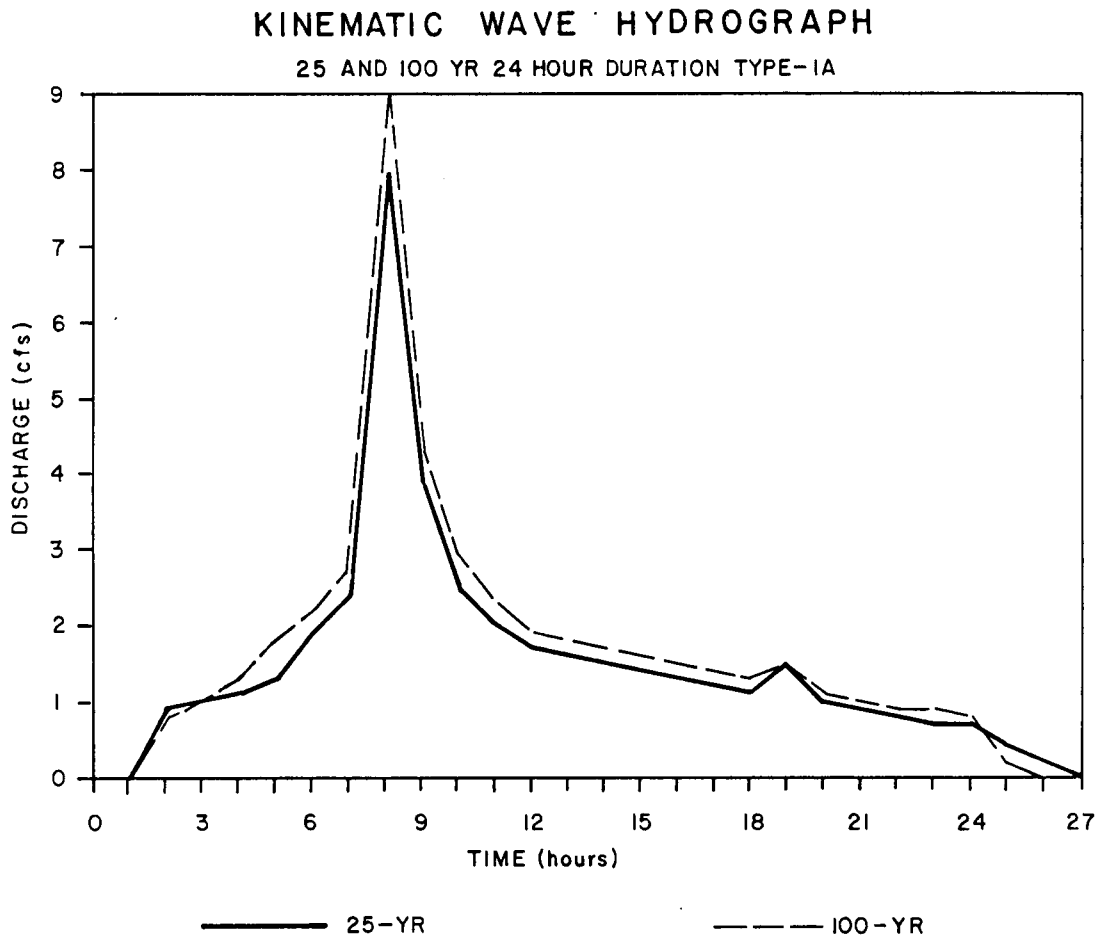


Figure 5-4. Kinematic Wave Runoff Hydrograph

The outflow hydrographs for the watershed Subbasins 2 and 3 were developed using the SCS Curve Number Procedure and the HEC-1 program. The SCS procedure was used to create outflow hydrographs for 25-year and 100-year storms with a 24-hour duration.

5.1.4 SCS Curve Number Method

The SCS of the U.S. Department of Agriculture has instituted a soil classification system for use in soil survey maps across the country. Based on experimentation and experience, the agency has been able to relate the drainage characteristics of soil groups to a curve number, CN (U.S. Soil Conservation Services, 1972 and 1975). The SCS provides information on relating soil group type to the curve number as a function of soil cover, land use type, and antecedent moisture conditions.

Precipitation loss is calculated based on supplied values of CN and IA (where IA is an initial surface moisture storage capacity in units of depth). CN and IA are related to a total runoff depth for a storm by the following relationships:

$$S = (1000/CN)-10 \qquad (30)$$

where:

S = currently available soil moisture storage deficit in inches.

$$Acexs = (Acran - IA)^2 / (Acran - IA + S) \qquad (31)$$

where:

Acexs = accumulated excess in inches
Acran = accumulated rainfall depth in inches.

If the HEC-1 user does not wish to specify IA, a default value is computed as IA equals 0.2S. Because no unusual characteristics were evident on the API, no modification was made for the default values of Ia.

This relationship is based on empirical data established by SCS. Because the SCS method gives total excess for a storm, the incremental excess (the difference between rainfall and precipitation loss) for a time period is computed as the difference between the accumulated excess at the end of the current period and the accumulated excess at the end of the previous period. The curve numbers selected were 95 for industrial areas or areas of low permeability and 80 for open spaces. The subbasin information was derived from area maps provided from the SCS survey for Solano County, which includes NSY Mare Island. Assumed percentage values for both subbasins are as follows:

Subbasin 2:

Area = 0.05 square miles
47 percent industrial (CN = 95)
53 percent open spaces (CN = 80)

CN = 95 X 0.47 + 80 X 0.53 = 87

Subbasin 3

Area = .005 square miles
33 percent industrial (CN=95)
67 percent open spaces (CN=80)

CN = 95 X 0.33 + 80 X 0.67 = 85

The basin lag time can be estimated as follows:

$$t = L^{0.8} \ (S+1)^{0.7} \ / \ (1900 \ X \ Y^{0.5}) \qquad (32)$$

where:

L = the hydraulic length of the watershed
Y = the average watershed slope in percent.

Subbasin 2:

$$S = 1000/87 - 10 = 1.494$$

Y is estimated from site maps as 1.4 percent.
L is estimated from site maps at 5000 feet.

$$\text{Lag Time} = 5000^{0.8} \ X \ (1.49 + 1)^{0.7} \ / (1900) \ X \ 1.4^{0.5} = 0.75 \text{ minutes}$$

Subbasin 3:

$$S = 1000/85 - 10 = 1.76$$

Y is estimated from site maps as 0.743 percent.
L is estimated from site maps at 400 feet.

$$\text{Lag Time} = (400)^{0.8} \ X \ (2.76)^{0.7} \ / \ (1900) \ X \ 0.743^{.5} = 0.15 \text{ minutes}$$

This information was used to determine runoff and peak flows for the SCS Curve Number Procedure for four widely varying return-period storms. Inflow and outflow hydrographs for these return-period storms (1, 5, 25, and 100 years) as simulated by HEC-1 are presented in Figures 5-5 and 5-6. In addition, channel routing data was input into the model to establish a relationship between the two subbasins and the area of discharge. The Muskingum method was used to determine the storage coefficient and lag times of discharge through the channel area. For most streams, x is between 0 and 0.3 with a mean value near 0.2. The storage constant K is the ratio of storage to discharge and has the

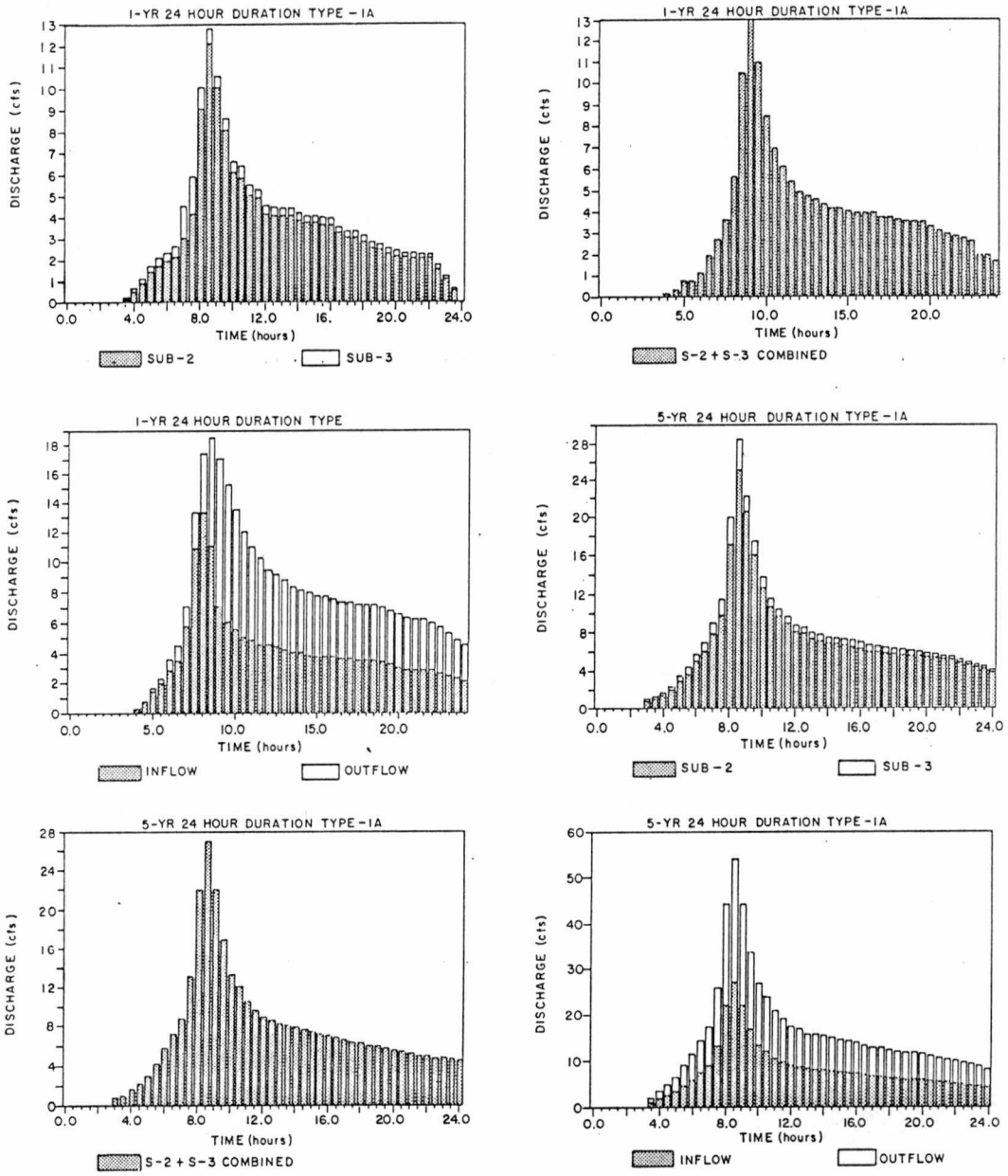


Figure 5-5. SCS Inflow/Outflow Hydrographs 1-Year and 5-Year Storms

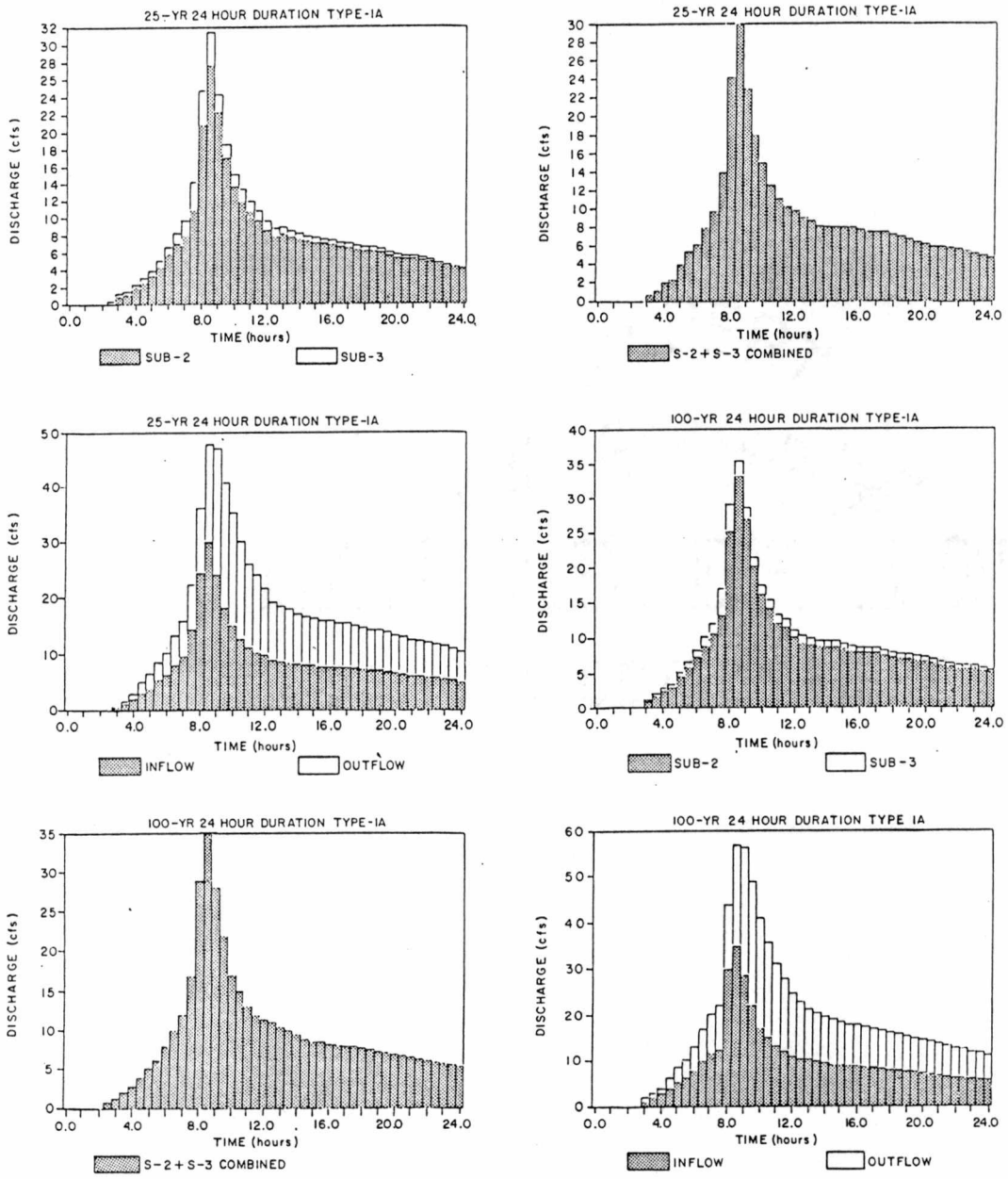


Figure 5-6. SCS Inflow/Outflow Hydrographs 25-Year and 100-Year Storms

dimensions of time. It is approximately equal to the travel time through the reach and, in the absence of better data, is sometimes estimated this way.

No flow values were available for this area and a stream travel time of 1 hour was estimated from similar channel data. This assumption is not critical, however, because the time of travel and peak discharge into the area near the bay is necessary as a means of combining the hydrographs for the two water-sheds in the HEC-1 model. The total outflow volumes, when combined in the channel, will be used to determine the sediment transport potential from the various storms.

5.2 SEDIMENT TRANSPORT MODELING

There are three major factors affecting the transport rate of sediment under shallow flow conditions: (1) fluid forces, (2) rainfall impact forces, and (3) particle-to-particle interactions. The first force is relatively well understood and is the basis for most transport equations. The second force has been investigated empirically by Young and Wiersma (1973), and the third force has been discussed by Bagnold (1972). Together, these forces represent the physical transport system. The U.S. Corps of Engineers (1977) HEC-6 Model employs the modified Einstein equation option and is considered appropriate for use in this study because of its ability to address the discrete transport components of bed load and suspended load independently. Other researchers have offered discrete equations; however, the basic method advanced by Einstein (1950) appears to have the most broad-based acceptance by practitioners in the field.

5.2.1 Einstein's Theory

Einstein (1950) postulated that a particle moves if the instantaneous hydrodynamic lift force overcomes the submerged particle weight. Therefore, both the beginning and ceasing of sediment motion are probabilistic events and do not depend on whether or not the average fluid force exceeds some threshold. Particles are assumed to travel along the bed in a series of quick movements followed by a relatively long rest, and the average distance traveled by the bed particles between consecutive points of rest in the bed is constant. Further, the computed total sediment discharge is calculated as the sum of the bed load discharge and the suspended sediment discharge. The bed load discharge is considered to be through a sediment layer that is two-grain diameters thick, and the suspended sediment is considered to be discharge from the water column to the bed layer over distance.

In laminar flow viscous effects dominate. Coleman (1967) reported that the lift force coefficient decreases as the Reynolds number decreases. In fact, at very low Reynolds numbers, negative lift coefficients were observed. The ratio of the lift coefficient to drag coefficient was 0.04 to 0.12 when the Reynolds number was within the range of 100 to 500. Therefore, in laminar flow such as demonstrated in the hydrologic modeling for the 900 Area, the lift force acting on a particle is mainly composed of the component of drag force, and the first type of lift force used by Einstein (1950) is negligible.

On this basis, the principal mechanism of sediment transport in laminar flow is similar to that of bed load transport in turbulent flow. The lift force required for motion is supplied primarily by a component of the fluid drag force. Therefore, the suspended transport and transitional transport phenomena discussed by Einstein (1950) may be neglected in this analysis. In the ensuing paragraphs the mathematical basis given by Einstein will be reviewed for the purpose of presenting the physical basis for parameter selection and testing. Following this discussion, the HEC-6 Model will be presented in the context of Einstein's basic equations being used in transport simulations.

5.2.2 Transport Mechanics

The quantity of sediment transported in a stream by rolling, sliding, or skipping within the bed layer is called the bed load. By assuming that the bed is neither eroding nor scouring (similar to an impervious surface such as asphalt), Einstein (1950) developed a bed load equation that can be represented as:

$$i_B q_B = \phi_* i_b p_s g^{3/2} D^{3/2} (S_s - 1)^{1/2} \qquad (33)$$

in which:

$i_B q_B$ = the rate at which a particle of diameter D in a mixture moves through a unit width of the bed layer per unit of time; i_B is the fraction of bed load in a given size range; q_B is the rate at which the bedlayer sediment moves through the unit width of cross section
ϕ_* = intensity of transport for an individual grain size
i_b = fraction of bed material in a given grain size
p_S = density of the solids
S_s = specific gravity of the sediment.

For a given particle of diameter D, Einstein assumed that all parameters on the right side of Equation 33 are constant except for ϕ_*. The intensity of transport, ϕ_*, is a function of the intensity of shear, ψ_*, for the individual grain size. A curve relating ψ_* and ϕ_* is given in Einstein (1950) and reproduced with several other relationships in Figure 5-7.

Einstein found that ϕ_* was a unique function of the hydraulic shear intensity parameter ψ_*, which may be defined by:

$$\psi_* = \xi\ Y\ \left[\frac{\log 10.6}{\log\left(\frac{10.6Xx}{d_{65}}\right)}\right]^2 \frac{p_s - p}{p}\ \frac{D}{R'_b S_e} \qquad (34)$$

where:

ξ	=	a correction of effective flow for various grains
Y	=	a correction of lift force in transition between hydraulically rough and smooth beds
X	=	a reference grain size for the particular bed
R'_b	=	hydraulic radius of the bed for grain roughness or surface drag
S_e	=	slope of the total energy line for the given flow conditions.

Colby and Hembree (1955) modified Equation 34 to complete the discharge of sediments in the sand range such as found in greensand. The modified equation for bed load in a cross section is:

$$(i_B Q_B)_M = \phi_{*M} 43.2\ w\ 1200\ i_b D^{3/2} \qquad (35)$$

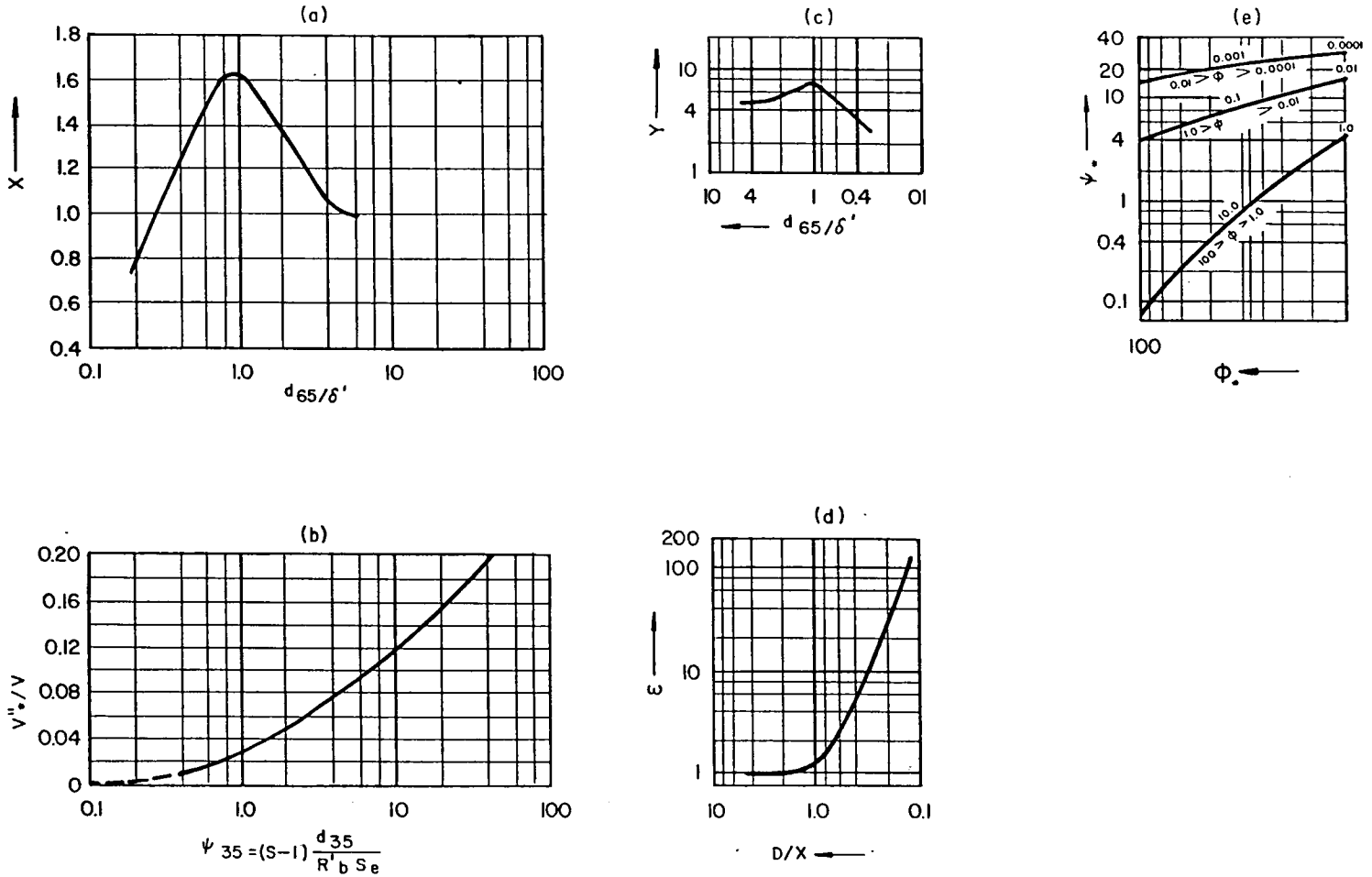


Figure 5-7. Einstein Transport Relations

in which:

$(i_B Q_B)_M$ = sediment discharge through the bed layer of particles of the given size range, in tons per day; equals $(i_B q_B)_M$ times 43.2w

where:

$(i_b q_b)_M$ = sediments discharge through the bed layer of particles of the given size range, in pounds per second per foot of width

w = width of channel in feet.

The subscript M denotes a parameter that was obtained according to modified method. The 43.2 is a constant for converting pounds per second to tons per day.

The modified method equation for determining $(i_B Q_B)_M$ is based on Equation 33. The value of the intensity of the bed load transport, ψ_{*M}, used in entering the relation [see Einstein (1950, Figure 10)], however, is based on D_{35} and D_{65}; and the value of ψ_* obtained from the relation is arbitrarily divided by 2 (Colby and Hembree, 1955). The use of this relation was suggested by U.S. Corps of Engineers researcher Dr. Michael Gee (Personnel Communication, 1988).

$$\psi_{*M} = \phi_*/2 \qquad (36)$$

The 1200 represents the constants in equation in which g is the gravitational constant, 32.2; p_s equals 5.17 and S_s equals 2.65 (Einstein, 1950). The quantity ϕ_{*M} is computed using the equations:

$$\phi_{*M} = (1.65\ D_{35})/(RS)_M \qquad (37)$$

$$\psi_{*M} = (0.66D_{65}) \quad /(RS)_M \tag{38}$$

The larger ψ_{*M} from these equations is used for each geometric mean particle size for a range of sizes.

5.3 GRAIN SIZE AND ELEMENTAL COMPOSITION OF SOIL ABRASIVES

Eight representative samples of both virgin and spent greensand were collected and a grain size analysis performed. Both classes of abrasives were very uniformly graded and the unused abrasive was found to be larger than the spent abrasive. Characteristic grain size distribution curves for spent and virgin greensand are given in Figures 5-8 and 5-9, respectively. Grain size of new greensand ranged from 3 mm to 0.5 mm with the median being approximately 1.7 mm. Spent greensand ranged in size from 8 mm to 0.075 mm with a median of about 0.45 mm.

In addition to mechanical grain size testing, a similar mass fraction analysis described in Section 4.4 was performed on the micron-size soils and blasting by-products materials. The total tested fraction represented approximately 10 percent of the spent abrasives sample by weight. Five locations along the central axis of the sampling grid were chosen to represent a typical cross section of estuarine- and land-type soils. Samples of spent and virgin greensand were also collected. These five samples were tested for 0.2 to 80.0 micron mass distribution. It is in this range of particle size where paint flakes and highly charged clay

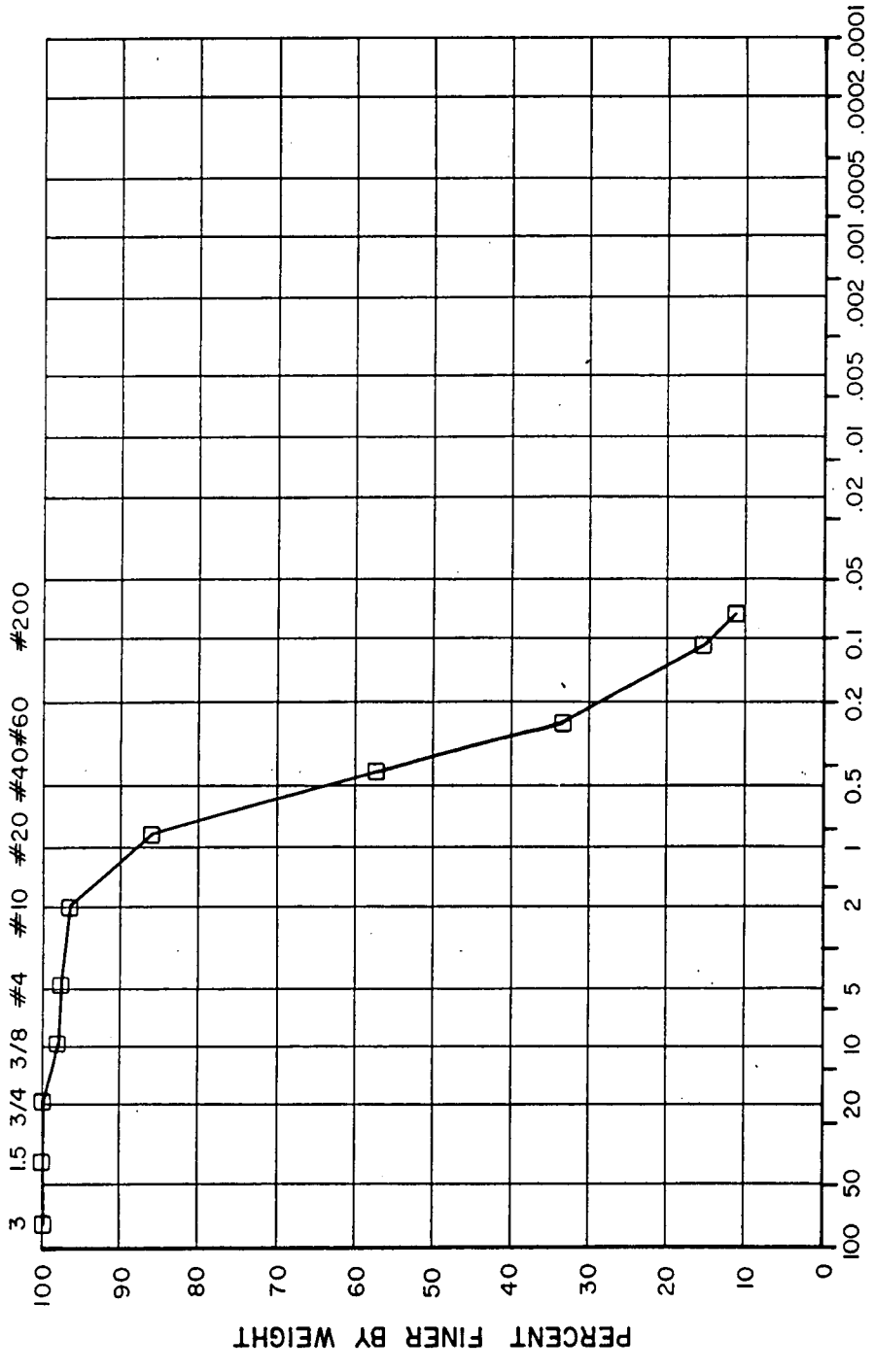


Figure 5-8. Grain Size Distribution: Spent Abrasive

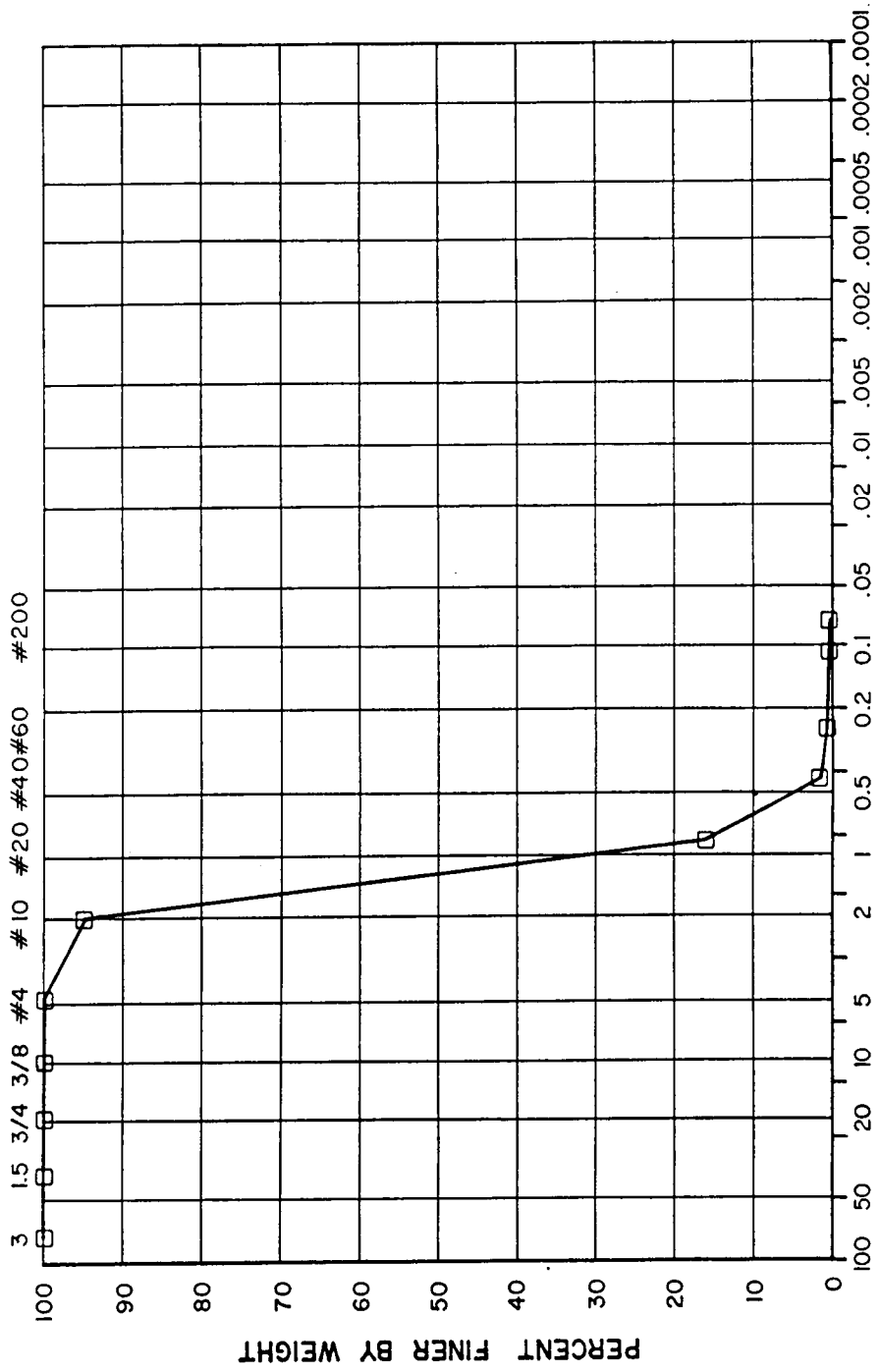


Figure 5-9. Grain Size Distribution: Virgin Abrasive

particles may be counted. Paint flakes and blasting debris with associated tributyltin (TBT) are considered to be the two most important components in the assessment of hazard impacts.

Based on the most likely chemical compound(s) represented by the observed particle properties, each particle type was assigned a density. The volume of each particle, computed from the projected area measurements, was multiplied by the particle density to obtain the particle's mass. Results of the CCSEM analyses have been summarized in Tables 5-5 through 5-8.

Table 5-5 presents a summary of CCSEM number distribution results for each analysis of each sample. In this table, relative number percent for each particle size bin is given. For all samples, it was observed that the majority of particles (>80 number percent) was in the size range <2.5 micrometers (μm) and are associated with clay materials. The remainder of particles, generally attributed to paint flakes, ranged from 2.5 μm to 80 μm, with most of these <10 μm in size. Table 5-6 presents a summary of CCSEM mass distribution results. In this table, relative weight percent for each particle size bin is given. Results indicated that for all samples (with the exception of 26658), the majority of mass (≥77 weight percent) concentrated in the size ranges >15 μm. The sample identified as "Site 2 Surface" displayed a shift in mass distribution noncharacteristic of the other four samples, with a higher weight percentage in the 5 to 10 μm particle size range.

Table 5-5. Summary of CCSEM Number Distribution Results (Num. %)

RJ Lee Group #	Run #	Identification	Particle Size Range (μm)						
			0.2-1.0	1.0-2.5	2.5-5.0	5-10	10-15	15-30	30-80
26657	1	Site 1 Surface	34	59	2	3	1	1	<1
26657	2	Site 1 Surface	45	48	2	4	<1	1	<1
26658	1	Site 2 Surface	43	48	4	5	<1	<1	<1
26659	1	Site 3 Surface	57	29	5	6	2	2	<1
26659	2	Site 3 Surface	38	49	7	5	<1	<1	<1
26660	1	Site 4 Surface	35	54	6	4	1	1	<1
26660	2	Site 4 Surface	31	53	8	9	<1	<1	<1
26661	1	Site 5 Surface	39	42	12	6	<1	<1	<1

Table 5-6. Summary of CCSEM Mass Distribution Results (Wt. %)

RJ Lee Group #	Run #	Identification	Particle Size Range (μm)						
			0.2-1.0	1.0-2.5	2.5-5.0	5-10	10-15	15-30	30-80
26657	1	Site 1 Surface	<1	<1	<1	2	5	30	64
26657	2	Site 1 Surface	<1	<1	<1	4	4	33	59
26658	1	Site 2 Surface	<1	4	4	35	8	35	15
26659	1	Site 3 Surface	<1	<1	<1	6	6	43	43
26659	2	Site 3 Surface	<1	<1	<1	2	4	7	87
26660	1	Site 4 Surface	<1	<1	<1	4	4	36	55
26660	2	Site 4 Surface	<1	1	1	14	1	9	74
26661	1	Site 5 Surface	<1	1	2	13	7	39	38

Table 5-7. Summary of CCSEM Particle-Type Distribution Results (Wt. %)

Particle Type	Site #1	Site #1R	Site #2	Site #3	Site #3R	Site #4	Site #4R	Site #5
Aluminum-rich						20.5	9.9	
Mix-clay[a]			33.2	69.8	63.2	46.4	62.1	35.6
Silicon-magnesium	93.3	86.1	41.7	15.9	20.7	18.5	19.1	48.9
Iron-rich		0.9	8.1			9.4	7.8	
Miscellaneous	6.7	13.0	17.0	14.3	16.1	5.2	1.1	15.5

[a]Includes silicon-rich, silicon-aluminum, and silicon-iron-rich types.

Table 5-8. Summary of CCSEM Elemental Distribution Results

(Percentage of X-Ray Counts)

Element	Site #1	Site #1R	Site #2	Site #3	Site #3R	Site #4	Site #4R	Site #5
Carbon	6	5	8	9	9	8	7	7
Nitrogen	0	0	0	0	0	0	0	0
Oxygen	9	8	12	9	10	8	9	10
Sodium	0	0	0	1	1	1	1	1
Magnesium	24	23	11	5	6	3	1	13
Aluminum	0	0	5	7	10	25	19	4
Silicon	47	42	43	54	50	37	41	48
Phosphorus	0	0	0	0	0	0	1	0
Sulfur	1	1	1	0	1	1	2	1
Chlorine	0	0	1	0	1	0	1	1
Potassium	0	0	2	3	2	2	3	1
Calcium	2	2	2	2	3	2	3	4
Titanium	0	0	1	1	1	1	3	1
Vanadium	1	1	1	1	1	0	1	1
Chromium	0	1	0	1	0	0	0	1
Manganese	0	1	0	0	0	0	0	1
Iron	9	8	12	6	6	9	8	9
Nickel	0	0	0	0	0	0	0	0
Copper	1	7	0	0	0	0	1	0

Table 5-7 presents a summary of CCSEM particle-type results obtained for each analysis of each sample. Particle types presented are definitions based on the most prominent elements within the particle. Table 5-8 presents a summary of the CCSEM elemental composition results. Percentage of x-ray counts for 19 elements ranging from carbon to copper are given for each analysis of each sample.

Figures B-1 through B-5 found in Appendix B present secondary electron micrographs taken at two magnifications of each sample analyzed in this study. These micrographs display the particle size distribution, area distribution, and morphology typical of each sample. Figures B-6 through B-13 display secondary electron images and elemental spectra obtained from the samples to represent the various particle types observed during the CCSEM analysis.

All samples were observed to have silicon as their major elemental component. The sample identified as "Site 1 Surface" displayed relatively high percentage (approximately 23 percent) of x-ray counts for magnesium, whereas the samples identified as "Site 4 Surface" displayed a relatively high percentage (approximately 22 percent) of x-ray counts for aluminum. Replicate analysis was performed on Samples 26657, 26659, and 26660. Results were in good agreement for the number distribution and elemental composition of each sample. Results for the mass distribution in Samples 26659 and 26660 indicated a shift toward the larger particle size range. This occurred as a result of more particles being analyzed in the 30 to 80 μm size range in the second analysis.

5.4 HEC-6 MODELING

The HEC-6 model is sixth in a series of hydrologic and hydraulic simulation models developed over the course of the last 20 years by the U.S. Army Corps of Engineers Hydrologic Engineering Center. HEC-6 is officially titled "Scour and Deposition in Rivers and Reservoirs" in the 1977 Users Manual. It is a one-dimensional, steady-state sediment transport model that was primarily developed for evaluating sedimentation behind dams designed and constructed by the U.S. Army Corps of Engineers Hydrologic Engineering Center.

The model considers an open channel of finite width. Sediment transport is calculated for a reach of river which is described by a series of representative cross sections. Geometry of the model is represented by cross sections, station locations along the river reach, elevation drop, and distance between cross sections. Water discharge is handled as a series of steady state flows over a given period of time. Friction losses are a function of Mannings "n" that describes the hydraulic roughness. Both granular and cohesive materials may be input, but the present version of the model does not allow for reentrainment of silts and clays once they settle to the stream bed. Main water flow through the channel may be augmented by discrete tributary input locations along the modeled reach.

Sediment available for movement is determined in the main channel to be the volume of material above an impermeable boundary elevation and is limited laterally by the width of the channel. Transport capacity is calculated at each cross section based on hydraulic data and grain size information at a given location. The left and right banks of the main channel are considered no-flow boundaries for water and sediment input. As such, the model can define both movable and nonmovable beds. Overland water and sediment runoff normal to the main channel may be modeled by performing a separate submodel that simulates sediment transport across the width of a subreach or subsection with the main channel representing the final location of deposition. These discrete submodels may then be input in the main channel models as tributaries.

The Users Manual discusses three options for the transport of bed materials: Toffaleti's application of Einstein's bed load formula (Toffaleti, 1966) previously discussed; a method by Laursen (Laursen, 1958), which is applicable for large rivers; and an undefined method which is believed to be after the work of DuBoys (1879). A fourth method, streampower function, by Yang (1984) is given in the job cards but not described in the text. The program defaults to the Toffaleti approach. In the previous discussion on transport mechanics, it was mentioned that the Toffaleti expression is the most relevant to sheet flow with shallow nonscouring boundaries such as found at the 900 Area.

Input to the model is in the form of 8 to 12 characters by eight field lines, each beginning with a two or more alphanumeric identifiers. Information is input in three type sets: geometric data, sediment data, and hydrologic data. Table 5-9 describes the main classes of input that are used in this model. Options are available for which additional and/or optional cards may be used. Table 5-10 addresses each input card used in the modeling of Subbasin 1 at the 900 Area and the values for the various fields. Output data may be dumped to a line printer or suppressed. The present version of HEC-6 output is generated at each cross section for elevation change, water surface level, flow rate, and sediment discharge by clay, silt and sand fractions.

The model developed for the 900 Area was subdivided into five cross sections coincident with the downstream face of the subwatersheds used in the hydrologic model previously discussed. Data is input from the downstream end of the channel. The cross sections used are at 170, 330, 490, 650, and 810 feet from the bulkhead line on the beach. An arbitrary, triangular-shaped, 40-foot-wide channel was selected for the HEC-1 model and subsequently for the HEC-6 model since this width provides adequate channel to accommodate the peak runoff from a 100-year storm. Utilizing a wide triangular channel is representative of actual site conditions and produces shallow depths for runoff which are coincident with promoting sheet flow. A nonscouring depth was set at 0.1 foot, which represents the average depth of greensand on the asphalt. To accommodate sediment load flowing from remote parts of the watershed to the channel, separate submodels were developed that simulated overland

Table 5-9. HEC-6 Input Data Identification

DATA CATEGORY	RECORD IDENTIFICATION	DESCRIPTION OF DATA
CROSS SECTION INITIALIZATION	T	JOB IDENTIFICATION
	NC	MANNINGS PARAMETERS
	X	CROSS SECTION IDENTIFICATION
	GR	CROSS SECTION DESCRIPTION
	H	CHANNEL CHARACTERIZATION
COMMENT CARDS	*1-5	DESCRIPTION OF GEOMETRIC MODEL
JOB PARAMETER	I	SEDIMENT PARAMETERS FOR THE JOB
INFLOW SEDIMENT	L	DESCRIBES SEDIMENT INFLOW CHARACTERISTICS
BED GRADATION	N	SEDIMENT DISTRIBUTION IN STREAMBEED
COMMENT CARD	*	REQUIRED FOR EACH DISCHARGE HISTOGRAM

Table 5-10. HEC-6 Input Logic for the 900 Area

RECORD IDENTIFICATION	DATA INPUT FIELD ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
T1-T3	Title cards used for job identification, location, format. Information regarding the subbasin transport mechanics and subdivisions information is entered using these cards.
NC	Input card for manning's "n" value at each station on the first cross-section This card contains the mannings value and contraction coefficients for each cross-section in the model. For this model one manning's value of .013 characterisic of asphalt paving was used for all cross-sections and channel locations.
X1	This card is required at each cross-section to define the cross-section geometry Field 1: Cross section identification number. The subbasin was divided into five zones for analysis. The distance between zones were 170, 160, 160, 160, and 130 for cross-sections 170. 330, 490,650, and 780 respectively. Field 2: The number of points across the section required to define the channel shape. Two points were used to describe the triangular channel used in this model. The channel was considered to be approximately 40 feet wide. Field 3: The station number for the left bank of the channel "0" was used for the starting point. Field 4: Distance to the station on the far right bank of the cross-section Forty feet was used as input for this model. Field 5,6,&7: Requirs input defining the distance between cross-sections for the right, left and center points of the cross-section except at the first section
GR	This card is used to specify the elevation and station of each point used to define the cross section at each station along the stream. Field 1: Elevation of the right bank. A flat rectangular channel was used to model sediment transport. This was representative of the sheet flow and bed transport expected. An elevation at the center of each section was selected. a 1 to 20 slope was used to describe the channel. Field 2: The distance in feet from the left bank of the channel to this point on the cross-section description. Subsequent fields are used to input elevation and distance information across the channel.

Table 5-10. (Continued)

RECORD IDENTIFICATION	DATA INPUT FIELD ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
H	This card describes the limits of the movable bed for scour and deposition calculations. Field 1: This field identifies the cross-section associated with this input data and is consistent with the X1, field 1 value. Field 2: Describes the elevation at which scour will not exceed. An elevation approximately one inch below channel bottom was used to reflect the presents of asphalt. Field 3: Defines the location to the left of the cross-section were a fixed to movable bed begins. A value of "20" feet was used to describe the center of the channel. Field 4: Defines the location to the right of the cross-section were a fixed to movable bed begins. A value of 20 feet was used to indicate the right boundary of the channel.
EJ	Describes the end of the geometric model. this will be followed by the sediment transport input.
*1-5	The 5 comment cards are required when using the geometric model format for sediment transport. This information is used to describe the sediment model used to define this site.
I1	This card is used to imput job parameters for the channel. Field 2: Number of iterations used to define the sediment transport and deposition. A value of 50 was used since this value provides the least amount of occilation. Field 3: This field instructs the program to use the gradation values on the following "N" cards to calculate the transport capacity. Field 4: Defines the maximum number of discharges that will be analyzed in parallel. A default value of 1 was used since tributary inflow was required to represent runoff contributions from subsequent subbasin zones.
I3	Used to identify silt as a integral part of the sediment mixture. The sizes indicated are representative of the results of the scanning electron microscopy. Field 3: These fields are used to input the ranges of grain size fractions to be transported. Sizes ranged from .003 to .063. the fraction of each size were determined from the scanning microscopy report.
I4	Instructs the program to analyzed for specified sand sizes in the sediment material. Field 2: This field specifies the transport relationship to be used for analysis. A value of one was used to instruct the program to use the Toffaleti's Method. Field 3: This input specifies the smallest grain size to be used in the sediment analysis. A value of 1 was used to represent the .062 to .125 millimeter range as the smallest. Field 4: This field represents the upper range of the grain sizes to be evaluated for transport. A value of 5 was used to represent the range of Very Coarse Sand between 1.0 and 2.0 mm. Field 5: This input field specifies the specific gravity of the sediment at 2.65.

Table 5-10. (Continued)

RECORD IDENTIFICATION	DATA INPUT FIELD ONE TWO THREE FOUR FIVE SIX SEVEN EIGHT
L	This card provides inflowing sediment data representative of steady state conditions. The values were selected by discrete analysis of overland flow in each zone. A relationship was established which represents the sediment available for runoff at various discharge values.
N	The bed material representing each grain size in the stream bed is presented in this section Field 1: This is a comment field and was used to indicate the cross-section identification Field 2: This input determines the area not covered by armor. this is equal to the surface area/acre. exposed to scour. A value of 1 was selected to reflect the asphalt conditions. Field 3: the maximum grain size at this cross-section in feet. A value of .067 feet was selected from the contaminated greensand grain size distribution charts. This was representative of a grain size with 100% passing. Field 4: Input into this field specifies changes in slope of the percent finer curve. between the maximum grain size and the largenst being transported. Since all grain sizes are considered to be transported a value of "0" was used. Field 5: The field inputs the percent finer value of the largest material under transport. A value of 95% was selected from the percent finer curve for spent greensand. Field 7: All remaining fields are used to input the fraction of greensand represented in this distribution A total of nine fields are used. the values were determined using the grain size distribution curves.
$HYD	Program command card used to specify use of a hydraulic model.
*	Comment cards used to specify the type of modeling, discharge values and printout options.
Q R T W	Discharge values to be used during each run. Values were selected at varying "Qs". Stage discharge boundary downstream. Downstream channel center elevation of 98.5 was used to specify the asphalt surface at the point of discharge. Water temperature estimated at approximately 65 degrees Fahrenheit. Duration in days model will be analyzed. Values were selected from the hydrographs for various discharges.

flow across a subwatershed to the central main channel. It was discovered during this modeling effort that sheet flow from the peak 25-and 100-year storms dispersed over the entire watershed did not provide sufficient energy for significant transport of sediment using the HEC-6 model. This prevented generating sediment load rating curves for tributary inflow to the main channel and providing subsequent steady-state conditions. To compensate for this deficiency, steady-state conditions were abandoned and the runoff area of the channel was evaluated for its potential to transport greensand at various discharge flows. Somewhat conservative values for discharge of sediment at the channel outlet will be predicted. This observation suggests that greensand runoff is minimal in all areas of the watershed where sheet flow is dominant. The effective contribution of the operation area is confined to the portions of the watershed where runoff combines to form rivlets or an equivalent and sufficient energy is developed to move sediment and/or paint materials.

Modeling Rationale and Results

An evaluation of the two worst-case discharge hydrographs, 25- and 100-year storms, generated using the HEC-1 Kinematic Wave model indicates that flow divisions fall into the following three categories:

- Approximately 4 to 6 hours is required for discharge before a rapid slope change occurs in the rising limb of each hydrograph.
- The time span over which peak discharge is achieved (length of rising limb on hydrograph) ranges from 2 to 4 hours.
- Runoff on the receding limb of each hydrograph encompasses a time frame of approximately 12 to 14 hours.

For each of the above time frames, the following time-discharge relationships were established:

Time (days)	Discharge (cfs)
0.21	0.5 to 2.0
0.13	3.0 to 8.0
0.54	0.5 to 2.5
0.12	less than 0.5 (hydrograph tails).

Because of the similarity in the time runoff relationships between the 0.54-day and the 0.21-day values, the 0.54 value was used to evaluate the appropriate time-runoff relationships in the HEC-6 model.

Using the HEC-6 model, values of discharge were varied for each range stated above holding the time constant. The resulting information for each station along the channel was verified by multiple runs and tabulated. Each station along the channel is geometrically similar and differs only in the amount of runoff expected at each location. This relationship was used to generate an average sediment discharge relationship for the entire Subbasin 1 site. Results from the HEC-6 program for each station were averaged for a given discharge. A graph showing the relationship of average sediment transport and discrete station transport and cumulative sediment load at the base of the watershed is presented in Figure 5-10. To support these findings, a linear regression analysis was calculated and equations generated for each station along the channel length. Values obtained through regression closely compare to actual values used to calculate average

Figure 5-10.

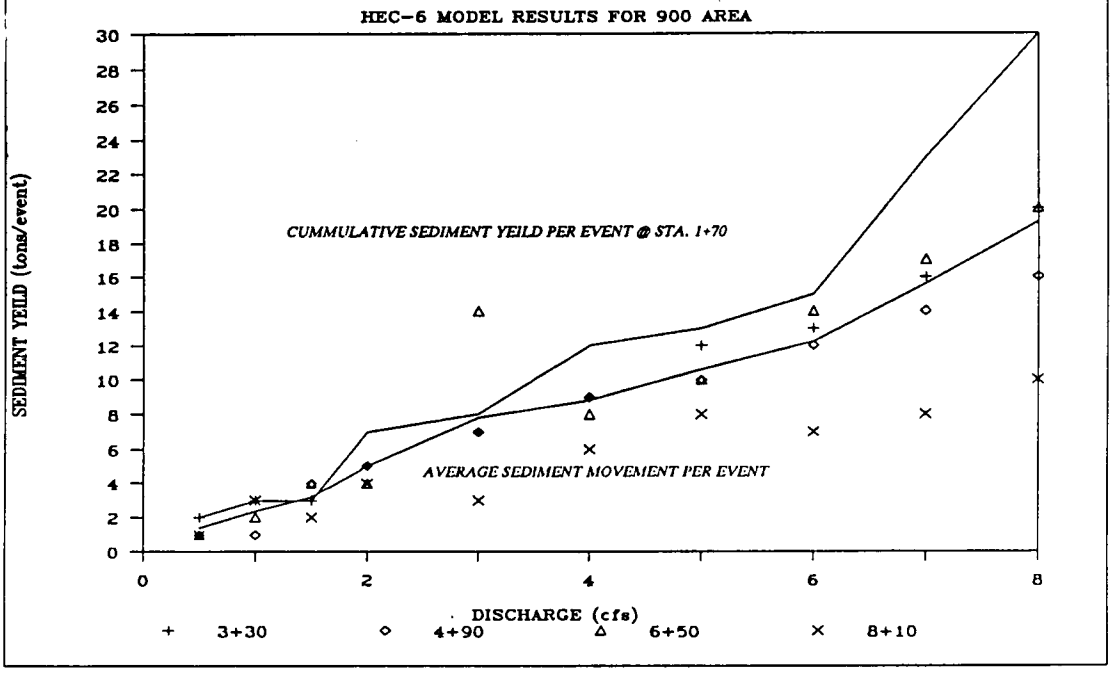


Figure 5-11.

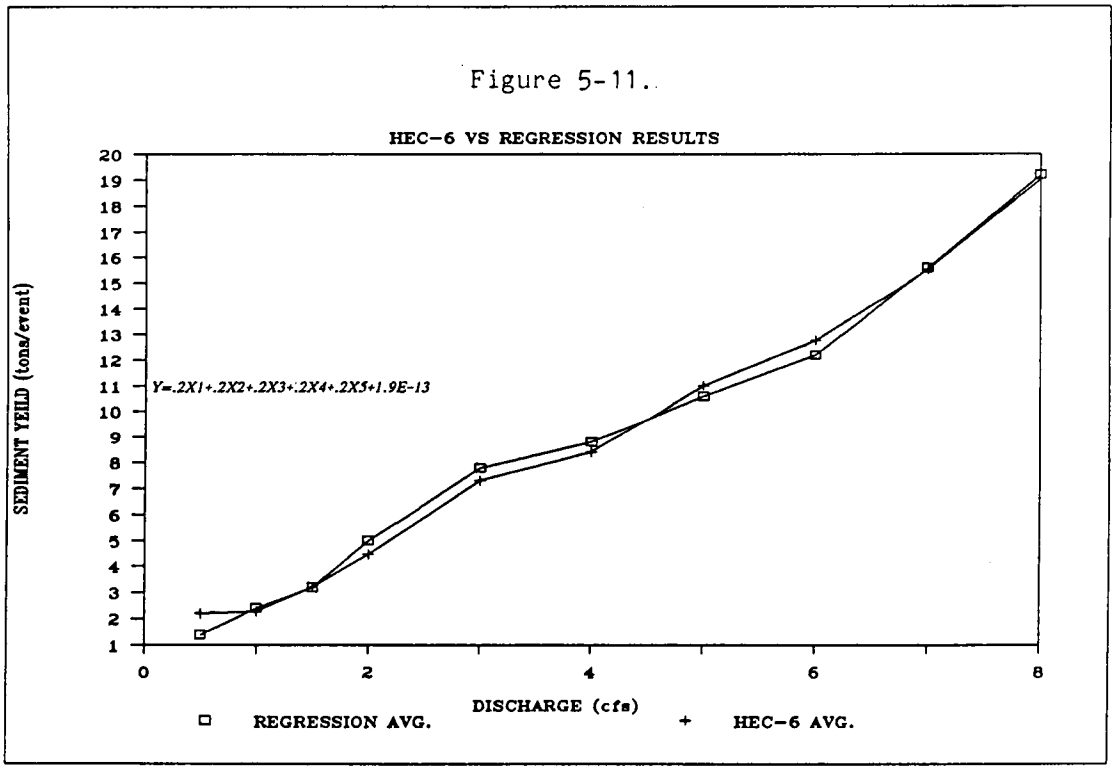


Figure 5-10. Sediment Load Rating Curve

Figure 5-11. Sediment Load Comparison Curve

discharge-runoff relations. A comparison of the regression and average results is shown in Figure 5-11. HEC-6 discharge-sediment load output along with regression values for each cross-section are tabulated in Table 5-11. A listing of the linear equations that were used to derive the regression values are also shown in Table 5-11. The correlation coefficient ranged from 0.95 to 0.99 for all linear equations derived. The expression given for Station 1+70 represents the cumulative sediment loading from the entire basin.

Table 5-11. HEC-6 Results

tons/day

DISCHARGE (cfs)	STATION 170	330	490	650	810	AVG
0.5	2	2	1	1	1	1.4
1	3	3	1	2	3	2.4
1.5	3	3	4	4	2	3.2
2	7	5	5	4	4	5
3	8	7	7	14	3	7.8
4	12	9	9	8	6	8.8
5	13	12	10	10	8	10.6
6	15	13	12	14	7	12.2
7	23	16	14	17	8	15.6
8	30	20	16	20	10	19.2

LINEAR REGRESSION RESULTS

tons/day

DISCHARGE (cfs)	STATION 170	330	490	650	810	AVG
0.5	3.1	1.2	1.3	3.4	2.0	2.2
1	2.5	3.1	2.8	0.5	2.4	2.3
1.5	2.9	3.1	2.9	4.9	2.3	3.2
2	5.2	5.6	4.4	3.6	3.5	4.5
3	8.0	7.3	7.5	11.1	2.7	7.3
4	10.9	9.5	7.9	8.1	5.6	8.4
5	15.0	11.7	10.5	10.1	7.7	11.0
6	17.4	12.5	11.5	15.1	7.5	12.8
7	22.4	16.0	13.6	17.4	8.2	15.5
8	28.7	20.0	16.7	19.8	10.0	19.0

STATION	REGRESSION EQUATION
1+70=X1	Y=2.56X2-.086X3-.353X4-1.39X5-.224
3+30=X2	Y=.256X1+.098X3+.720X4+.194X5-.303
4+90=X3	Y=.416X1-.037X2+.434X4+.267X5-.189
6+50=X4	Y=2.10X1-.381X2+.679X3-2.31X5+1.63
8+10=X5	Y=-.172X1+.885X2+.125X3-.263X4+.697
GENERAL	Y=.2X1+.2X2+.2X3+.2X4+.2X5+1.9E-13

6.0 FIELD AND LABORATORY DATA ANALYSIS

6.1 CHEMICAL ANALYSIS RESULTS

A total of 63 sampling points were used to determine the areal distribution and associated concentrations of metals in the zone of accumulation. In addition, up to 26 samples were analyzed for one or more soluble fraction metals in the 0- to 1-foot interval. In 30 borings, soil samples were analyzed for soluble metals in the 1- to 2-foot interval. Two types of data evaluation are presented in this section: computer-aided data contouring and statistical analysis of individual observations.

Data contouring allows for physical interpretation of chemical distribution over the entire grid. It can be performed in two or three dimensions. Three fundamental aspects of statistics are used to quantify the level of risk to human health and the environment associated with any given concentration when compared to established statutory guidelines and environmental health standards. The following three components are considered:

- Measures of location
  - Mean
- Quantiles
  - Percentiles
  - Median
- Measures of variability
  - Range
  - Variance
  - Standard deviation.

Data were accumulated and synthesized using the microcomputer software spreadsheet package Lotus 1-2-3®. Frequency distribution diagrams and histograms presented in the following discussion were generated from Lotus 123. Another software package called SURFER® was employed to generate three-dimensional contour plots of the two sampling layers and all lithologic data. Statistics cited were produced by PC SAS®, a widely used and documented statistics software package.

The benchmark against which all chemical sampling and analysis are tested includes total and STLC values for each metal compound as presented in California Administrative Code (CAC) Title 22, Chapter 15.

Total concentration of heavy metals is not routinely determined by any state regulatory agency in Mare Island Strait or in San Pablo Bay. Soluble metals in San Pablo and Suisun bays are periodically checked, and reference background values were presented in Section 3.0. It can be seen from the background values that in the water column only trace concentrations are found because the vast volume of water in the bays has the ability to potentially dilute large quantities of soluble chemicals. Therefore, it is reasonable to assume that elevated levels of heavy metals detected at the 900 Area are by-products of the sandblasting operations and subsequent runoff.

The quantities and area distribution of chromium, zinc, copper, lead, and nickel were evaluated in discrete layers: 0 to 1 foot and 1 to 2 feet. Sixty-two observations were made in the upper 1 foot of the 525-foot by

300-foot grid. Sixty-three observations were made in the 1- to 2-foot interval. Individual observation results for total metals in the two layers are given in Tables 6-1 and 6-2. Simple measures of location and variability are presented in Table 6-3.

The California WET was performed on selected samples to determine the fraction of each metal which may be available in soluble form. This information is used in two ways: (1) comparison against Title 22 STLC limits and (2) risk assessment with appropriate reference to the Bay Area water quality control plan in the State Water Code. The rationale for specific locations tested has been previously discussed in Section 4.0. A compilation of all soluble data is given in Tables 6-4 and 6-5.

6.1.1 Chromium

The highest concentration of any metal in both layers is chromium. Chromium in surface sediments ranges from a low of 18.8 milligram/kilogram (mg/kg) to a high of 3,790 mg/kg. In the 1- to 2-foot interval, chromium ranges from 17.2 to 5,340 mg/kg. The mean concentration in all soils is less than 1,100 mg/kg. There is a large amount of variability in the data as evidenced by a variance of 1×10^6. The standard deviation about the mean is 1,146 mg/kg, which means 63 percent of the data points lie between 0 and 2,300 mg/kg.

Referring to Table 4-1, chromium is the third most abundant metal in both virgin and spent abrasive material with 118 and 131 mg/kg, respectively. Iron is an order of magnitude greater and nickel is approxi-

Table 6-1. Total Metals in Soils From 0-1 Foot Deep

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/kg	COPPER mg/kg	LEAD mg/kg	NICKEL mg/kg	ZINC mg/kg	SAMPLE ID-NO.
1	B21	525.00	300.00	100.00	60.70	206.00	7.20	882.00	MI04B21-1
2	B18	450.00	300.00	18.80	29.60	10.90	25.60	73.20	MI04B18-1
3	B16	400.00	300.00	78.30	49.00	108.00	7.30	804.00	MI04B16-1
4	E14	350.00	225.00	343.00	103.00	1466.00	154.00	797.00	MI04E14-1
5	E18	450.00	225.00	1950.00	195.00	214.00	590.00	720.00	MI04E18-1
6	E12	300.00	225.00	1530.00	173.00	317.00	783.00	692.00	MI04E12-1
7	E16	400.00	225.00	3790.00	160.00	74.90	1500.00	286.00	MI04E16-1
8	E10	250.00	225.00	1010.00	74.20	59.80	443.00	199.00	MI04E10-1
9	E21	525.00	225.00	2370.00	374.00	175.00	785.00	893.00	MI04E21-1
10	G10	250.00	175.00	1240.00	641.00	73.20	708.00	254.00	MI04G10-1
11	G14	350.00	175.00	2020.00	164.00	98.00	1040.00	302.00	MI04G14-1
12	G07	175.00	175.00	48.30	132.00	219.00	13.40	521.00	MI04G07-1
13	G19	475.00	175.00	480.00	412.00	59.30	255.00	150.00	MI04G19-1
14	G17	425.00	175.00	36.20	24.30	30.50	29.80	69.50	MI04G17-1
15	G13	325.00	175.00	2080.00	196.00	74.40	1020.00	303.00	MI04G13-1
16	G01	25.00	175.00	156.00	92.90	92.40	96.70	250.00	MI04G01-1
17	G12	300.00	175.00	2190.00	179.00	80.80	954.00	282.00	MI04G12-1
18	G04	100.00	175.00	242.00	120.00	58.20	129.00	270.00	MI04G04-1
19	G22	550.00	175.00	58.20	26.60	34.70	22.20	69.40	MI04G22-1
20	H11	275.00	150.00	2310.00	160.00	84.50	953.00	283.00	MI04H11-1
21	H15	375.00	150.00	62.90	46.20	37.70	40.70	84.30	MI04H15-1
22	H13	325.00	150.00	1920.00	165.00	71.60	1800.00	249.00	MI04H13-1
23	H09	225.00	150.00	2810.00	119.00	55.40	1240.00	316.00	MI04H09-1
24	H17	425.00	150.00	32.90	30.30	35.00	27.40	83.50	MI04H17-1
25	I11	275.00	125.00	2010.00	175.00	79.00	1060.00	223.00	MI04I11-1
26	I10	250.00	125.00	1700.00	130.00	52.60	1300.00	232.00	MI04I10-1
27	I12	300.00	125.00	97.20	54.50	20.00	47.00	98.40	MI04I12-1
28	I09	225.00	125.00	1490.00	240.00	1250.00	2360.00	697.00	MI04I09-1
29	I01	25.00	125.00	136.00	86.20	42.10	115.00	187.00	MI04I01-1
30	I13	325.00	125.00	2140.00	160.00	63.40	955.00	248.00	MI04I13-1
31	I16	400.00	125.00	182.00	54.90	31.80	98.10	88.10	MI04I16-1
32	I07	175.00	125.00	2740.00	147.00	29.10	886.00	150.00	MI04I07-1
33	I15	375.00	125.00	123.00	38.00	18.30	74.80	78.60	MI04I15-1
34	I14	350.00	125.00	2240.00	119.00	94.10	1170.00	236.00	MI04I14-1
35	I19	475.00	125.00	24.00	79.50	71.20	20.40	127.00	MI04I19-1
36	J11	275.00	100.00	2060.00	150.00	61.90	990.00	217.00	MI04J11-1
37	J09	225.00	100.00	2100.00	320.00	119.00	1100.00	428.00	MI04J09-1
38	J04	100.00	100.00	155.00	82.80	42.40	112.00	177.00	MI04J04-1
39	J17	425.00	100.00	1800.00	316.00	225.00	580.00	735.00	MI04J17-1
40	J15	375.00	100.00	1670.00	145.00	60.80	544.00	123.00	MI04J15-1
41	J22	550.00	100.00	23.80	40.50	67.90	21.50	105.00	MI04J22-1
42	J13	325.00	100.00	24.10	21.00	12.60	37.50	43.70	MI04J13-1
43	K07	175.00	75.00	2010.00	130.00	64.21	644.00	271.00	MI04K07-1
44	K17	425.00	75.00	817.00	121.00	192.00	259.00	482.00	MI04K17-1

Table 6-1. (Continued)

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/kg	COPPER mg/kg	LEAD mg/kg	NICKEL mg/kg	ZINC mg/kg	SAMPLE ID-NO.
45	K16	400.00	75.00	1340.00	135.00	48.10	729.00	164.00	MI04K16-1
46	K09	225.00	75.00	1580.00	200.00	68.60	1650.00	305.00	MI04K09-1
47	K10	250.00	75.00	3270.00	256.00	99.90	1780.00	481.00	MI04K10-1
48	K14	350.00	75.00	2100.00	264.00	181.00	724.00	228.00	MI04K14-1
49	K12	300.00	75.00	1400.00	248.00	77.50	1360.00	166.00	MI04K12-1
50	K19	475.00	75.00	655.00	110.00	123.00	187.00	330.00	MI04K19-1
51	L17	425.00	50.00	175.00	59.70	176.00	65.70	340.00	MI04L17-1
52	L13	325.00	50.00	1650.00	125.00	47.30	540.00	163.00	MI04L13-1
53	L11	275.00	50.00	1400.00	169.00	120.00	438.00	435.00	MI04L11-1
54	L15	375.00	50.00	66.20	29.40	69.70	23.40	238.00	MI04L15-1
55	L09	225.00	50.00	1170.00	109.00	40.70	1020.00	166.00	MI04L09-1
56	M09	225.00	25.00	193.00	52.10	48.20	69.90	135.00	MI04M09-1
57	M13	325.00	25.00	156.00	64.70	171.00	81.50	255.00	MI04M13-1
58	M15	375.00	25.00	110.00	78.30	129.00	65.60	410.00	MI04M15-1
59	M11	275.00	25.00	134.00	85.60	66.40	132.00	225.00	MI04M11-1
60	M07	175.00	25.00	364.00	82.80	72.70	144.00	213.00	MI04M07-1
61	M19	475.00	25.00	88.30	86.80	63.50	84.90	203.00	MI04M19-1
62	M17	425.00	25.00	112.00	120.00	102.00	89.70	303.00	MI04M17-1

Table 6-2. Total Metals in Soils from 1-2 Feet Deep

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/kg	COPPER mg/kg	LEAD mg/kg	NICKEL mg/kg	ZINC mg/kg	SAMPLE ID-NO.
1	B16	400.00	300.00	79.60	55.40	32.80	63.80	102.00	MI04B16-2
2	B21	525.00	300.00	115.00	25.30	23.50	15.60	722.00	MI04B21-2
3	B18	450.00	300.00	20.80	31.50	15.60	26.80	72.90	MI04B18-2
4	E12	300.00	225.00	93.70	60.10	34.30	76.00	95.70	MI04E12-2
5	E21	525.00	225.00	2960.00	311.00	228.00	822.00	725.00	MI04E21-2
6	E14	350.00	225.00	387.00	117.00	80.20	186.00	194.00	MI04E14-2
7	E10	250.00	225.00	472.00	53.00	36.50	198.00	126.00	MI04E10-2
8	E16	400.00	225.00	210.00	94.20	51.70	90.70	112.00	MI04E16-2
9	E18	450.00	225.00	455.00	55.80	179.00	119.00	642.00	MI04E18-2
10	G13	325.00	175.00	1940.00	407.00	82.30	1480.00	303.00	MI04G13-2
11	G07	175.00	175.00	42.20	102.00	292.00	11.50	403.00	MI04G07-2
12	G10	250.00	175.00	2160.00	356.00	103.00	1400.00	307.00	MI04G10-2
13	G22	550.00	175.00	57.50	51.60	48.40	33.20	103.00	MI04G22-2
14	G12	300.00	175.00	1990.00	189.00	73.70	1280.00	301.00	MI04G12-2
15	G19	475.00	175.00	27.80	27.70	43.80	21.20	120.00	MI04G19-2
16	G14	350.00	175.00	2090.00	216.00	61.90	861.00	211.00	MI04G14-2
17	G15	375.00	175.00	889.00	128.00	45.80	386.00	142.00	MI04G15-2
18	G16	400.00	175.00	23.70	26.50	28.30	23.40	70.30	MI04G16-2
19	G17	425.00	175.00	29.30	33.20	36.10	30.80	103.00	MI04G17-2
20	G04	100.00	175.00	323.00	127.00	142.00	123.00	365.00	MI04G04-2
21	G01	25.00	175.00	110.00	84.60	61.20	125.00	275.00	MI04G01-2
22	H09	225.00	150.00	2570.00	141.00	85.5	1180.00	399.00	MI04H09-2
23	H11	275.00	150.00	2500.00	270.00	110.00	993.00	316.00	MI04H11-2
24	H15	375.00	150.00	109.00	54.30	15.40	5570.00	79.40	MI04H15-2
25	H13	325.00	150.00	1820.00	289.00	95.40	1280.00	267.00	MI04H13-2
26	H17	425.00	150.00	28.70	28.60	47.80	23.20	124.00	MI04H17-2
27	I16	400.00	125.00	90.30	28.00	10.50	133.00	38.10	MI04I16-2
28	I09	225.00	125.00	185.00	81.70	324.00	57.50	409.00	MI04I09-2
29	I13	325.00	125.00	2350.00	158.00	93.50	1020.00	402.00	MI04I13-2
30	I01	25.00	125.00	189.00	97.20	146.00	105.00	331.00	MI04I01-2
31	I14	350.00	125.00	2660.00	290.00	142.00	2470.00	529.00	MI04I14-2
32	I15	375.00	125.00	145.00	36.90	21.90	93.20	90.80	MI04I15-2
33	I12	300.00	125.00	1430.00	524.00	146.00	1310.00	688.00	MI04I12-2
34	I07	175.00	125.00	2480.00	127.00	25.50	782.00	122.00	MI04I07-2
35	I17	425.00	125.00	133.00	40.30	25.70	178.00	79.80	MI04I17-2
36	I11	275.00	125.00	2470.00	145.00	69.00	1810.00	248.00	MI04I11-2
37	I19	475.00	125.00	126.00	38.60	24.60	208.00	71.60	MI04I19-2
38	I10	250.00	125.00	5340.00	126.00	147.00	2400.00	441.00	MI04I10-2
39	J17	425.00	100.00	719.00	86.90	141.00	208.00	607.00	MI04J17-2
40	J22	550.00	100.00	17.20	25.60	25.90	16.80	89.00	MI04J22-2
41	J13	325.00	100.00	2130.00	175.00	24.60	3180.00	137.00	MI094J13-
42	J15	375.00	100.00	2160.00	234.00	57.30	1050.00	275.00	MI04J15-2
43	J11	275.00	100.00	2290.00	157.00	57.80	1020.00	217.00	MI04J11-2
44	J04	100.00	100.00	160.00	66.70	125.00	61.70	251.00	MI04J04-2

Table 6-2. (Continued)

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/kg	COPPER mg/kg	LEAD mg/kg	NICKEL mg/kg	ZINC mg/kg	SAMPLE ID-NO.
45	K19	475.00	75.00	45.00	13.30	42.50	14.80	425.00	MI04K19-2
46	K07	175.00	75.00	4410.00	255.00	105.00	1340.00	420.00	MI04K07-2
47	K14	350.00	75.00	2440.00	255.00	71.60	897.00	235.00	MI04K14-2
48	K17	425.00	75.00	196.00	270.00	79.30	62.10	3080.00	MI04K17-2
49	K12	300.00	75.00	1060.00	135.00	125.00	377.00	358.00	MI04K12-2
50	K09	225.00	75.00	596.00	79.10	71.80	170.00	187.00	MI04K09-2
51	K10	250.00	75.00	1720.00	149.00	107.00	721.00	338.00	MI04K10-2
52	L15	375.00	50.00	113.00	88.10	119.00	76.50	325.00	MI04L15-2
53	L11	275.00	50.00	1080.00	57.80	58.70	331.00	211.00	MI04L11-2
54	L17	425.00	50.00	92.70	107.00	169.00	53.50	549.00	MI04L17-2
55	L13	325.00	50.00	4770.00	439.00	81.20	2590.00	401.00	MI04L13-2
56	L09	225.00	50.00	521.00	75.50	102.00	136.00	226.00	MI04L09-2
57	M13	325.00	25.00	133.00	94.20	123.00	90.00	263.00	MI04M13-2
58	M15	375.00	25.00	81.70	66.60	47.90	68.70	166.00	MI04M15-2
59	M07	175.00	25.00	152.00	78.00	57.00	98.90	195.00	MI04M07-2
60	M09	225.00	25.00	44.60	44.80	37.30	40.90	119.00	MI04M09-2
61	M11	275.00	25.00	136.00	77.00	55.70	88.20	219.00	MI04M11-2
62	M19	475.00	25.00	110.00	84.70	97.80	79.60	2852.00	MI04M19-2
63	M17	425.00	25.00	107.00	84.40	67.80	87.70	261.00	MI04M17-2

Table 6-3. Statistical Analysis: Total Metals and Soluble Metals

	METAL	CHROMIUM			COPPER			LEAD			NICKEL			ZINC		
	SAMPLE DEPTH	0-1	1-2	TOTAL	0-1	1-2	TOTAL	0-1	1-2	TOTAL	0-1	1-2	TOTAL	0-1	1-2	TOTAL
T	AVERAGE	1070.7	1022.0	1046.1	138.9	130.6	134.7	108.4	83.8	96.0	542.3	545.0	543.6	299.0	317.0	308.1
O	COUNT	62.0	63.0	125.0	62.0	63.0	125.0	62.0	63.0	125.0	62.0	63.0	125.0	62.0	63.0	125.0
T	MAXIMUM	3790.0	5340.0	5340.0	641.0	524.0	641.0	1250.0	324.0	1250.0	2360.0	3180.0	3180.0	893.0	3080.0	3080.0
A	MINIMUM	18.8	17.2	17.2	21.0	13.3	13.3	10.9	10.5	10.5	7.2	11.5	7.2	43.7	38.1	38.1
L	STANDARD DEVIATION	1000.4	1273.5	1146.5	106.3	110.0	120.4	158.4	61.5	120.4	565.9	733.7	655.9	213.8	389.9	315.2
	VARIANCE	1E+06	2E+06	1E+06	11298.6	12105.9	14496.9	3E+04	4E+03	1E+04	3E+05	5E+05	4E+05	5E+04	2E+05	1E+05
S	AVERAGE	8.0	8.3	8.2	5.9	8.4	7.6	5.1	4.9	5.0	9.4	8.6	9.0	38.0	35.8	37.1
O	COUNT	1.0	8.0	9.0	5.0	10.0	15.0	26.0	29.0	55.0	16.0	16.0	32.0	6.0	4.0	10.0
L	MAXIMUM	8.0	14.0	14.0	24.0	30.0	30.0	13.0	28.0	28.0	18.0	13.0	18.0	55.0	63.0	63.0
U	MINIMUM	8.0	3.5	3.5	0.4	0.2	0.2	1.3	0.8	0.8	3.8	4.6	3.8	23.0	12.0	12.0
B	STANDARD DEVIATION	0.0	3.9	3.7	9.1	8.5	8.8	3.5	5.5	4.6	3.7	2.3	3.1	10.3	19.4	14.7
L	VARIANCE	0E+00	2E+01	1E+01	8E+01	7E+01	8E+01	1E+01	3E+01	2E+01	1E+01	5E+00	1E+01	1E+02	4E+02	2E+02
E																

*values in mg/kg (total)
mg/l (soluble)

Table 6-4. Soluble Metals in Soils From 0-1 Foot Deep

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/l	COPPER mg/l	LEAD mg/l	NICKEL mg/l	ZINC mg/l	SAMPLE ID-NO.
1	B16	400.00	300.00			3.00		34.00	MI04B16-1
2	B21	525.00	300.00			12.00		47.00	MI04B21-1
3	E12	300.00	225.00			3.80	14.00	23.00	MI04E12-1
4	E14	350.00	225.00			6.50		33.00	MI04E14-1
5	E18	450.00	225.00			8.40	3.80	36.00	MI04E18-1
6	E21	525.00	225.00		24.00	13.00	5.70	55.00	MI04E21-1
7	G01	25.00	175.00			1.40			MI04G01-1
8	G07	175.00	175.00			11.00			MI04G07-1
9	G12	300.00	175.00			6.40	8.50		MI04G12-1
10	G14	350.00	175.00			6.20	7.60		MI04G14-1
11	H11	275.00	150.00			7.10	8.60		MI04H11-1
12	I09	225.00	125.00			9.60	12.00		MI04I09-1
13	I11	275.00	125.00			9.20	8.60		MI04I11-1
14	I14	350.00	125.00			5.00	5.10		MI04I14-1
15	J09	225.00	100.00		1.30	1.90	6.90		MI04J09-1
16	J17	425.00	100.00		2.20	2.70	8.00		MI04J17-1
17	K10	250.00	75.00		0.39	2.80	18.00		MI04K10-1
18	K12	300.00	75.00			4.80	15.00		MI04K12-1
19	K14	350.00	75.00		1.40	3.10	11.00		MI04K14-1
20	K17	425.00	75.00			3.10	6.90		MI04K17-1
21	K19	475.00	75.00			2.50			MI04K19-1
22	L11	275.00	50.00			1.4	10.00		MI04L11-1
23	L17	425.00	50.00			2.00			MI04L17-1
24	M13	325.00	25.00			2.40			MI04M13-1
25	M15	375.00	25.00			1.30			MI04M15-1
26	M17	425.00	25.00			1.40			MI04M17-1

Table 6-5. Soluble Metals in Soils From 1-2 Feet Deep

SAMPLE NO.	GRID LOCATION	X-COORD ft.	Y-COORD ft.	CHROMIUM mg/l	COPPER mg/l	LEAD mg/l	NICKEL mg/l	ZINC mg/l	SAMPLE ID-NO.
1	E14	350.00	225.00			2.40			MI04E14-2
2	E18	450.00	225.00			8.00			MI04E18-2
3	E21	525.00	225.00	14.00	30.00	15.00	5.60	63.00	MI04E21-2
4	G04	100.00	175.00			3.60			MI04G04-2
5	G07	175.00	175.00			3.80			MI04G07-2
6	G10	250.00	175.00		6.50	6.60	6.20		MI04G10-2
7	G14	325.00	175.00		6.50	5.60	10.00		MI04G14-2
8	H09	225.00	150.00	3.50		5.20	9.80		MI04H09-2
9	M11	275.00	150.00		9.00	6.60	8.00		MI04M11-2
10	H13	325.00	150.00		5.60	5.40	8.50		MI04H13-2
11	I01	25.00	125.00			1.20			MI04I01-2
12	I09	225.00	125.00			8.50		24.00	MI04I09-2
13	I10	250.00	125.00	3.80		28.00	9.80		MI04I10-2
14	I12	300.00	125.00		14.00	4.40	5.10		MI04I12-2
15	I13	325.00	125.00	14.00		6.50	11.00		MI04I13-2
16	I14	350.00	125.00	8.20	12.00	11.00	7.20		MI04I14-2
17	J04	100.00	100.00			2.90			MI04J04-2
18	J17	425.00	100.00			3.70	8.80	12.00	MI04J17-2
19	K07	175.00	75.00	9.70	0.27	1.50	8.30		MI04K07-2
20	K10	250.00	75.00	7.80		1.00	9.30		MI04K10-2
21	K12	300.00	75.00			2.30	12.00		MI04K12-2
22	K17	425.00	75.00		0.22	1.8		44.00	MI04K17-2
23	L09	225.00	50.00			1.00			MI04L09-2
24	L11	275.00	50.00			1.10	4.60		MI04L11-2
25	L13	325.00	50.00	5.20	0.37	1.60	13.00		MI04L13-2
26	L15	375.00	50.00			0.90			MI04L15-2
27	L17	425.00	50.00			2.60			MI04L17-2
28	M13	325.00	25.00			1.00			MI04M13-2
29	M19	475.00	25.00			0.80			MI04M19-2

mately four times more prevalent. The U.S. Geological Survey (1984) has performed a comprehensive survey of natural metal content in shallow soils throughout the United States. Natural chromium may be present at levels up to 2000 mg/kg. The 900 Area is underlain by engineered fill to varying degrees. If locations B16 and B18 are considered local background levels because they are overlain by impervious asphalt, then a more specific range of natural concentrations may be ascertained. Chromium in these borings range from 18 to 79 mg/kg, which is close to the mean concentration of 51 mg/kg published by the U.S. Geological Survey (1984).

Another comparison of site data is the CAC Title 22 Total Threshold Limit Concentration (TTLC) values. Four locations in surface sediments and six locations at depth exceeded the TTLC value of 2,500 mg/kg; only four values were found above 3,000 mg/kg. Less than 8 percent of all observations are higher than the TTLC as evidenced in Figure 6-1 for shallow and subsurface samples, respectively. The highest concentration of chromium is centered around the wooden bulkheads between lines I and J which act as retardants to sediment transport. Six of the ten observations above 2,500 mg/kg are found in the bulkhead core area, two on line E (E16, E21) at the asphalt beach interface, and two in tidal water influenced line K (K07, K10).

A similar pattern of deposition is evident for both layers. Deposition increases rapidly from the point where the asphalt ends and peaks along line I coincident with the bulkheads, as can be seen on concentration

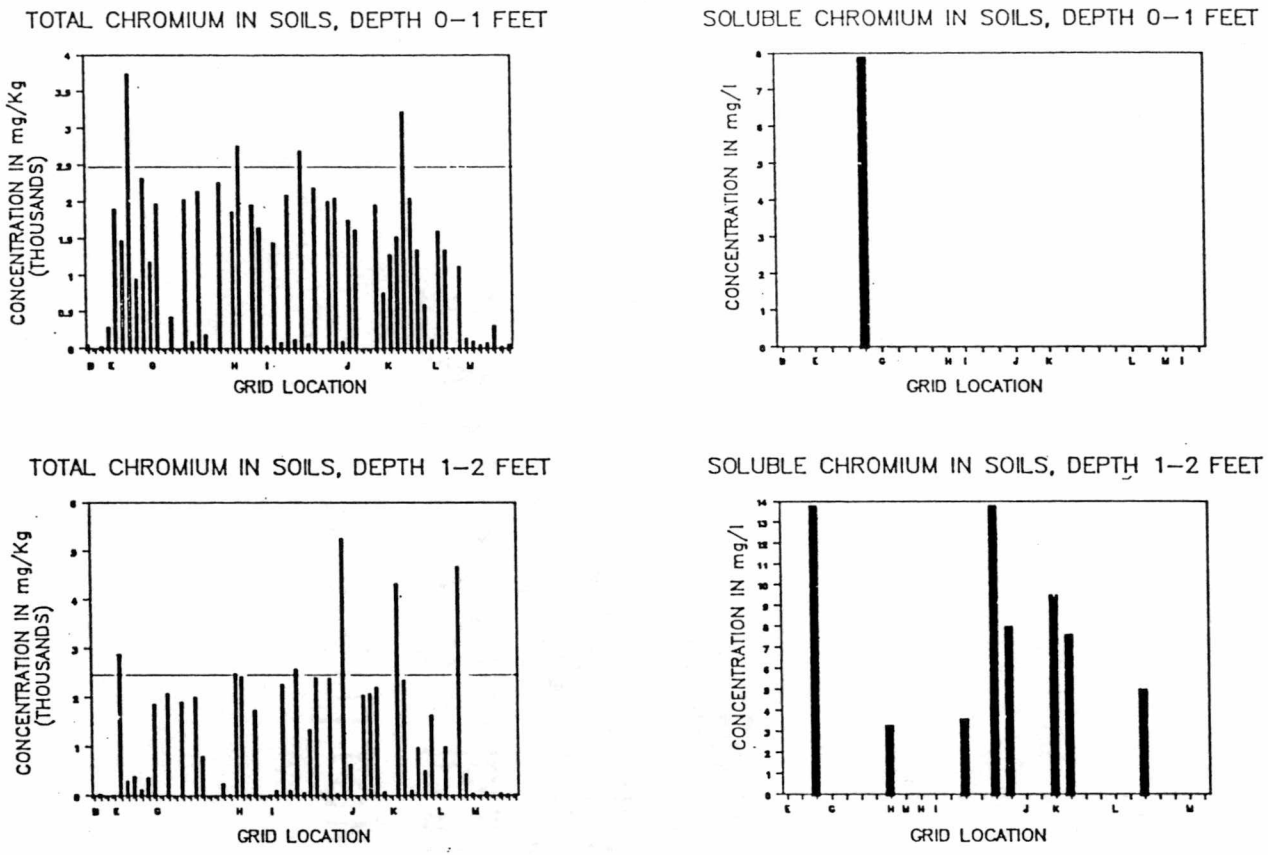
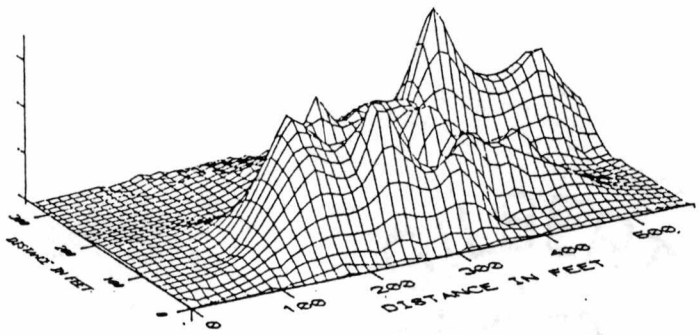


Figure 6-1. Chromium in Soils

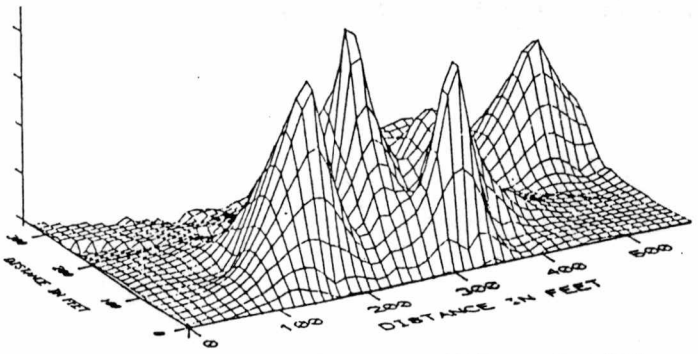
contour plots (Figure 6-2). Washout of sediment beneath the bulkheads or overtopping during large storms creates a sharply decreasing amount of chromium at the point where tides influence the velocity of sediment being transported overland.

Chromium exists in two oxidation states in aqueous systems: Cr(III) and Cr(VI). A distinction was not made between valence states in the analytical program. The hexavalent form is quite soluble, existing in solution as a complex anion, and is not sorbed to any significant degree by clays or hydrous metal oxides. Trivalent chromium reacts with aqueous hydroxide ion to form the insoluble chromium hydroxide $Cr(OH)_3$. It is the most stable form under redox conditions normally found in natural waters and sediments and, when in solution at pH greater than 5, quickly precipitates due to formation of the insoluble hydroxide or oxide.

One location in the uppermost layer was selected for analysis of soluble chromium, E21. This location coincides with the fifth highest reading for total chromium and lies along the bulkhead axis. A value of 8 mg/l was detected, well below the STLC limit of 25 mg/l. Eight extractions were performed in the lower layer coinciding with the highest concentrations of total chromium found and from both above the bulkhead line and bayside of the line. Results ranged from 3 to 14 mg/l again, all below the STLC. The highest values are found on the E and I lines which represent the transition from asphalt to barren soil and the bulkhead area, respectively. Almost all the chromium present in the 900 Area appears to be insoluble and, therefore, not available to most



MARE ISLAND - CHROMIUM, DEPTH 0-1 FEET



MARE ISLAND - CHROMIUM, DEPTH 1-2 FEET

Figure 6-2. Distribution of Chromium in Soils

environmental pathways. Frequency histograms for samples in both layers are provided in Figure 6-2.

6.1.2 Nickel

Nickel exhibits the second highest concentration of the five metals tested. A maximum total concentration of 2,360 mg/kg was detected in surface sediments, and a value of 3,180 mg/kg was found at the 1- to 2-foot interval. The lowest total value detected was 7.2 mg/kg and 11.5 mg/kg in the upper and lower layers, respectively. A mean of 543.6 mg/kg is well below the TTLC limit of 2,000 mg/kg for nickel. Similar to chromium, nickel exhibits the second highest dispersion in data with a standard deviation of 656 mg/kg. Only one data point (I09) exceeds the TTLC in the surface layer, and four points (I10, I14, J13, L13) are above the TTLC in the lower layer. This represents less than 4 percent of all the points sampled as shown in Figure 6-3. Location L13 is the sole point within saturated sediments where the TTLC was exceeded; the remainder lie along the bulkhead line.

Unlike chromium where much greater concentrations of the chemical were found in sampled sediments versus pure abrasive material, nickel concentrations are similar to parent greensand. Nickel in virgin and spent abrasives was measured at 453 and 693 mg/kg, respectively. It may be theorized that nickel in the sediments is a reflection of the parent material and chromium is a by-product of the paint or metal parts which are cleaned in the sandblasting process. This contention is further

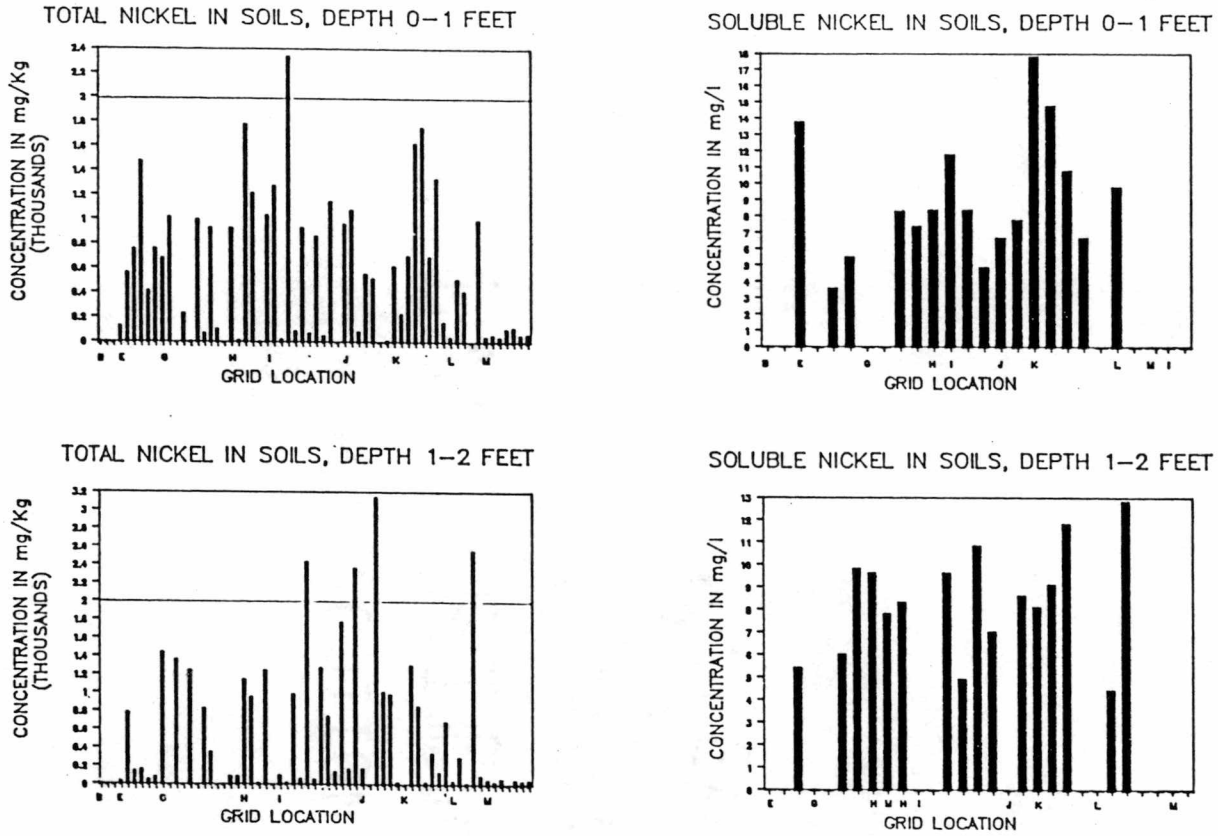
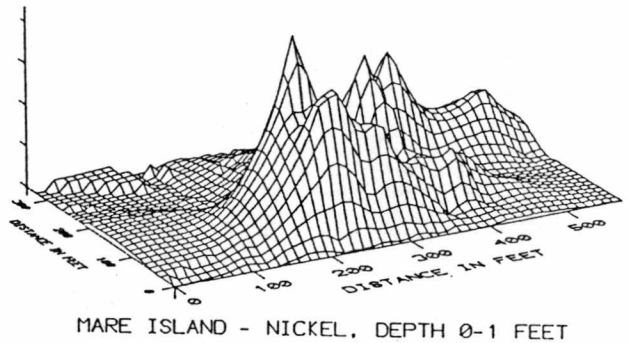


Figure 6-3. Nickel in Soils

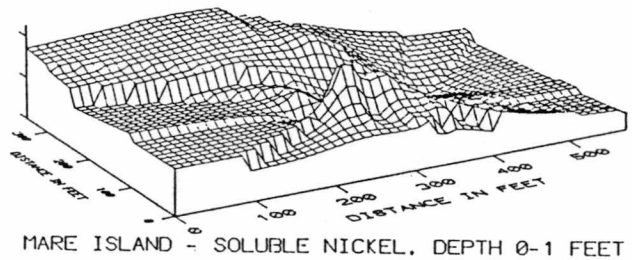
supported by the 7 to 63 mg/kg range of nickel found at background locations B16 and B18. These by-products are transported along with the abrasives to the beach area.

Although the source of nickel and chromium appear to be different, their areal distribution patterns are strikingly similar. This phenomenon is a function of clay or abrasive particle relationship with paint materials. Figure 6-4 depicts nickel distribution in three dimensions. Referring back to the plots for chromium, it can be noted that nickel similarly increases in concentration from the west to east across the flat barren soil above the beach. A maximum is reached at or near the bulkheads and decreases geometrically towards the water line. Nickel beyond the limits of the core area to the south is almost nonexistent. This observation suggests that leaching of nickel by virgin abrasive off of Subbasins 2 and 3 is minimal. Alternatively, the reason for low levels of nickel at the western edge of the sampling grid is that contamination is associated with paint flakes, not greensand, and only areas where sandblasting is performed may contribute metals to the environment. This observation appears consistent for all (total) metals analyzed.

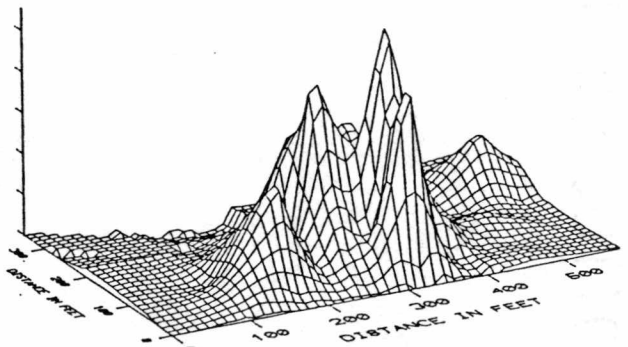
Thirty-two samples were analyzed for soluble nickel content, 16 in each layer. The maximum value detected was 18 mg/l and the minimum was 3.8 mg/l. Considering all 32 observations, a mean concentration of 9 mg/kg may be calculated. The spread of values was slight and fit a normal curve without significant bias in the tails. The total standard



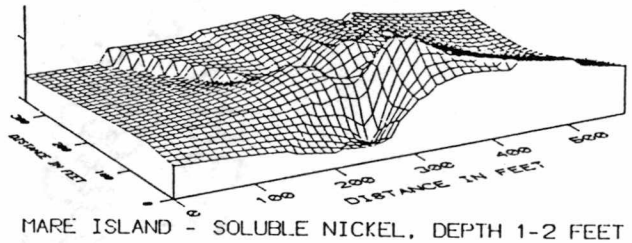
MARE ISLAND - NICKEL, DEPTH 0-1 FEET



MARE ISLAND - SOLUBLE NICKEL, DEPTH 0-1 FEET



MARE ISLAND - NICKEL, DEPTH 1-2 FEET



MARE ISLAND - SOLUBLE NICKEL, DEPTH 1-2 FEET

Figure 6-4. Distribution of Nickel in Soils

deviation is 3.1 and the variance is 10. Seventy-five percent of all observations were below 10 mg/l as evidenced on the histograms presented in Figure 6-3.

None of the observations exceeded the STLC limit of 20 mg/l. This presents a rather interesting condition because nickel is one of the most mobile heavy metals, and total nickel concentrations above 2,000 mg/l were detected. In aerobic environments below pH 9 such as in the estuarine waters, soluble compounds of nickel are formed with numerous anions and organics, including hydroxide, carbonate, sulfate, and humic acids. Humic acids, which are ubiquitous in natural waters in particular, have been shown to increase the solubility of nickel in water. One potential explanation for the unusual sorption of nickel is that the chemical is siderophilic and will alloy itself with metallic iron whenever such a phase is present. Recall from Table 4-1 that iron is the most abundant component in both new and spent abrasive. Nickel is only slightly miscible in iron and may be bound to the solids matrix. Enough locations were sampled to enable the plotting of general contours in both the upper and lower layers. A review of Figure 6-4 shows a even distribution of nickel throughout most of the sampling grid.

6.1.3 Copper

All total copper samples were below the TTLC of 1,000 mg/kg. The highest level found was 641 mg/kg at location G10, 0- to 1-foot depths. Only two samples showed concentrations above 500 mg/kg. Analytical results are graphed in the frequency histograms and pie charts in Figure 6-5 for both

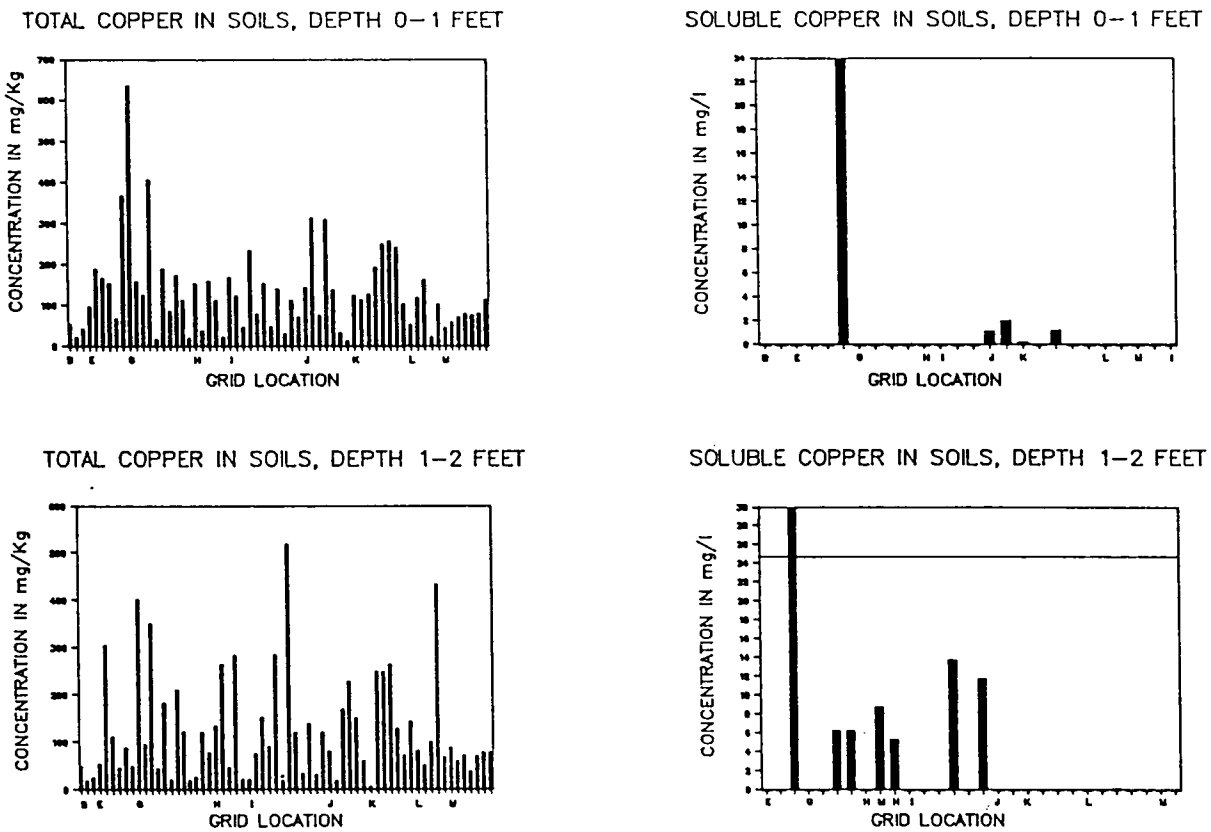
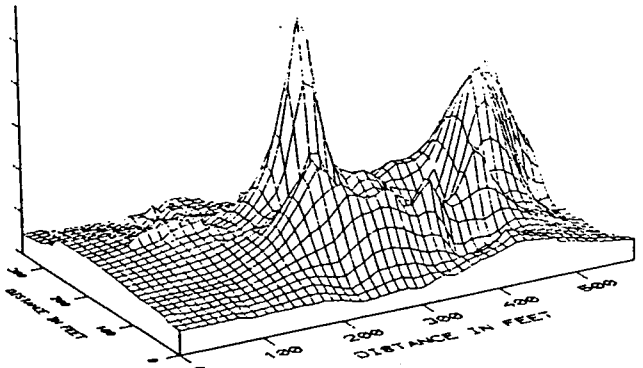


Figure 6-5. Copper in Soils

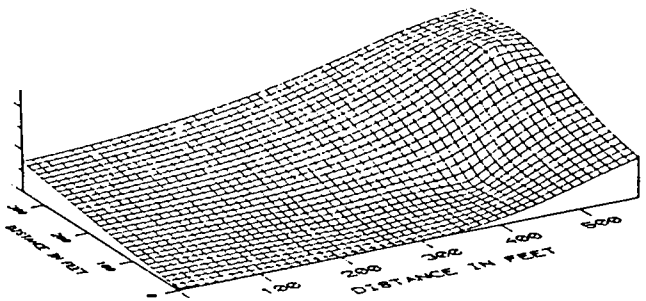
lyers. The distribution of data is tightly grouped about the sample mean of 130.4 mg/kg with a standard deviation of 61 mg/kg. Normal distribution is the most prominent in copper, having insignificant skewness and kurtosis values.

Minor amounts of copper were detected in the parent virgin and spent greensand (reference Table 4-1). Like chromium, copper levels may be coincident with the materials sandblasted rather than the greensand itself. The rate of copper addition to the beach area would then be a function of the types and frequency of materials undergoing blasting rather than erosion of abrasives and environmental media partitioning. When compared to chromium and nickel, areal distribution patterns of total copper are about the same. Figure 6-6 contours plots for both sampling layers. Distribution patterns for the two individual layers are also alike, supporting the contention that abrasives are strongly surface transport linked.

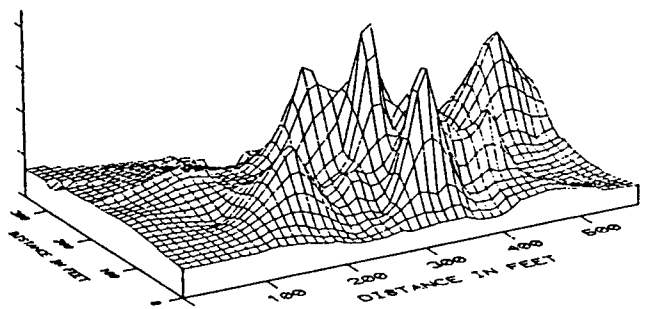
One sample analyzed for soluble copper in the 0- to 1-foot layer along line E was just below the STLC value. The sample contained 24 mg/l of copper versus the STLC of 25 mg/l. In the uppermost layer, the second highest soluble value detected was 2.5 or an order of magnitude less than the STLC (see Figure 6-5). In the lower layer, one sample did exceed the STLC with a value of 30 mg/l. None of the nine other locations tested for soluble copper contained the compound above 14 mg/l as shown in



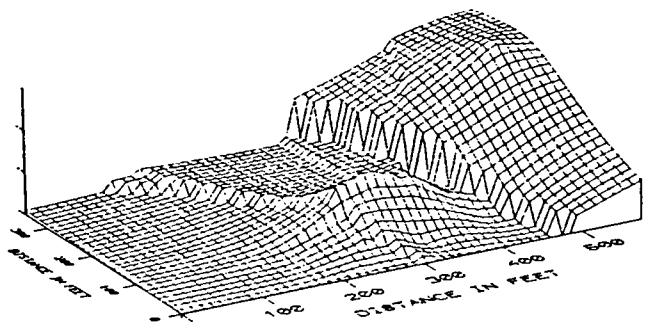
MARE ISLAND - COPPER, DEPTH 0-1 FEET



MARE ISLAND - SOLUBLE COPPER, DEPTH 0-1 FEET



MARE ISLAND - COPPER, DEPTH 1-2 FEET



MARE ISLAND - SOLUBLE COPPER, DEPTH 1-2 FEET

Figure 6-6. Distribution of Copper in Soils

Figure 6-5. The mean copper concentration in all 15 samples tested was 2.1 mg/l with a standard deviation of 5.7. The data are highly skewed towards the left probability curve tail (0 mg/l).

Sorption processes are quite active and efficient in scavenging dissolved copper and in controlling its mobility in natural unpolluted waters. In unpolluted water, the effectiveness of these processes varies according to pH, Eh, and the occurrence of potential sorption surfaces. Copper has a strong affinity for hydrous iron and manganese oxides, clays, carbonate minerals, and organic matter. Conversely, studies have shown that organic acids increase the solubility of copper in the presence of clay. Hence, an influx of soluble organic matter into the esturary will favor the prolonged dispersion of copper in solution. Some of this effect is caused by the lowering of the pH by acidic organics on a local scale. It may be theorized that constant transient movement of bay waters at a neutral pH will promote a highly buffered condition. This condition in turn may be the reason why in an estuarine environment soluble copper concentrations are very low.

A rough estimation of soluble copper distribution in the sampling layers was made. In the upper layer where five data points were used, available curve fitting techniques necessarily smooth contours by statistically averaged interpolation. Interpretation of such data must be made with caution. In the lower layer where ten points were used, the opposite effect of oversmoothing, which is blocking, may be seen because interpolation is sufficient to produce relevant localized contouring; however,

overall grid analysis is somewhat disjointed. Nevertheless, the graphics presented in Figure 6-6 support the general patterns of distribution seen in the four other metals. Concentrations of soluble copper are highest in the uppermost reach of the grid or along the bulkhead line.

6.1.4 Lead

Lead is second only to copper in the heavy metal group in its affinity to sorb onto soil particles. The tendency for lead to form complexes with naturally occurring organic materials (e.g., humic and fulvic acids) increases its adsorptive affinity for clays and other mineral surfaces. Gaddle and Laitmen (1973) demonstrated that hydrous iron oxides have a high sorption capacity for lead, sorbing as much as 91 percent of added lead at pH 8.1. It appears that, under most conditions, adsorption to clay and other mineral surfaces and incorporation into cationic lattice sites in crystalline sediments are also important sorption processes.

At one location (I09), total lead was found above the TTLC limit value of 1000 mg/kg. All other samples were less than one third the TTLC. The mean concentration of total lead is 96 mg/kg with only moderate dispersion as evidenced by a standard deviation of 120 mg/kg. Almost three quarters of all observations taken in the surface layer were below 100 mg/kg, and 26 percent were below 50 mg/kg. In the lower layer, 68 percent of the observations were below 100 mg/kg and 1/3 under 50 mg/kg. Figure 6-7 graphically depicts range and grouping of lead observations.

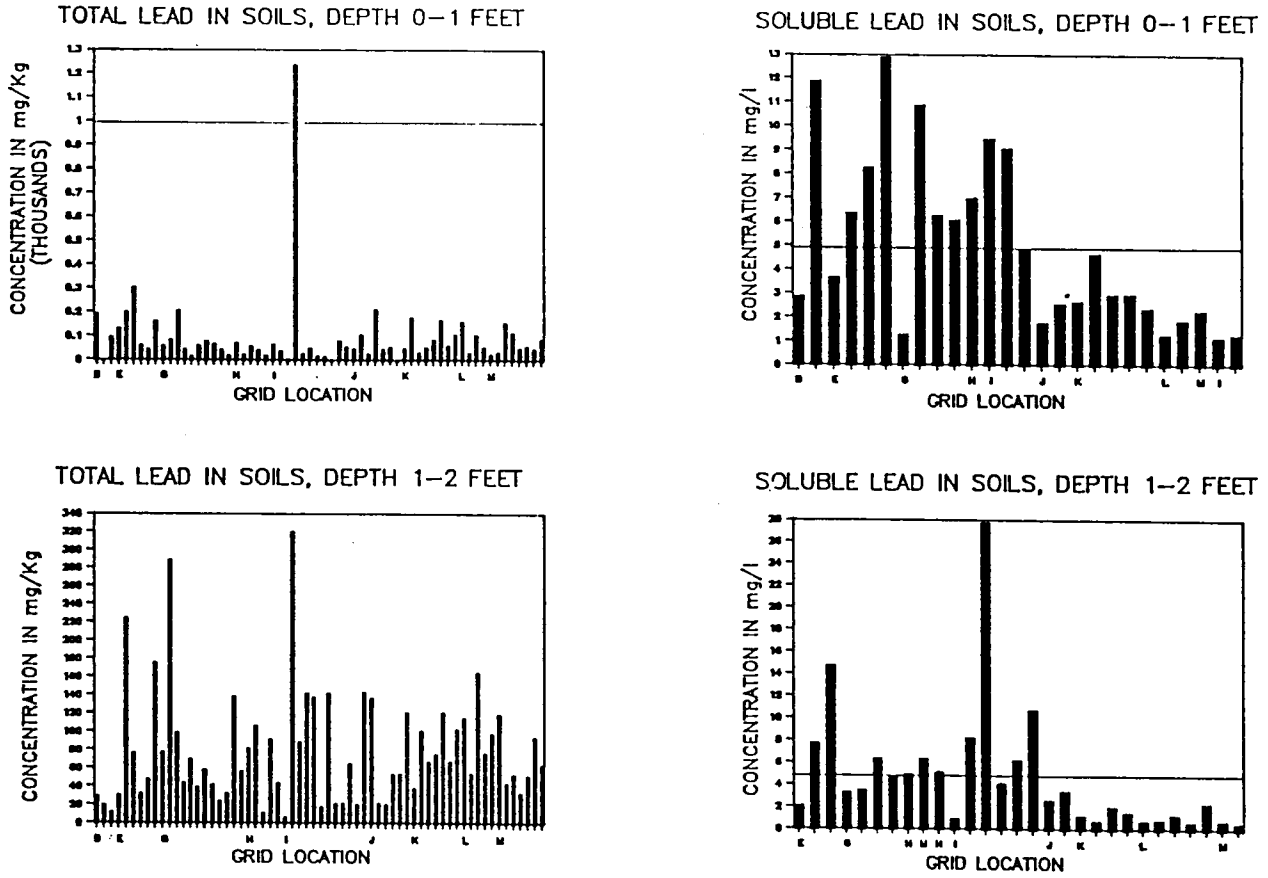
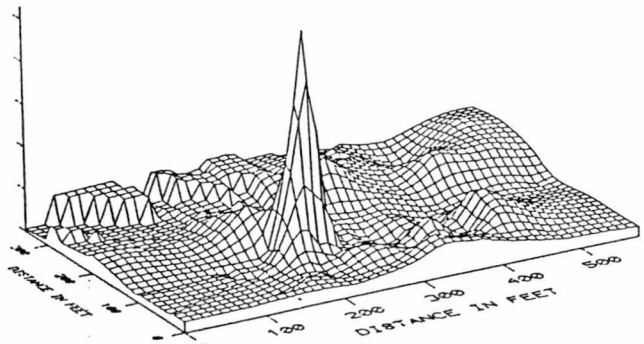


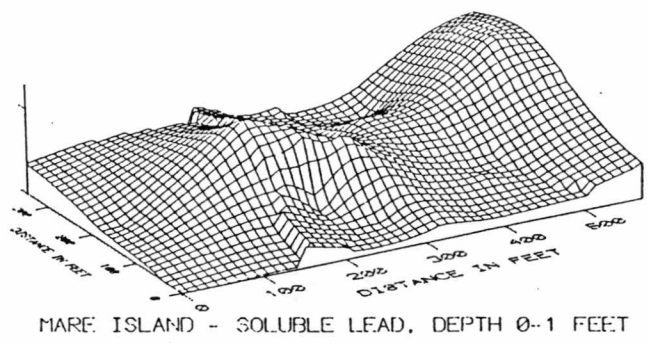
Figure 6-7. Lead in Soils

Lead was not detected in either new or spent greensand (refer to Table 4-1). Natural levels of lead in soils range from 10 to 700 mg/kg (U.S. Geological Survey, 1984). Lead is present in borings B16 and B18 between 15 and 108 mg/kg, which is consistent with the mean concentration of all samples (96). However, lead is a common component of paint, which is routinely sandblasted from ship parts at the 900 Area. Paint flakes may be seen infrequently in the greensand on the surface near the bulkheads when using a hand magnifying lense. Lead is also found in metal parts, and some of the lead present may emanate from the component storage area located in the north-central portion of the grid as noted in Figure 4-1. The levels of lead are noticeably higher in and near the storage area as shown on the contour plots (Figure 6-8). Except for the prominent peak in the 0- to 1-foot layer at I09, lead is largely confined to the area west of the bulkheads and almost nonexistent within the saturated sediments.

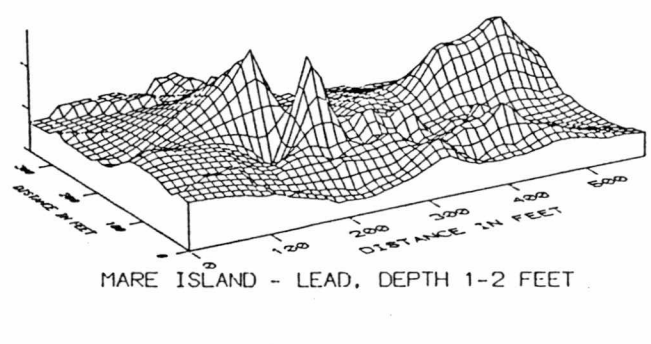
Fifty-six locations were tested for soluble lead: 26 points in the upper layer and 30 points in the lower layer. Consistent with the above discussion, lead was detected in similar concentrations with those of copper. The highest concentration of lead, 28 mg/l, was almost identical to the highest detected copper (30 mg/l). This one value found at location I10 in the lower layer is the only value greater than 15 mg/l. Values ranged from 28 to a low of 0.8 mg/l. The mean for all samples was 5.0 mg/kg with individual layer means of 4.8 mg/l (upper) and 5.1 mg/l



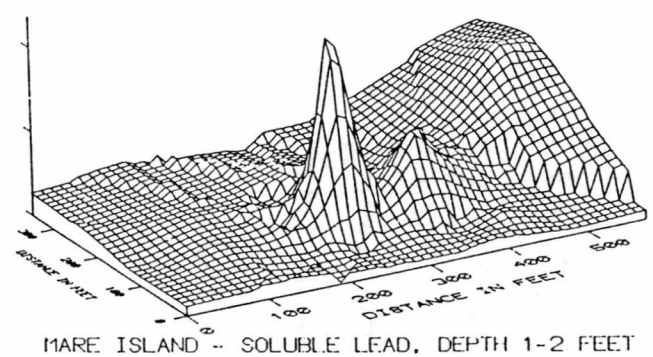
MARE ISLAND - LEAD, DEPTH 0-1 FEET



MARE ISLAND - SOLUBLE LEAD, DEPTH 0-1 FEET



MARE ISLAND - LEAD, DEPTH 1-2 FEET



MARE ISLAND - SOLUBLE LEAD, DEPTH 1-2 FEET

Figure 6-8. Distribution of Lead in Soils

(lower). Dispersion of data was tight as evidenced by a standard deviation of 4.6 and the second lowest variance of all metals with a value of 20.

Lead, when present, is a soluble form and has been proven to have the highest environmental significance of the five target metals. Lead has been given the lowest STLC limit of the metals in this study with 5.0 mg/kg. Upon review of the frequency histograms for both the upper and lower layers in Figure 6-7, it can be seen that 38.5 percent of the samples in the upper layer and 41.4 percent of the samples in the lower layer exceed the STLC. Recall, however, that the WET uses an acid solvent to remove metals from a soil matrix. It has been previously demonstrated that lead and copper are particularly stable in neutral environments found in the estuary at the 900 Area. The acid extraction significantly overestimates the amount of potentially soluble lead to the environment. The frequency of significant contamination appears small as only 6 of the 56 samples were found to be above 10 mg/l.

With a large number of data points selected, primarily because of the low action limit, a comprehensive contour plot of potentially soluble lead may be generated. Figure 6-8 depicts the distribution of lead in both layers. Consistent with the four previous metals, lead is most prevalent in the northwest corner of the sampling grid and steadily declines to the bulkhead line and is lowest in the tidally influenced part of the grid. Also consistent with all other metals, lead in the depositional areas of virgin greensand (southern section of the grid) is negligable. This

observation further substantiates the contention that materials such as paint intermixed with the greensand, not the greensand itself, is contributing metals to the environment.

6.1.5 Zinc

The TTLC limit for zinc is the highest of all the metals under consideration with a value of 5,000 mg/kg. In the surface layer, there were not any observations above 900 mg/kg as shown in the frequency histogram (Figure 6-9). In the second layer, one observation of 3,080 mg/kg was made but no other samples exhibited concentrations above 1,000 mg/kg (see Figure 6-9). The mean concentration of all samples is 308 mg/kg with a standard deviation of 315. The largest percentage of readings fell into the 100 to 500 mg/kg range with 71 percent and 73 percent of the upper and lower layer samples, respectively.

Slightly more than 4 mg/kg of total zinc was detected in new and spent abrasives samples. The typical range for zinc in western soils is 10 to 2,100 mg/l with a mean of 60 mg/kg (U.S. Geological Survey, 1984). Reviewing soils data for B16 and B18, natural zinc concentrations lie between 72 and 804 mg/l. This suggests that a significant percentage of zinc detected is associated with the natural soil composition.

Distribution of total zinc across the sampling grid is the most uniform of all the metals. It is generally highest in the uppermost bare soils and drops off markedly bayward from the bulkheads. Zinc distribution is

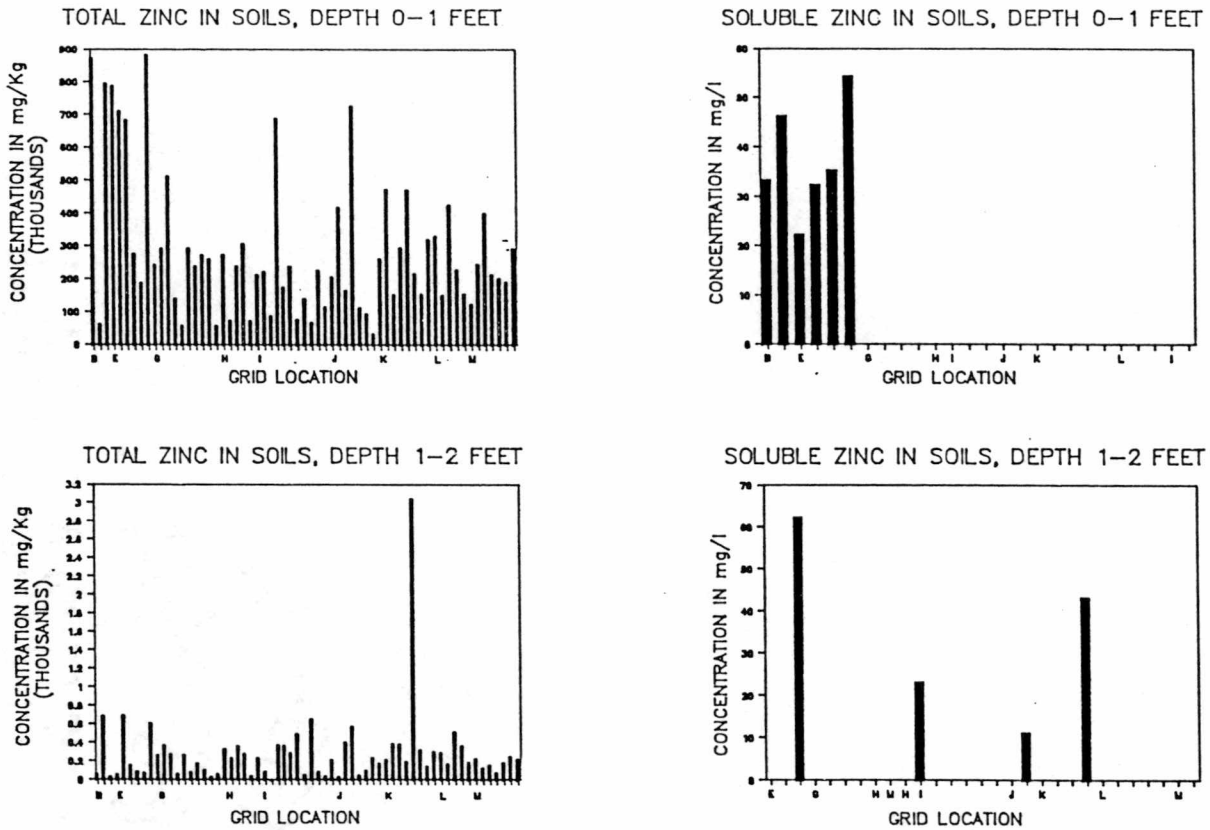
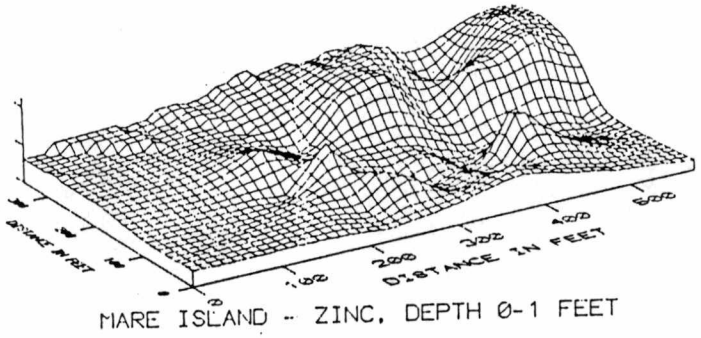


Figure 6-9. Zinc in Soils

plotted in Figure 6-10. This situation is consistent is both layers except for one spurious point east of the bulkheads in the lower layer also depicted in Figure 6-10.

Soluble zinc, as with total zinc, is not generally perceived to be a highly significant chemical from a health risk standpoint as evidenced by its 250 mg/l STLC limit. Under neutral pH conditions, zinc is more mobile than lead and copper but less mobile than nickel and chromium. In aqueous solution, zinc always has a valence of +2, and it exhibits amphoteric properties, dissolving in acids to form hydrated zinc cations and in strong bases to form zincate anions. Compounds of zinc with the common ligands of surface waters are soluble in neutral and acidic solutions, so that zinc is readily transported in most natural waters and is one of the more mobile of the heavy metals. This holds true at the 900 Area where soluble zinc as a percentage of total zinc detected averages almost 10 percent, more than twice the percentage of soluble to total lead.

Zinc is easily absorbed by clays and organics with organics having an overwhelming effect on the chemical form in which zinc will be present in polluted waters. Guy and Chakrabarti (1976), in their study of metal-organic interactions in natural waters, found that humic acids in solution and other natural complexing agents can maintain zinc ions in a bound form at a pH as low as 3. The release of zinc from sediments,



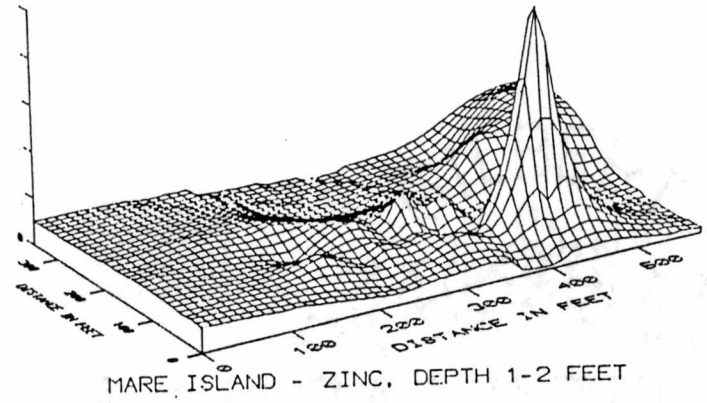


Figure 6-10. Distribution of Zinc in Soils

therefore, is apparently controlled by a combination of ion exchange and complex formation whereby the stability of the metal-organic complex determines the amount of metal solubilized.

Ten samples coincident with locations of highest total zinc were tested for soluble zinc fraction. Four of these samples were from the upper layer and six from the lower layer. None of the samples exceeded 65 mg/l, fully less than 25 percent of the STLC. Figure 6-9 presents histograms and pie charts of zinc observations. An insufficient number and distribution of sampling points precludes a valid contouring of the data. Considering that the values of zinc were far below an action level, further investigation of other locations exhibiting lower total zinc concentrations was deemed unwarranted. From the evidence presented here, it appears zinc in the 900 Area is a product of parent soils rather than a by-product of sandblasting operations.

6.2 GROUND WATER QUALITY

One background water quality sample was taken from beneath the asphalt at grid location B16. Results shown in Table 6-6 reflect minimal or no impact of blasting operations. Chromium and lead, the two most environmentally sensitive compounds, were not detected above quantification limits. All compounds are well below California standards for drinking water. In comparison to surface water quality in the North Bay, copper and zinc are significantly higher in the ground water than in the

Table 6-6. Total Metals in Ground Water (µg/l)

Sample number	1
Sample identification number	4B16-1-0
Grid location	B16
X-Coordinate	400
Y-Coordinate	300
Chromium	<5.0
Copper	34.4
Lead	<3.0
Nickel	95.4
Zinc	96.8

receiving stream. Copper was detected in ground water at 34.4 µg/l and at 10 µg/l in San Pablo Bay. Zinc was found to be 96.8 µg/l in ground water versus 10 µg/l in the Bay.

The origin of the copper and zinc components is not well understood. Reviewing the mineralogical data in Appendix D, soils and fill material are predominantly alumino-silicates. Zinc was not found to be present in the soils to a significant level, and copper was found in only one of the five samples and then only accounted for 7 percent of the elemental composition. Two plausible explanations exist for the presence of these compounds: (1) heterogeneous fill used at the site may contain these compounds at that specific location (the occurrence is site unique) and (2) the chemicals are being transported from upgradient natural or man-made sources. The most likely answer rests with the heterogeneous nature of the fill placed at the site for more than 50 years dating back to World War I.

6.3 SOLUBILITY OF METALS UNDER ENVIRONMENTAL CONDITIONS

Data previously discussed regarding the soluble fraction of metals in site soils may be overestimated. All testing for soluble metals was performed using the California WET. This particular test uses a 0.2 Molar Sodium Citrate solution as the solvent to extract metals from the solid matrix. The corresponding pH of the solvent is in the range of 4 to 5. Conversely, the average pH of Mare Island Strait water taken over a 24-hour period is approximately 7. Discussions pertaining to the

mobility of the target metals presented earlier show that these metals will dissolve into solution under acidic conditions but are stable under neutral conditions.

A bench test was devised to evaluate the significance of the acidic pH used in the WET test versus the neutral pH of the true solvent, surface, and ground water at the site. A sample each of virgin and spent greensand was collected from the 900 Area and shipped to the IT Corporation Cerritos laboratory in southern California. There each sample underwent three discrete analyses:

- Total digestion using a strong acid
- Soluble metals content using the WET test
- Soluble metals content using water as a solvent.

By totally digesting the solid sample, the maximum content of a given metal in the solid matrix is determined. Digestion or leaching by any less acidic solvent will produce some fraction of the total amount in the sample. Performing the two extractions using the acidic WET test and an identical test only using neutral tap water will determine the effect of pH on apparent solubility. Metals were analyzed using inductively coupled argon plasma emission spectroscopy according to EPA method SW 846-6010. The total digestion method used was EPA SW 846-3550.

In addition to analyzing for metals, general wet chemistry parameters were also run. The general chemistry parameters were extracted using tap water as a solvent. These parameters included alkalinity, bicarbonate, carbonate, chloride, fluoride, nitrate, nitrite, phosphate, and

sulfate. The purpose of establishing these values was to aid in evaluating the form in which the metals may be bound in the solid. Certain combinations of metal hydroxides and halides will move more readily into solution than will other forms of compounds.

Results of the three analyses for metals are presented in Table 6-7. The results of the total concentration of the five target metals are significantly higher than the values given in Table 4-1. The values shown in Table 4-1 were generated by another contractor for the U.S. Navy, and the protocols used are not known. Because the numbers between new and spent greensand compare favorably, the tests used here are considered accurate. Total digestion numbers were converted from mg/kg to equivalent mg/l to make comparisons with the soluble data.

From reviewing the data, it can be readily seen that a marked difference between the WET extraction and the water extraction exists. Chromium using the WET method predicts that 1.5 mg/l of new greensand and 3.5 mg/l of spent greensand is soluble. Using a solvent which simulates site conditions, however, suggests that none of the chromium in the new greensand is soluble and only 0.02 mg/l of chromium in spent greensand is soluble. This represents two orders of magnitude difference. Soluble copper in spent greensand according to the WET method is 34 mg/l versus only 0.04 mg/l using water. Nickel which is the most abundant target metal in the abrasive is at most 1.1 percent soluble. If data from the

Table 6-7. Comparative Extraction Methods for Metals in Solids

Parameter	Method	Detection Limit[a]	Total Metals		Soluble Metals (pH 4)		Soluble Metals (pH 7)	
			New Greensand	Spent Greensand	New Greensand	Spent Greensand	New Greensand	Spent Greensand
Calcium	6010	5	930	2610	ND<50	ND<50	ND<5	ND<5
Chromium	6010	0.01	910	1590	1.5	3.5	ND<0.01	0.02
Copper	6010	0.03	12	400	ND<0.3	34	ND<0.03	0.04
Iron	6010	0.1	21700	38500	130	310	ND<0.1	0.3
Lead	6010	0.2	21	56	ND<2	3	ND<0.2	ND<0.2
Magnesium	6010	5	40600	62600	110	130	ND<5	ND<5
Nickel	6010	0.04	1280	1140	15	8.6	ND<0.04	ND<0.04
Potassium	6010	5	ND<300	ND<300	ND<50	ND<50	ND<5	ND<5
Sodium	6010	5	ND<300	ND<300	--	--	ND<5	ND<5
Zinc	6010	0.02	23	120	0.7	12	ND<0.02	0.03

[a]Detection limits are based upon concentration in the aqueous extract and are expressed in milligrams per liter. Detection limits may vary due to sample matrix.

ND - The analyte was not detected at or above the stated detection limit.

water extraction are used, nickel is totally insoluble under site conditions. Zinc too was found to be insoluble under environmental conditions yet was found to be as high as 12 mg/l in the WET test.

Data for the general water chemistry parameters are given in Table 6-8. It can be noted that alkalinity and carbonate concentrations are very low, suggesting only minor amounts of buffering capacity in the solid. With these levels the effect of adding acid on potential dissolution of metals is increased. The most abundant anion was sulfate which is to be expected since sulfate is very stable. All of the above tests were performed using EPA method 300 series upon extraction.

In summary, a significant disparity can be seen between apparent solubilities of all target metals when employing an acid solvent during extraction. The level of significance may be as high as two orders of magnitude and at a minimum of tenfold increase. Because all previous analyses and comparative interpretations of data have been based on WET test methods, a large amount of conservatism is present. The availability of metals to the estuarine setting in a dissolved form has probably been overestimated. Metals digested by organisms such as clams would not be relevant to this comparison.

6.4 ASSOCIATION MECHANICS OF PAINT FLAKES AND ABRASIVES

In the presentation of soil sampling results it was theorized that the predominant impact on the 900 Area was due to blasting residuals rather than the abrasives themselves. Paint once removed from the component or

Table 6-8. General Soluble Chemistry Parameters
Water Extraction

Parameter	Method	Units	New Greensand	Spent Greensand
Alkalinity	310.1	mg/l	8	18
Bicarbonate	310.1	mg/l	6.8	12
Carbonate	310.1	mg/l	1.2	5.7
Chloride	200.0	mg/l	6.4	30
Fluoride	300.0	mg/l	ND<2	ND<8
Nitrite	300.0	mg/l	ND<1	ND<2
Nitrate	300.0	mg/l	1.7	1.4
Sulfate	300.0	mg/l	46	15
Phosphate	300.0	mg/l	ND<2	ND<2

ND - The analyte was not detected at or above the stated detection limit.

part may be bound to the abrasive or loosely scattered on the ground. If the paint is attached to the spent abrasive, it may do so in one of two ways: physical attachment or chemical adsorption. Blasting equipment can generate particle velocities in excess of 200 miles per hour at close range. Heat generated during inertial impaction can cause adhesion of paint to the abrasive. Alternatively, if enough energy is created to catalyze a chemical reaction, paint may chemically interact with the abrasive. Intuitively, chemical bonding does not appear plausible, due to a lack of a suitable catalyst and short contact time, or at least it is insignificant in nature. Physical bonding, however, may be significant as bonding may occur during mixing in transport.

The mechanism by which paint and paint-related materials are associated with the abrasives has a direct bearing on their transportability and ultimate fate on the shoreline. Paint flakes merely tumbling with abrasives during runoff events will move farther and faster than their more dense sandlike counterparts. If the paint is bonded to the abrasive, then the paint will tend to move with the solid particle and can be modeled using standard methods for sediment transport such as those presented in Section 5.0. A benchtop test was derived to investigate how the paint is associated with the abrasive and to determine the type of bonding mechanism.

Two primary variables for the test were identified: turbulence and pH. Paint traveling randomly with solid grains will have a tendency to be collected in a liquid medium with only minor amounts of agitation. Paint

flakes bound to the greensand may be sheared into solution at high amounts of agitation. Metals will dissolve into solution at low pH values (acidic conditions) but will remain in the solid phase (if chemically bound) at neutral pH values. Hence, two states of agitation, mild and vigorous, were selected, and two pH levels were chosen pH 2 and pH 7. The acidic pH of 2 was chosen to provide enough dissolution potential for weakly bound paint but was inadequate to totally dissolve the solid greensand. Thus, four combinations of each test were performed.

Five sampling locations were chosen to represent the path of runoff over the watershed. Each location has been discussed in Section 4.4. It is sufficient to state here that Sample 1 was a greensand which had not been used. The remainder of the samples were collected from across the sampling grid. Sample 2 is the first location where a transition if made from asphalt to soil surface and where the grade flattens significantly. Sample 3 was taken at the bulkhead line where the highest amounts of deposition should occur due to the wooden logs. Sample 4 was taken immediately downgradient of the bulkhead but above the general tide level. Sample 5 was located in estuarine sediments subject to tidal action. The methods and procedures of the benchtop tests are provided in Section 4.5.

Results of the total digestion of each of the five samples are given in Table 6-9. It can be seen that, similar to the previous discussion on environmental solubility, an abundant amount of metals exists in each

Table 6-9. Initial Analysis of Metals in Bench Study Samples

Site ID	Total Metals (mg/kg dry soil)					Moisture (wt%)
	Nickel	Zinc	Copper	Chromium	Lead	
1	2466	41	23	1173	17	0.02
2	2238[a]	342[a]	241[a]	1963[a]	162[a]	6.70
3	912	364	171	1247	105	11.2
4	2499	445	454	3470	134	13.5
5	631	349	140	659	70	6.42

[a]Average of triplicate analysis.

sample. From this baseline, information salient to the relative insolubility of the abrasive/paint mixture can be supported. It should also be noted that the difference between the metals content of Sample 1 and the remaining samples is the sum of native metals in the parent soil and paint flakes or associated blasting residues.

Tables 6-10 and 6-11 present the results of the four different analyses performed on ten samples. By comparing digested data with soluble data, it can be readily seen that only a small fraction of metals become available to the environment. This further supports the original premise that a pH 2 solvent cannot dissolve abrasives. With the exception of two cases in Sample 1 (pH 2), all concentrations of metals are lower in the mild agitation state than in the high agitation state. A fraction of each sample, therefore, contains paint-related materials that are loosely intermixed with the solid media. Averaging the ratios of mild to vigorous agitation samples by metal and by sample produces strikingly similar results. The incremental ratios by metal for pH 7 range from 23 to 35 percent with a weighted average of 30 percent. Alternatively, the incremental ratios for pH 2 samples range from 14 percent to 35 percent with a total weighted average of 27 percent.

Comparing specific observations in Tables 6-10 and 6-11, 36 of 40 combinations show no significant difference between the concentration obtained at pH 2 and at pH 7. Three of the four outliers to this test are in the pure greensand (Sample 1) which has no effect on paint distribution or binding. Zinc present as zinc oxide paints and coatings

Table 6-10. Distribution of Heavy Metals in Bench Study Samples at pH 7

Sample ID	Metal in Supernatant (mg/l)				
	Nickel	Zinc	Copper	Chromium	Lead
1PH7LO	2.13	4.11	<1.2	<1.1	<2.5
1PH7HI	3.54	4.38	<1.2	2.68	<2.5
2PH7LO[a]	3.51	10.30	7.00	4.00	4.96
2PH7HI[a]	9.90	41.95	21.10	15.60	14.28
3PH7LO	3.19	7.24	5.70	1.67	<2.5
3PH7HI	12.33	50.81	26.48	13.89	11.86
4PH7LO	4.34	29.90	6.74	2.61	4.81
4PH7HI	29.15	158.51	75.09	26.80	26.53
5PH7LO	4.32	9.91	5.58	3.05	3.05
5PH7HI	11.43	44.37	19.28	13.27	9.98

[a]Average of triplicate experimental runs.
Legend for sample identification.

Table 6-11. Distribution of Metals in Bench Study Samples at pH 2

Sample ID	Metal in Supernatant (mg/l)				
	Nickel	Zinc	Copper	Chromium	Lead
1PH2LO	9.88	4.90	<1.2	<1.1	10.21
1PH2HI	14.14	2.71	<1.2	6.56	<2.5
2PH2LO[a]	3.18	8.90	5.03	3.09	4.19
2PH2HI[a]	10.58	42.87	20.40	17.58	13.89
3PH2LO	3.27	8.66	5.82	2.14	2.82
3PH2HI	12.88	52.76	24.89	17.87	13.74
4PH2LO	5.60	26.01	4.72	1.98	3.29
4PH2HI	41.04	128.49	44.62	22.02	22.42
5PH2LO	4.86	19.57	5.33	1.67	<2.5
5PH2HI	13.10	56.16	26.64	13.01	9.16

[a]Average of triplicate experimental runs.

was detected at the highest concentrations. Compared with the total amount of zinc in pure greensand, zinc is disproportionately high, supporting the premise that paint is indeed a major factor in metals found in solution.

In summary, several salient observations may be made from the benchtop study. First, little or no chemical mechanism is apparent for binding of paint and abrasives. Because pH changes did not produce any marked difference in concentration of metals and dissolution of parent greensand was discounted, chemical binding is probably not occurring. Second, both physical binding and loose paint associations are present. Changes in agitation increase the concentration of metals in the supernatent. This phenomenon is attributed to paint and related materials shearing from the solid and entering the liquid phase. Finally, based on relatively consistent ratios of metals in solution irrespective of pH level, approximately 30 percent of the paint materials are randomly intermixed and 70 percent are held by some physical binding mechanism. Recall that approximately 20 percent of the micron-sized particles could be identified by electron scanning as paint particles. The total fraction reviewed was 10 percent of the total sample which in turn means that about 2 percent of the material entering the beachfront is paint materials. Thus, paint affixed to sediments constitutes some 1.4 percent of all sediments in motion.

The study does not support any evidence of chemical binding between paint and abrasives. This information was factored into the sediment and paint

materials transport modeling given in Section 5.0. The most important conclusion that can be advanced here is that paint-related materials will transport essentially by the same processes as sediments, that 30 percent will tend to move directly to Mare Island Strait with the carrying water flow, and that about 2 percent of all material in motion is paint flakes.

6.5 FIELD STUDIES AND MODEL VERIFICATION

The U.S. Army Corps of Engineers has tested both the HEC-1 and HEC-6 models extensively on large urban and forested watersheds. The application of the HEC-6 program to small urban runoff situations is not documented in published literature. As such, this study presents a new and novel application for the model. Upon completion of the simulation runs and laboratory chemical and physical analyses, an experimental test was devised to test the accuracy of the HEC-6 results under field conditions.

Recalling the assumptions previously described, it can be noted that three conditions appear to limit the general applicability of the sediment yield estimates to small urban watersheds:

- Sediment along the outermost portions of the watershed are immobile due to insufficient energy to move sediment and intermixed paint flakes.
- Runoff water funnels into a definable central channel are determined from topographic surveying.
- Sediment transport is limited to the central channel which creates the largest energy potential.

The focus of the field verification thus considered two fundamental objectives: (1) test the validity of the three limiting model assumptions and (2) measure the total sediment (abrasives) yield and compare them to those predicted by the HEC-6 model. A third objective not outlined in this work was to evaluate the impact of abrasives deposition on the general environmental quality of the estuary.

6.5.1 System Design

Upon review of the time and budgetary constraints of the project, two steady-state flow rates were chosen, 0.5 and 1.0 cfs. The 0.1-square-mile watershed requires an output of almost 450 gpm to simulate a rainfall that produces 1.0-cfs maximum runoff. This flow volume was determined to be the largest that available equipment could deliver on a sustainable basis. The second flow volume (0.5 cfs) was chosen to further validate the measurements under different conditions. Figure 6-11 shows the system used to create the runoff simulation. A sustained 450 and 225 gpm of water was added to the watershed through 250 linear feet of perforated 6-inch diameter polyvinyl chloride pipe.

A water storage reservoir was created by two 10,000-gallon capacity Baker tanks. Water levels were maintained in the tanks from fire hydrants in the area. A 10-horsepower supply pump produced effluent velocities between 3 and 8 feet per second at 450 gpm. The plumbing also included two upstream gate valves for flow control, a downstream check valve, needle valve, and inline flowmeter, accurate to ±2.5 gpm.

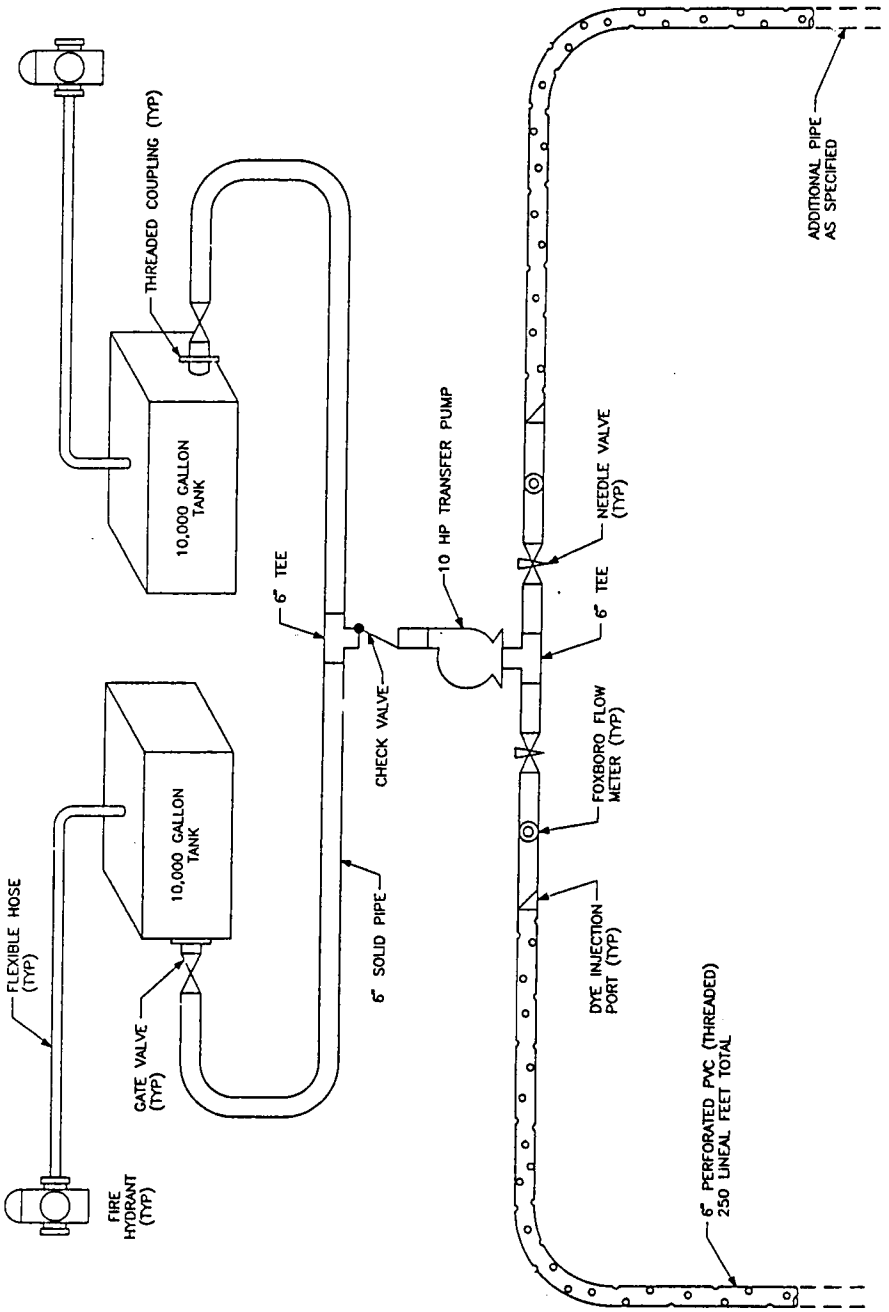


Figure 6-11. Schematic of Water Dispensing System

A temporary light gauge metal dike was constructed along the bottom periphery of the watershed, approximately 170 feet in length. A synthetic liner, 60 mil-thick and cut in 10-foot-wide sections, was bolted to the metal curb for the purpose of collecting runoff solids (collection mats). An aluminum runner was nailed over the upstream end of the fabric. This runner was removed and replaced after each test. The width of the sections was chosen because it was considered most economical for lifting and weighing purposes. The original design also included wire mesh angles at both ends of the collection trough; however, these proved impractical and were replaced with solid angles 6 inches high by 3 feet long. High-density polystyrene energy breaks were placed at each 10-foot interval in an effort to reduce the amount of sediment moving laterally along the collection trough. Each energy baffle resembled an auto speed bump, 3 feet long and 8 inches high at its peak.

6.5.2 Testing Model Assumptions

At the onset of this section, three fundamental assumptions were determined to be key in general application of the HEC-6 model to small urban watersheds. In the following paragraphs, two experiments will be described that address these model assumptions. The first test conducted considered the significance of sediment (abrasives) in the outer regions of the watershed.

Three tons of spent abrasives were spray-painted bright orange and spread throughout the outreaches of the watershed downstream of the distribution piping. A minimum distance of 75 feet was maintained from the water pipe

to allow for a velocity reduction that would be most consistent with those found at the top of a watershed. The value of 75 feet was established by first adding a small amount of dye to the water system at an inline tap and estimating where the velocity of sheet flow slowed to less than 1.5 feet per second. Spent abrasives were distributed over an area shown in Figure 6-12 and ranged in depth from less than 0.2 inch to 2.0 inches.

Because the most critical condition would be realized at the higher flow rate, only the 1.0 cfs case was considered. The entire watershed was lightly sprinkled with garden hoses to prewet the test area for purposes of minimizing initial friction influences of dry pavement. The needle valve, having been previously set to 450 gpm during the velocity measurements, was unlocked and the pump started. The test was run until it appeared from visual observations that no significant sediment transport was occurring. The first run took 27 minutes. Total distance of the sediment front was mapped and after the pavement had dried, the abrasives were swept up by a street sweeper and then redeposited in approximately the same original position.

The test was run a second time at 450 gpm to check the test method. This run was stopped at 27 minutes, the sediment front mapped, and the test restarted and continued for 33 minutes more to ensure significant sediment movement was not overlooked. The extended second test produced no additional discernable sediment movement at the front of the advance wave.

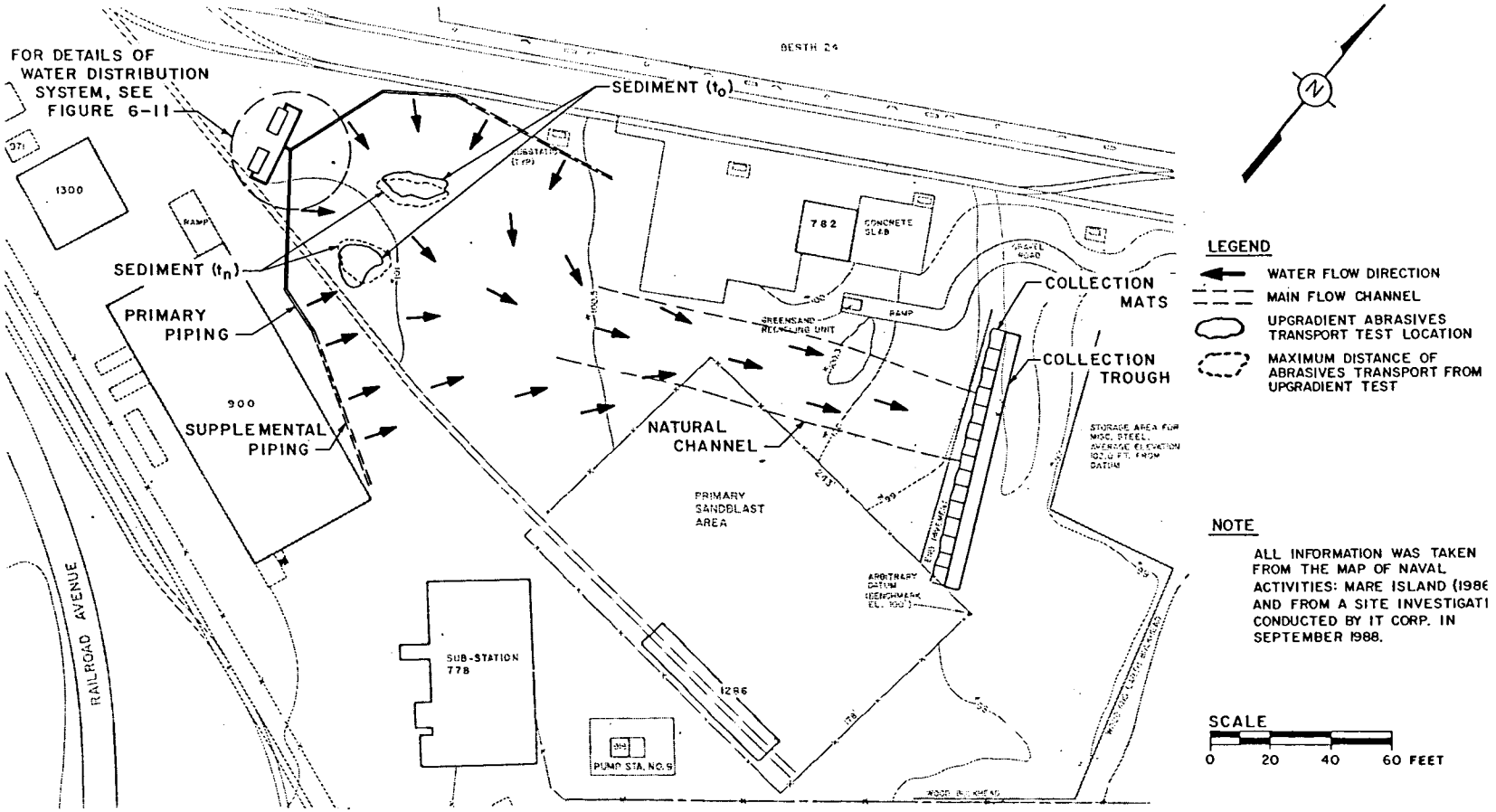


Figure 6-12. Field Verification Test Layout

Results of mapping from both test runs are also depicted in Figure 6-12. It can be noted that the maximum distance traveled by sediment over the duration of either test was only 3.6 feet. Visual observation noted that over one-half of this movement occurred in the first 5 minutes of each run. As noted, no significant movement occurred throughout the additional 33 minutes of the second test. Sediment advanced slightly farther in the second run versus the first run, 3.6 feet and 3.1 feet, respectively. The difference is attributed to the probable variance in grain size distribution and is not considered significant within the confidence limits of the test. It appears quite evident that even though relatively high energy was applied to the particles, there is not enough to create a condition whereby outerreach sediments contribute to the primary sediment yield of the basin. The model assumption is valid and is considered transferrable to other similar watersheds.

The second test was designed to validate the runoff patterns and qualify the 40-foot width used in the HEC-6 model. A more encompassing aspect of this test is its contention that small watersheds may be modeled accurately by knowing the surface contours of a semi-impervious basin, large or small. An additional 200 feet of pipe was added to the system to encompass as much of the watershed periphery as possible. Effluent along the final 50 feet of either side was noticeably minor. The concept of the test was to observe the water flow patterns through the watershed. This was accomplished by adding dye to the water supply and observing the

flow patterns. Bright red and orange nonstainable dyes were chosen. Red was injected on one side of the piping system and orange on the other, and the dye advance was monitored.

Again, two runs were made switching the dye colors to opposite sides after approximately one-half of each test had been completed. Here, however, one run was made at 450 gpm and one at 225 gpm to determine if there was any marked difference between relatively low and relatively high overland flow rates. Each run lasted 20 minutes with four injections of dye, two of both colors on each side.

Results support the topographic mapping almost exactly. Two notable observations were made. First, distinct eddys formed around the cracks in the pavement which may produce local accumulations of sediments. In general sheet flow moved in a linear fashion toward the central portion of the watershed where the water depth reached a maximum of 1.2 inches at the 450-gpm flow rate and 0.7 inches at a lower flow rate. Significant mixing became noticeable across a central channel width that varied from 17 feet at the top of the watershed to 47 feet at the collection trough. Overall, the average mixing zone (channel width) was estimated by virtue of five cross-section measurements, to be 38 feet. It was evident that sheet flow from small urban watershed can be modeled by a buildup from a topographic survey.

6.5.3 Sediment Transport Measurements

From the experiments described above, it was evident that the initial choice of a 40-foot width was adequate within the confidence margin of modeling and measurement. Once the watershed had been allowed to dry, spent abrasives were reapplied to original positions to the extent feasible. A series of ten random locations was chosen to measure sediment depth. Depth, measured with a caliper, varied from 0.05 to 0.19 feet with an overall average of 0.12 feet. Computer simulations performed before these field tests used 0.10 feet, the difference between these two values, were considered to be insignificant.

Two runs at 450 gpm (1.0 cfs) and two runs at 225 gpm (0.5 cfs) were completed. Each run lasted 6.5 hours. At the conclusion of each run, the collection mats were detached and weighed. After each run, the mats were also tiered again. Although there were a total of 17 mats along the downstream face of the watershed, significant amounts of sediment were collected in only the central most seven mats. Because of the relatively heavy weights involved with three of the mats, a backhoe was used to lift the mats and place them on the truck scale used for weighing. The scale used was accurate to ±1.0 pound.

Results of the sediment transport tests are presented in Table 6-12. At 1.0 cfs, the average yield was 1,433 pounds and was 1,024.5 pounds at 0.5 cfs. By comparison, the HEC-6 model predicted approximately 3 tons per day yield rate for 1.0 cfs and 2 tons per day yield rate for 0.5 cfs. These latter values translate to approximately 1,620 pounds of sediment

Table 6-12. Comparison of Field and Model Results for Sediment Yield From Watershed

COMPARISON OF FIELD AND MODEL RESULTS FOR SEDIMENT YIELD FROM WATERSHED				
MAT NO.	WEIGHT (lbs)			
	Q = 1.0 cfs		Q = 0.5 cfs	
	RUN 1	RUN 2	RUN 1	RUN 2
1	41	30	27	19
2	203	245	123	94
3	271	303	231	250
4	403	409	297	317
5	298	289	215	189
6	145	164	111	125
7	29	36	31	20
TOTAL	1390	1476	1035	1014
MODEL	1620		1080	

in 6.5 hours at 1.0 cfs and 1,080 pounds of sediment in 6.5 hours at 0.5 cfs. The model based on these field tests estimated sediment yields within +11.5 percent of actual at the higher flow rate and +5.1 percent of actual at the lower flow rate.

It is interesting to note that there is a significant correlation between field runs and between simulation estimates and field tests. It should also be noted that the HEC-6 program produces results to the nearest whole number and, as such, if a value is less than 0.5 tons per day, the program records a value of zero. Nevertheless, unique results were generated in simulations of 0.5 and 1.0 cfs which suggests that the model is sensitive to low flow conditions. The runoff tests also further supported the assumption that insufficient energy exists outside a central channel to move even fine-grained sediments a significant distance, as evidenced by the lack of sediments outside of the central seven mats.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The increasing awareness of hazards associated with chemicals released into the environment has spawned unparalleled public concern and regulatory response. Basic research studies are at the heart of regulatory programs such as the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, the Resource Conservation and Recovery Act, the Federal Insecticide, Fungicide, and Rodenticide Act, and the Toxic Substances Control Act. This particular study is aimed at extending the ability of engineers to apply a specific analytical model, HEC-6, developed for large-scale applications to much smaller-scale sites. These relatively small watersheds (less than 20 acres) represent the vast majority of hazardous waste sites presently under investigation. It also considered the binding mechanics involved with potentially hazardous sandblasting operations.

7.1 CONCLUSIONS

This study sought to accomplish one fundamental objective: investigate the suitability of a large-scale predictive sediment transport model for estimating the yield of spent blasting abrasives off a small urban watershed. Supporting research was performed in the area of paint residue and blasting abrasives interaction and overall composition in the sediment mixture. To this end, the study showed that paint flakes are physically bound or chemically disassociated with spent abrasives. Evidence of chemical binding between paint and abrasives brought about by high-intensity energy transfer from the abrasive to the paint was not

found. Field verification studies conducted at a high and low flow rate to support computer simulations generated by the HEC-6 model indicate that the model may be adequately used in small watersheds where shallow overland flow situations previously not known to be valid. Simulations generated in abrasives yield estimates within +5.1 percent of measured values at low flow rates and +11.5 percent of measured values at high flow rates.

7.1.1 Supporting Research on Abrasives-Paint Interaction and Composition

Greensand abrasive is found throughout the 900 Area. The major contributor to its movement into Mare Island Strait is rainfall runoff. Expected volumes of water flowing onto the beachfront from the paved blasting area were estimated through the use of hydrologic simulations to be 0.5 to 8 cfs depending on storm intensity and duration. The Rational and Kinematic Wave Methods were employed in simulating precipitation events. Coupling fluid flow with empirical sediment transport relations allowed for an estimation of the total mass of greensand and paint particles that is depositing on the beach over any given period of time. Two discrete classes of sediment were reviewed: coarse-grain greensand and residual materials and fine paint flakes. Over 95 percent of the total sediment load is associated with coarse-grained material. Less than 5 percent of the total mass is low-density paint flakes and related silts that may flow directly into the strait, based on electron scanning particle size analysis. The modeling performed here, however, is not sensitive enough to quantify the mass transport rates of these particles.

Specialized electron scanning techniques were employed to refine the understanding of paint flake mass and size distribution throughout the sampling grid. At four locations within the grid, spent greensand and virgin greensand were analyzed for 19 different compounds and size distribution sensitive to 0.2 μm. Components associated with paint materials were found to range in size from 1.0 to 80 μm, with the largest percentage grouped near 1.5 μm. Predominate particle types on the site are silicon-magnesium rich or aluminum rich. Soils at the site contain a high fraction (>50 percent) of clay and are relatively low in iron.

A benchtop study was also conducted to better understand the dynamics of abrasives and paint flake association. Using two variables, agitation and pH (acidity), sample splits from the spectral grain size work were investigated. Two agitation speeds were attempted, mild and vigorous. Also, different pH values were tested on each sample, pH 7 and pH 2. Results suggest that approximately 70 percent of the paint or paint-related materials are physically bound to the abrasive or to other sediments and are transported directly with individual grains. Thirty percent of the fine materials are merely intermixed with the sediment mass and travel independently of coarse grains. Having a lower density than coarse grains, independent paint flakes will tend to move directly to the receiving Mare Island Strait with little or no significant residence time on the shore.

7.1.2 Abrasives-Sediment Transport Modeling

The primary objective of this investigation was to determine the applicability of a comprehensive large scale computer model for simulating sediment transport over a small urban watershed. Upon determining the physical characteristics of the transporting sediment-abrasives-paint medium, and estimating representative water flow rates, sediment yield simulations were performed using HEC-6. The values obtained from the computer simulations were then tested against on-site field tests described in Section 6.5.

At the onset of the field program three model limiting assumptions were tested, (1) the outermost portions of the watershed are immobile due to lack of energy, (2) topographic surveying defines a central, shallow, concentrated flow channel at the site, and (3) sediment transport is limited to the main channel. Carefully executed preliminary tests showed that sediment and abrasives in the outer reaches of the watershed moved less than 4.0 feet, far short of the required 75 feet needed to reach the central portion of the watershed. Performing an overland flow test and injecting floracene dye as a tracer it was observed that a prominent main channel formed. Its width was within ±5 percent of the width predicted by topographic surveying and used in the computer simulations. Finally, sediment collected from the downstream edge of the watershed occurred dominantly across the 40-foot width of the main channel. There was no significant accumulation of sediment outside 15 feet from either side of the main channel.

Sediment yield was measured at two flow rates, 0.5 cfs and 1.0 cfs. Each test was performed twice for the purpose of checking the accuracy of the first runs. Results of the field investigation closely fit the predicted sediment yield from computer simulations. Although the computer model overpredicted sediment/abrasives transport for all flow runs by 5.1 to 11.5 percent, this difference is well within acceptable engineering limits. At 0.5 cfs HEC-6 predicted a 1,080-pound yield and the average measured value was 1,024 pounds. At 1.0 cfs HEC-6 predicted 1,620 pounds of sediment would be yielded over a 6.5-hour period. Field measured amounts averaged 1,433 pounds of sediment-abrasive material. It is readily apparent given that most runoff estimates try to achieve an accuracy of an order of magnitude or less, that this investigation has shown acceptable correlation between predicted and measured values. Although additional testing is always warranted, the HEC-6 model may not only be used successfully for large natural watersheds, but apparently also for small-scale conditions and situations such as where hazardous waste transport may be involved.

With regard to modeling commingled potentially hazardous waste (i.e. paint residues) and abrasives/sediments, it should be noted that this data set showed that 70 percent of the paint residues appear to be physically bound to carrier abrasive particles. As such, this commingled material may be adequately described by the HEC-6 model. However, any site to be modeled should conduct sufficient bench chemical tests to derive the amount of commingled material that is physically bound to noncohesive sediments. The HEC-6 model would not be valid for low density particles found in a discrete phase.

7.1.3 Environmental Significance of Blasting Operations

Over 120 discrete samples were taken throughout the sampling area. Chemical analyses were performed for five heavy metals. In general, results of these tests show that metals found in virgin and spent greensand do not exceed current acceptable levels as defined by CAC Title 22 for STLC and TTLC. Parent or background soils also do not exceed these limits. Concentrations of metals above the cumulative average concentrations for soil and abrasives, however, were detected in more than 70 percent of the samples. The difference is attributed to paint and associated sandblasting residues within the greensand mass. Therefore, it can be hypothesized that elevated concentrations of metals, where they exist, are a strong function of paint flake and blasting residue distribution and not the sandblasting abrasives per se.

Finally, the impacts of this type of operation on environmental quality appear minimal. Even including the contribution of the paint, only rarely do metal concentrations exceed either the appropriate TTLC and STLC limits. Only 10 of the 126 chromium samples exceeded the TTLC; there were no samples that were above the STLC. Five of 126 nickel samples were above the TTLC and, like chromium, no soluble samples topped the STLC. All copper samples were well below benchmark values. Zinc was also found to be below total and soluble limits for all samples. One sample exhibited a total lead concentration above the TTLC. Soluble lead, however, proved to have the greatest number of samples above a

benchmark value. Twenty of the 56 samples showed levels of soluble lead slightly above the 5 mg/l STLC. Less than one-third of the 56 samples exceeded two times the STLC. Lead has also been given the lowest or the most strict STLC.

7.2 RECOMMENDATIONS

After reviewing the study's findings, several recommendations for future research can be offered. The effects of sandblasting intensity should be reviewed with respect to paint and abrasives interaction. It is not known if increasing or possibly decreasing contact intensity would produce a greater adverse environmental impact. Bench chemical tests with abrasives could consider lowering the pH to below 2 and further increasing agitation speed. Although both of these scenarios would simulate conditions not found naturally, they do represent situations that may be present in industrial areas.

Higher flow rates, longer durations, and varying overland slopes are three variables that warrant expansion in field verification of the HEC-6 model for overland flow scenarios. A method of coupling the HEC-1 and HEC-6 models and making them more interactive would be very beneficial. A critical area where more research would be helpful to sediment transport modeling lies in quantifying the minimum velocity head required to physically transport particles under sheet flow conditions. Flume studies and classical river sediment collection projects are not well-suited for this purpose. Larger-scale, yet highly controlled parameters would need to be established. A corollary to that type of work would be

to study the additive effects of collector channels under sheet flow conditions and evaluate where a critical situation exists.

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APPENDICES

APPENDIX A

INPUT/OUTPUT HEC-1 MODEL

APPENDIX A-1

HEC-1 INPUT/OUTPUT SUBBASIN 1
25-YEAR STORM

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

****

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

1 HEC-1 INPUT PAGE 1

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  KINEMATIC WAVE MODEL 900 AREA ASPHALT SUBBASIN
    2     ID  RUNOFF EVALUATION 25-YR RETURN 24 HOUR DURATION STORM
    3     ID  MULTIPLE BASINS WITH OVERLAND FLOW AND GUTTER FLOW
    4     ID
    5     IT   15 21MAR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING THE RUNOFF HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC  .0302 .0571 .0960 .1243 .1798 .2229 .2867 .3287 .3943 .4393
   12     PC  .5068 .5516 .6180 .6630 .7351 .7860 .8639 .9175 1.002 1.061
   13     PC  1.157 1.225 1.330 1.403 1.527 1.615 1.742 1.829 1.980 2.100
   14     PC  2.483 2.818 3.162 3.302 3.483 3.591 3.730 3.812 3.928 4.009
   15     PC  4.108 4.175 4.273 4.337 4.429 4.487 4.565 4.618 4.696 4.749
   16     PC  4.832 4.882 4.959 5.009 5.081 5.128 5.199 5.246 5.316 5.362
   17     PC  5.430 5.475 5.541 5.585 5.650 5.693 5.756 5.798 5.860 5.900
   18     PC  5.960 5.999 6.058 6.096 6.153 6.261 6.269 6.282 6.336 6.371
   19     PC  6.423 6.457 6.508 6.541 6.590 6.622 6.670 6.700 6.746 6.776
   20     PC  6.820 6.850 6.890 6.920 6.960 7.000   0    0    0    0
   21     LS   0   98   0   0   85   0
   22     BA .00065
   23     UK   100  .008  .13   80
   24     UK   100  .008  .08   20
   25     RK   130  .004  .13       TRAP   0   20
   26     RK   160  .004  .13       TRAP   0   20

   27     KK  SUB B
   28     KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN B
   29     LS   0   98   0   0   85   0
   30     BA .0017
   31     UK   170  .008  .13   80
   32     UK   170  .008  .08   20
   33     RK   160  .004  .13       TRAP   0   20
   34     RK   160  .004  .13       TRAP   0   20   YES
```

```
35    KK  SUB C
36    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN C
37    LS    0    98    0    0    85    0
38    BA  .0024
39    UK    210  .008  .13   80
40    UK    210  .008  .08   20
41    RK    160  .004  .13        TRAP    0    20
42    RK    160  .004  .13        TRAP    0    20   YES

43    KK  SUB D
44    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN D
45    LS    0    98    0    0    85    0
46    BA  .0024
47    UK    240  .008  .13   80
48    UK    240  .008  .08   20
49    RK    160  .004  .13        TRAP    0    20
50    RK    160  .004  .13        TRAP    0    20   YES
```



```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

51    KK  SUB E
52    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN E
53    LS    0    98    0    0    85    0
54    BA  .0025
55    UK    240  .008  .13   80
56    UK    240  .008  .08   20
57    RK    160  .004  .13        TRAP    0    20

58    KK  COMB
59    KM  COMBINING THE RUNOFF HYDROGRAPHS FROM PREVIOUS BASINS WITH SUBBASIN E
60    HC    2
61    ZZ
```

1

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT

LINE (V) ROUTING (---->) DIVERSION OR PUMP FLOW

NO. (.) CONNECTOR (<----) RETURN OF DIVERTED OR PUMPED FLOW

8 SUB A

V

V

27 SUB B ***

V

V

35 SUB C ***

V

V

43 SUB D ***

.

.

51 . SUB E

. .

. .

58 COMB .....

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

****

KINEMATIC WAVE MODEL 900 AREA ASPHALT SUBBASIN
RUNOFF EVALUATION 25-YR RETURN 24 HOUR DURATION STORM
MULTIPLE BASINS WITH OVERLAND FLOW AND GUTTER FLOW

```
6 IO        OUTPUT CONTROL VARIABLES
              IPRNT       5  PRINT CONTROL
              IPLOT       2  PLOT CONTROL
              QSCAL       0.  HYDROGRAPH PLOT SCALE

  IT        HYDROGRAPH TIME DATA
              NMIN       15  MINUTES IN COMPUTATION INTERVAL
              IDATE   21MAR89  STARTING DATE
              ITIME     0600  STARTING TIME
                NQ      120  NUMBER OF HYDROGRAPH ORDINATES
             NDDATE   22MAR89  ENDING DATE
             NDTIME     1145  ENDING TIME

          COMPUTATION INTERVAL     .25 HOURS
            TOTAL TIME BASE   29.75 HOURS

     ENGLISH UNITS
1                                       STATION    SUB A

              (O) OUTFLOW
      .0    .1    .2    .3    .4    .5    .6    .0    .0    .0    .0    .0    .0
                                                        (L) PRECIP,  (X) EXCESS
      .0    .0    .0    .0    .0    .0    .0    .0    .4    .3    .2    .1    .0
DAHRMN PER
210600  1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
210615  2O      .     .     .     .     .     .     .     .     .     .     .     .   LLL.
210630  3O      .     .     .     .     .     .     .     .     .     .     .     .   LLLL.
210645  4O      .     .     .     .     .     .     .     .     .     .     .     .   LLX.
210700  5O      .     .     .     .     .     .     .     .     .     .     .     .  LLLLXX.
210715  6O      .     .     .     .     .     .     .     .     .     .     .     .   LLXX.
210730  7.O     .     .     .     .     .     .     .     .     .     .     .     .  LLXXXX.
210745  8. O    .     .     .     .     .     .     .     .     .     .     .     .   LXXX.
210800  9.  O   .     .     .     .     .     .     .     .     .     .     .     .  LLLXXXX.
210815 10.   O  .     .     .     .     .     .     .     .     .     .     .     .   LXXX.
210830 11...O.................................................................LLXXXXX.
210845 12.   O  .     .     .     .     .     .     .     .     .     .     .     .   LXXX.
210900 13.   O  .     .     .     .     .     .     .     .     .     .     .     .  LLXXXXX.
210915 14.   O  .     .     .     .     .     .     .     .     .     .     .     .   LXXXX.
210930 15.   O  .     .     .     .     .     .     .     .     .     .     .     .  LXXXXXX.
210945 16.    O .     .     .     .     .     .     .     .     .     .     .     .   LXXXX.
211000 17.    O .     .     .     .     .     .     .     .     .     .     .     .  LXXXXXXX.
```

211015 18. O. . . . . XXXXX.
211030 19. O. . . . . LXXXXXXX.
211045 20. O . . . . . LXXXXX.
211100 21. . . . . O . . . . . LLXXXXXXXX.
211115 22. .O . . . . . LXXXXXX.
211130 23. . O . . . . . LLXXXXXXXXX.
211145 24. . O . . . . . XXXXXXX.
211200 25. . O . . . . . LXXXXXXXXXX.
211215 26. . O . . . . . .LXXXXXXXX.
211230 27. . O . . . . . LXXXXXXXXXXX.
211245 28. . O . . . . . .LXXXXXXXX.
211300 29. . O . . . . . LXXXXXXXXXXXXX.
211315 30. . O. . . . . LXXXXXXXXXX.
211330 31. . . . . O . . . . . LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211345 32. . . . . O . . . . LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211400 33. . . . . O . . . . LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211415 34. . . . . O . . . . . XXXXXXXXXXXXX.
211430 35. . . . O . . . . . XXXXXXXXXXXXXXXXX.
211445 36. . . O. . . . . LXXXXXXXXX.
211500 37. . . O . . . . . XXXXXXXXXXXXX.
211515 38. . .O . . . . . XXXXXXX.
211530 39. . O. . . . . LXXXXXXXXXX.
211545 40. . O . . . . . XXXXXX.
211600 41. . . . . O . . . . . LXXXXXXXXX.
211615 42. . O . . . . . XXXXXX.
211630 43. . O . . . . . XXXXXXXXX.
211645 44. . O . . . . . XXXXX.
211700 45. . O . . . . . .XXXXXXXX.
211715 46. . O . . . . . XXXXX.
211730 47. . O . . . . . XXXXXXX.
211745 48. . O . . . . . XXXX.
211800 49. .O . . . . . XXXXXXX.
211815 50. .O . . . . . XXXX.
211830 51. . . . . O . . . . . XXXXXXX.
211845 52. .O . . . . . XXXX.
211900 53. .O . . . . . XXXXXXX.
211915 54. .O . . . . . XXXX.
211930 55. O . . . . . XXXXXX.
211945 56. O . . . . . XXXX.
212000 57. O . . . . . XXXXXX.
212015 58. O . . . . . XXXX.
212030 59. O . . . . . XXXXXX.
212045 60. O . . . . . XXXX.
212100 61. . . . . O . . . . . XXXXXX.
212115 62. O. . . . . LXXX.
212130 63. O. . . . . XXXXXX.
212145 64. O. . . . . XXX.
212200 65. O. . . . . LXXXXX.

212215 66. O. . . . . XXXX.
212230 67. O. . . . . XXXXXX.
212245 68. O. . . . . XXXX.
212300 69. O. . . . . XXXXXX.
212315 70. O. . . . . XXXX.
212330 71. . . . O. . . . . XXXXXX.
212345 72. O. . . . . XXXX.
220000 73. O. . . . . XXXXXX.
220015 74. O. . . . . XXXX.
220030 75. O. . . . . XXXXXX.
220045 76. O. . . . . XXXXXXXXXXX.
220100 77. . O . . . . . X.
220115 78. O . . . . . X.
220130 79. O . . . . . XXXXX.
220145 80. O . . . . . XXX.
220200 81. . . . O. . . . . XXXXX.
220215 82. O. . . . . XXX.
220230 83. O. . . . . XXXXX.
220245 84. O. . . . . XXX.
220300 85. O. . . . . XXXXX.
220315 86. O. . . . . XXX.
220330 87. O. . . . . XXXXX.
220345 88. O. . . . . XXX.
220400 89. O. . . . . XXXXX.
220415 90. O. . . . . XXX.
220430 91. . . . O. . . . . XXXX.
220445 92. O. . . . . XXX.
220500 93. O. . . . . XXXX.
220515 94. O. . . . . XXX.
220530 95. O. . . . . XXXX.
220545 96. O. . . . . XXXX.
220600 97. O. . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. O. . . . . .
220715 102O . . . . . .
220730 103O . . . . . .
220745 104O . . . . . .
220800 105O . . . . . .
220815 106O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O. . . . . .
220945 112O . . . . . .
221000 113O . . . . . .

```
221015 114O     .    .    .    .    .    .    .    .    .    .    .    .    .
221030 115O     .    .    .    .    .    .    .    .    .    .    .    .    .
221045 116O     .    .    .    .    .    .    .    .    .    .    .    .    .
221100 117O     .    .    .    .    .    .    .    .    .    .    .    .    .
221115 118O     .    .    .    .    .    .    .    .    .    .    .    .    .
221130 119O     .    .    .    .    .    .    .    .    .    .    .    .    .
221145 120O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
1
1                                   STATION   SUB B

                  (O) OUTFLOW
      .0    .4    .8   1.2   1.6   2.0    .0    .0    .0    .0    .0    .0    .0
                                                      (L) PRECIP,  (X) EXCESS
      .0    .0    .0    .0    .0    .0    .0    .0    .4    .3    .2    .1    .0
DAHRMN PER
210600  1O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
210615  2O     .    .    .    .    .    .    .    .    .    .    .    .    LLL.
210630  3O     .    .    .    .    .    .    .    .    .    .    .    .    LLLL.
210645  4O     .    .    .    .    .    .    .    .    .    .    .    .    LLX.
210700  5O     .    .    .    .    .    .    .    .    .    .    .    .    LLLLXX.
210715  6O     .    .    .    .    .    .    .    .    .    .    .    .    LLXX.
210730  7.O    .    .    .    .    .    .    .    .    .    .    .    .    LLXXXX.
210745  8. O   .    .    .    .    .    .    .    .    .    .    .    .    LXXX.
210800  9. O   .    .    .    .    .    .    .    .    .    .    .    .    LLLXXXX.
210815  10.  O  .    .    .    .    .    .    .    .    .    .    .    .    LXXX.
210830  11. . .O.....................................................LLXXXXXX.
210845  12.  O .    .    .    .    .    .    .    .    .    .    .    .    LXXX.
210900  13.  O .    .    .    .    .    .    .    .    .    .    .    .    LLXXXXX.
210915  14.  O .    .    .    .    .    .    .    .    .    .    .    .    LXXXX.
210930  15.  O .    .    .    .    .    .    .    .    .    .    .    .    LXXXXXX.
210945  16.   O.    .    .    .    .    .    .    .    .    .    .    .    LXXXX.
211000  17.   O.    .    .    .    .    .    .    .    .    .    .    .    LXXXXXXX.
211015  18.   O.    .    .    .    .    .    .    .    .    .    .    .    XXXXX.
211030  19.   O.    .    .    .    .    .    .    .    .    .    .    .    LXXXXXXX.
211045  20.   O.    .    .    .    .    .    .    .    .    .    .    .    LXXXXX.
211100  21. . . .O.....................................................LLXXXXXXXX.
211115  22.    O    .    .    .    .    .    .    .    .    .    .    .    LXXXXXX.
211130  23.    .O   .    .    .    .    .    .    .    .    .    .    .    LLXXXXXXXXX.
211145  24.    .O   .    .    .    .    .    .    .    .    .    .    .    XXXXXXX.
211200  25.    . O  .    .    .    .    .    .    .    .    .    .    .    LXXXXXXXXXX.
211215  26.    .  O .    .    .    .    .    .    .    .    .    .    .    LXXXXXXXX.
211230  27.    .  O .    .    .    .    .    .    .    .    .    .    .    LXXXXXXXXXXX.
211245  28.    .  O .    .    .    .    .    .    .    .    .    .    .    LXXXXXXXX.
211300  29.    .  O .    .    .    .    .    .    .    .    .    .    .    LXXXXXXXXXXXXX.
211315  30.    .   O.    .    .    .    .    .    .    .    .    .    .    LXXXXXXXXXX.
211330  31. . . . . . . . . . .O.....................................LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211345  32.    .    .    .  O .    .    .    .    .    .    .    LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211400  33.    .    .    .    .  O .    .    .    .    .    .    LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
```

211415 34. . . . . O . . . . . XXXXXXXXXXXXX.
211430 35. . . . O . . . . . XXXXXXXXXXXXXXXX.
211445 36. . . O . . . . . LXXXXXXXXX.
211500 37. . .O . . . . . XXXXXXXXXXXXX.
211515 38. . O. . . . . .XXXXXXX.
211530 39. . O . . . . . LXXXXXXXXXX.
211545 40. . O . . . . . .XXXXXX.
211600 41. .....O.....LXXXXXXXXXX.
211615 42. . O . . . . . .XXXXXX.
211630 43. . O . . . . . XXXXXXXXX.
211645 44. . O . . . . . .XXXXX.
211700 45. . O . . . . . .XXXXXXXX.
211715 46. . O . . . . . .XXXXX.
211730 47. .O . . . . . .XXXXXXX.
211745 48. O . . . . . .XXXX.
211800 49. O . . . . . .XXXXXXX.
211815 50. O . . . . . .XXXXX.
211830 51. .....O.....XXXXXXX.
211845 52. O . . . . . .XXXX.
211900 53. O . . . . . .XXXXXXX.
211915 54. O . . . . . .XXXXX.
211930 55. O . . . . . .XXXXXX.
211945 56. O. . . . . .XXXXX.
212000 57. O. . . . . .XXXXXX.
212015 58. O. . . . . .XXXXX.
212030 59. O. . . . . .XXXXXX.
212045 60. O. . . . . .XXXXX.
212100 61. ....O.....XXXXXX.
212115 62. O . . . . . .LXXXX.
212130 63. O . . . . . .XXXXXX.
212145 64. O . . . . . .XXXX.
212200 65. O . . . . . .LXXXXX.
212215 66. O . . . . . .XXXX.
212230 67. O . . . . . .XXXXX.
212245 68. O . . . . . .XXXX.
212300 69. O . . . . . .XXXXX.
212315 70. O . . . . . .XXXX.
212330 71. ....O.....XXXXX.
212345 72. O . . . . . .XXXX.
220000 73. O . . . . . .XXXXX.
220015 74. O . . . . . .XXXX.
220030 75. O . . . . . .XXXXX.
220045 76. O . . . . . XXXXXXXXXX.
220100 77. O . . . . . .X.
220115 78. O. . . . . .X.
220130 79. O . . . . . .XXXXX.
220145 80. O . . . . . .XXX.
220200 81. ...O.....XXXXX.

220215 82. O . . . . . XXX.
220230 83. O . . . . . XXXXX.
220245 84. O . . . . . XXX.
220300 85. O . . . . . XXXXX.
220315 86. O . . . . . XXX.
220330 87. O . . . . . XXXXX.
220345 88. O . . . . . XXX.
220400 89. O . . . . . XXXXX.
220415 90. O . . . . . XXX.
220430 91. . . O . . . . . XXXX.
220445 92. O . . . . . XXX.
220500 93. O . . . . . XXXX.
220515 94. O . . . . . XXX.
220530 95. O . . . . . XXXX.
220545 96. O . . . . . XXXX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101.O. . . . . .
220715 102.O . . . . . .
220730 103.O . . . . . .
220745 104O . . . . . .
220800 105O . . . . . .
220815 106O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O. . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O———.———.———.———.———.———.———.———.———.———

```
1                                   STATION   SUB C

                   (O) OUTFLOW
          .0    .5    1.0   1.5   2.0   2.5   3.0   3.5   4.0    .0    .0    .0    .0
                                                             (L) PRECIP,  (X) EXCESS
          .0    .0    .0    .0    .0    .0    .0    .0    .4    .3    .2    .1    .0
DAHRMN PER
210600  1O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
210615  2O      .     .     .     .     .     .     .     .     .     .     .  LLL.
210630  3O      .     .     .     .     .     .     .     .     .     .     .  LLLL.
210645  4O      .     .     .     .     .     .     .     .     .     .     .  LLX.
210700  5O      .     .     .     .     .     .     .     .     .     .     . LLLLXX.
210715  6O      .     .     .     .     .     .     .     .     .     .     .  LLXX.
210730  7.O     .     .     .     .     .     .     .     .     .     .     . LLXXXX.
210745  8. O    .     .     .     .     .     .     .     .     .     .     .  LXXX.
210800  9.  O   .     .     .     .     .     .     .     .     .     .     . LLLXXXX.
210815 10.   O  .     .     .     .     .     .     .     .     .     .     .  LXXX.
210830 11....O..................................................................LLXXXXX.
210845 12.    O.    .     .     .     .     .     .     .     .     .     .     .  LXXX.
210900 13.    O.    .     .     .     .     .     .     .     .     .     .     . LLXXXXX.
210915 14.    O     .     .     .     .     .     .     .     .     .     .     .  LXXXX.
210930 15.    O     .     .     .     .     .     .     .     .     .     .     . LXXXXXX.
210945 16.    .O    .     .     .     .     .     .     .     .     .     .     .  LXXXX.
211000 17.    .O    .     .     .     .     .     .     .     .     .     .     . LXXXXXXX.
211015 18.    . O   .     .     .     .     .     .     .     .     .     .     .  XXXXX.
211030 19.    . O   .     .     .     .     .     .     .     .     .     .     . LXXXXXXX.
211045 20.    . O   .     .     .     .     .     .     .     .     .     .     .  LXXXXX.
211100 21.......O.................................................................LLXXXXXXXX.
211115 22.    .  O  .     .     .     .     .     .     .     .     .     .     . LXXXXXX.
211130 23.    .  O  .     .     .     .     .     .     .     .     .     .     LLXXXXXXXXX.
211145 24.    .  O.       .     .     .     .     .     .     .     .     .     . XXXXXXX.
211200 25.    .   O.      .     .     .     .     .     .     .     .     .     LXXXXXXXXXXX.
211215 26.    .   .O      .     .     .     .     .     .     .     .     .     .LXXXXXXXXX.
211230 27.    .   . O     .     .     .     .     .     .     .     .     .     LXXXXXXXXXXXX.
211245 28.    .   . O     .     .     .     .     .     .     .     .     .     .LXXXXXXXXX.
211300 29.    .   .  O    .     .     .     .     .     .     .     .     .     LXXXXXXXXXXXXXX.
211315 30.    .   .  O    .     .     .     .     .     .     .     .     .     LXXXXXXXXXXX.
211330 31.................O...............................LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211345 32.    .     .     .     .     .  O  .     .     . LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211400 33.    .     .     .     .     .     .     . O   . LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211415 34.    .     .     .     .     .     .     .  O  .     .     . XXXXXXXXXXXXXXX.
211430 35.    .     .     .     .     .     O     .     .     .     . XXXXXXXXXXXXXXXXXXXX.
211445 36.    .     .     .     .  O  .     .     .     .     .     .     LXXXXXXXXXXX.
211500 37.    .     .     . O   .     .     .     .     .     .     .     XXXXXXXXXXXXXXX.
211515 38.    .     .    .O     .     .     .     .     .     .     .     . XXXXXXXX.
211530 39.    .     .   O.      .     .     .     .     .     .     .     LXXXXXXXXXXXX.
211545 40.    .     .  O  .     .     .     .     .     .     .     .     . XXXXXXX.
```

211600 41. ..... O ..... LXXXXXXXXXX.
211615 42. . . O . . . . XXXXXXX.
211630 43. . .O . . . . XXXXXXXXXX.
211645 44. . O . . . . XXXXXX.
211700 45. . O . . . . .XXXXXXXXX.
211715 46. . O. . . . . XXXXXX.
211730 47. . O . . . . .XXXXXXXX.
211745 48. . O . . . . XXXXX.
211800 49. . O . . . . .XXXXXXXX.
211815 50. . O . . . . XXXXX.
211830 51. ..... O ..... XXXXXXXX.
211845 52. . O . . . . XXXXX.
211900 53. . O . . . . .XXXXXXXX.
211915 54. . O . . . . XXXXX.
211930 55. . O . . . . .XXXXXXX.
211945 56. . O . . . . XXXXX.
212000 57. . O . . . . .XXXXXXX.
212015 58. . O . . . . XXXXX.
212030 59. . O . . . . .XXXXXXX.
212045 60. . O . . . . XXXXX.
212100 61. ..... O ..... XXXXXXX.
212115 62. . O . . . . LXXXX.
212130 63. . O . . . . .XXXXXXX.
212145 64. . O . . . . XXXX.
212200 65. . O . . . . .LXXXXXX.
212215 66. . O . . . . XXXX.
212230 67. . O . . . . .XXXXXX.
212245 68. . O . . . . XXXX.
212300 69. . O . . . . .XXXXXX.
212315 70. . O . . . . XXXX.
212330 71. ..... O ..... XXXXXX.
212345 72. . O . . . . XXXX.
220000 73. . O . . . . .XXXXXX.
220015 74. . O . . . . XXXX.
220030 75. . O . . . . .XXXXXX.
220045 76. . O . . . . XXXXXXXXXXX.
220100 77. . O . . . . X.
220115 78. . O . . . . X.
220130 79. O . . . . .XXXXX.
220145 80. O. . . . . XXX.
220200 81. .... O ..... XXXXX.
220215 82. O. . . . . XXX.
220230 83. O . . . . .XXXXX.
220245 84. O . . . . XXX.
220300 85. O . . . . .XXXXX.
220315 86. O . . . . XXX.
220330 87. O . . . . .XXXXX.
220345 88. O . . . . XXX.

220400 89. O. . . . . XXXXX.
220415 90. O. . . . . XXX.
220430 91. . . . .O. . . . . XXXX.
220445 92. O. . . . . XXX.
220500 93. O. . . . . XXXX.
220515 94. O. . . . . XXX.
220530 95. O. . . . . XXXX.
220545 96. O. . . . . XXXX.
220600 97. O. . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. O . . . . . .
220715 102. O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105.O . . . . . .
220815 106.O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O———.———.———.———.———.———.———.———.———.———.

1 STATION SUB D

(O) OUTFLOW

0. 1. 2. 3. 4. 5. 6. 0. 0. 0. 0. 0. 0.

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .4 .3 .2 .1 .0

DAHRMN PER

210600 1O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.

210615 2O . . . . LLL.

210630 3O . . . . LLLL.

210645 4O . . . . LLX.

210700 5O . . . . LLLLXX.

210715 6O . . . . LLXX.

210730 7O . . . . LLXXXX.

210745 8.O . . . . LXXX.

210800 9. O . . . . LLLXXXX.

210815 10. O . . . . LXXX.

210830 11. . .O. . . . . .LLXXXXX.

210845 12. O . . . . LXXX.

210900 13. O . . . . LLXXXXX.

210915 14. O . . . . LXXXX.

210930 15. O . . . . LXXXXXX.

210945 16. O . . . . LXXXX.

211000 17. O . . . . LXXXXXXX.

211015 18. O. . . . . XXXXX.

211030 19. O. . . . . LXXXXXXX.

211045 20. O . . . . LXXXXX.

211100 21. . . . .O. . . . . LLXXXXXXXX.

211115 22. . O . . . . LXXXXXX.

211130 23. . O . . . . LLXXXXXXXXX.

211145 24. . O . . . . XXXXXXX.

211200 25. . O . . . . LXXXXXXXXXX.

211215 26. . O . . . . LXXXXXXX.

211230 27. . O . . . . LXXXXXXXXXXX.

211245 28. . O. . . . . LXXXXXXX.

211300 29. . O. . . . . LXXXXXXXXXXXX.

211315 30. . O . . . . LXXXXXXXXXX.

211330 31. . . . . O. . . . . LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

211345 32. . . . O. . . . . LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

211400 33. . . . . O . . . LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.

211415 34. . . . . O. . . . . XXXXXXXXXXXXXX.

211430 35. . . . O . . . . . XXXXXXXXXXXXXXXXX.

211445 36. . . . O . . . . . LXXXXXXXXX.

211500 37. . . O. . . . . XXXXXXXXXXXXX.

211515 38. . . O . . . . . . XXXXXXX.

211530 39. . . O . . . . . LXXXXXXXXXX.

211545 40. . O. . . . . XXXXXX.

211600 41. .....O.....LXXXXXXXXXX.
211615 42. . O . . . . XXXXXXX.
211630 43. . O . . . . XXXXXXXXXX.
211645 44. . O . . . . XXXXXX.
211700 45. . O . . . . .XXXXXXXXX.
211715 46. . O . . . . XXXXXX.
211730 47. . O . . . . .XXXXXXXX.
211745 48. . O . . . . XXXXX.
211800 49. . O . . . . .XXXXXXXX.
211815 50. . O . . . . XXXXX.
211830 51. .....O.....XXXXXXXX.
211845 52. . O . . . . XXXXX.
211900 53. . O . . . . .XXXXXXXX.
211915 54. . O . . . . XXXXX.
211930 55. .O . . . . XXXXXXX.
211945 56. .O . . . . XXXXX.
212000 57. .O . . . . XXXXXXX.
212015 58. .O . . . . XXXXX.
212030 59. .O . . . . XXXXXXX.
212045 60. .O . . . . XXXXX.
212100 61. .....O.....XXXXXXX.
212115 62. O . . . . LXXXX.
212130 63. O . . . . XXXXXXX.
212145 64. O . . . . XXXX.
212200 65. O . . . . LXXXXXX.
212215 66. O . . . . XXXX.
212230 67. O . . . . XXXXXX.
212245 68. O . . . . XXXX.
212300 69. O. . . . . XXXXXX.
212315 70. O. . . . . XXXX.
212330 71. .....O.....XXXXXX.
212345 72. O. . . . . XXXX.
220000 73. O. . . . . XXXXXX.
220015 74. O. . . . . XXXX.
220030 75. O. . . . . XXXXXX.
220045 76. O. . . . . XXXXXXXXXXX.
220100 77. .O . . . . X.
220115 78. O . . . . X.
220130 79. O . . . . XXXXX.
220145 80. O . . . . XXX.
220200 81. ....O.....XXXXX.
220215 82. O . . . . XXX.
220230 83. O . . . . XXXXX.
220245 84. O . . . . XXX.
220300 85. O . . . . XXXXX.
220315 86. O . . . . XXX.
220330 87. O . . . . XXXXX.
220345 88. O . . . . XXX.

220400 89. O . . . . . XXXXX.
220415 90. O . . . . . XXX.
220430 91. . . . O. . . . . XXXX.
220445 92. O . . . . . XXX.
220500 93. O . . . . . XXXX.
220515 94. O . . . . . XXX.
220530 95. O . . . . . XXXX.
220545 96. O . . . . . XXXX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. O . . . . . .
220715 102. O . . . . . .
220730 103. O . . . . . .
220745 104. O . . . . . .
220800 105. O . . . . . .
220815 106. O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O———.———.———.———.———.———.———.———.———.———.

1 STATION SUB E

(O) OUTFLOW

.0 .4 .8 1.2 1.6 2.0 2.4 .0 .0 .0 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .4 .3 .2 .1 .0

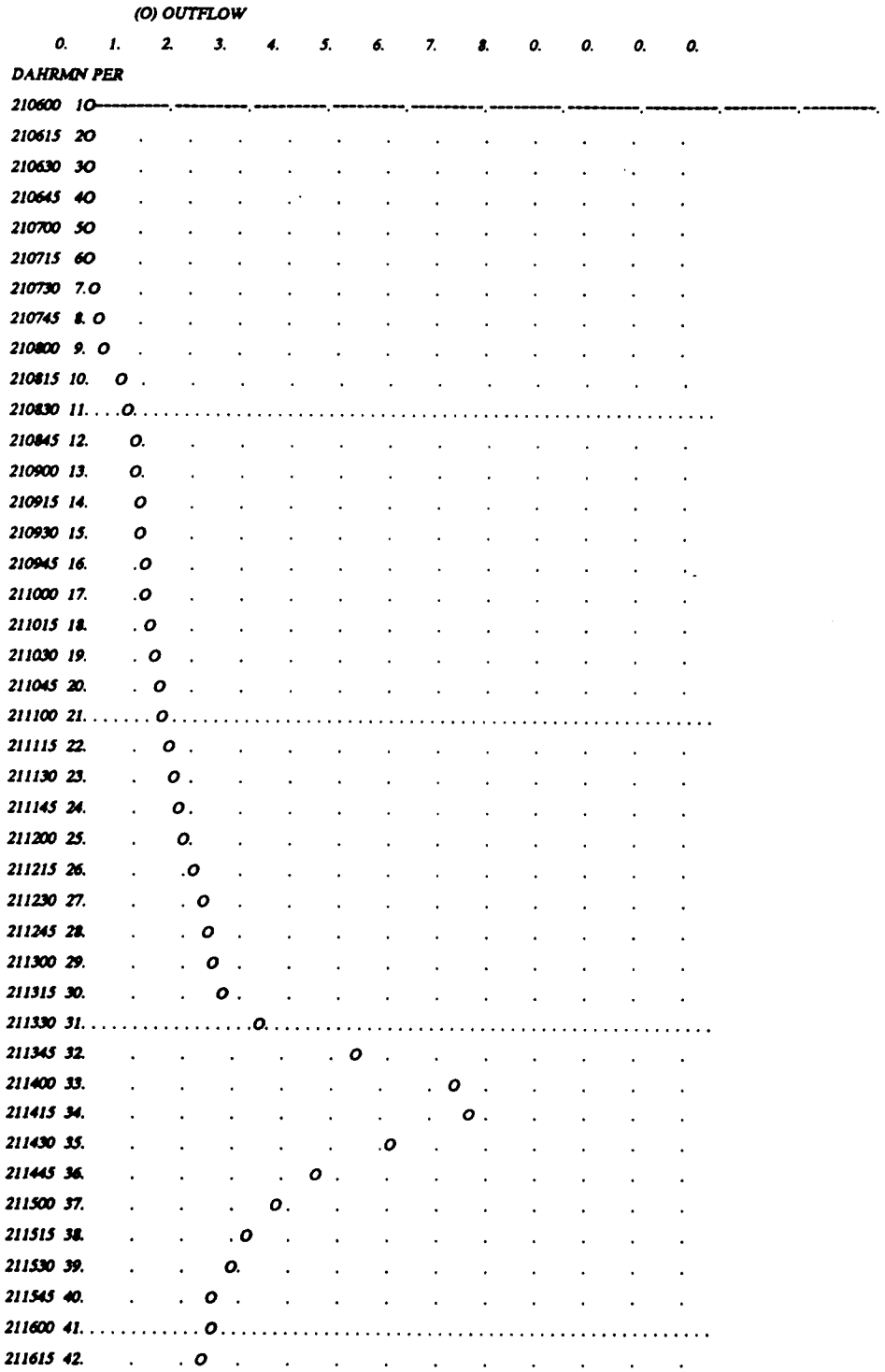
DAHRMN PER

```
210600 1O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
210615 2O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLL.
210630 3O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLL.
210645 4O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLX.
210700 5O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLXX.
210715 6O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLXX.
210730 7.O .  .  .  .  .  .  .  .  .  .  .  .  .  LLXXXX.
210745 8. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
210800 9. O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLXXXX.
210815 10. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
210830 11...O.....................................................LLXXXXX.
210845 12. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
210900 13. O .  .  .  .  .  .  .  .  .  .  .  .  .  LLXXXXX.
210915 14. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXXX.
210930 15. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXX.
210945 16. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXXX.
211000 17. O .  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXX.
211015 18. O.  .  .  .  .  .  .  .  .  .  .  .  .  XXXXX.
211030 19. O.  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXX.
211045 20. O.  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXX.
211100 21.....O.....................................................LLXXXXXXXXX.
211115 22. .O  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXX.
211130 23. .O  .  .  .  .  .  .  .  .  .  .  .  .  LLXXXXXXXXX.
211145 24. .O  .  .  .  .  .  .  .  .  .  .  .  .  XXXXXXX.
211200 25. .O  .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXXXXX.
211215 26. . O .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXX.
211230 27. . O .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXXXXXX.
211245 28. . O .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXX.
211300 29. . O .  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXXXXXXXX.
211315 30. . O.  .  .  .  .  .  .  .  .  .  .  .  LXXXXXXXXXX.
211330 31.....O.....................LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211345 32. .  .  .  .O  .  .  .  .  LLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211400 33. .  .  .  .  . O .  .  .  LXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
211415 34. .  .  .  .  O  .  .  .  .  .  XXXXXXXXXXXXXX.
211430 35. .  .  .  O .  .  .  .  .  .  .  .XXXXXXXXXXXXXXXXX.
211445 36. :  . O .  .  .  .  .  .  .  .  .  LXXXXXXXXX.
211500 37. .  . O  .  .  .  .  .  .  .  .  .  XXXXXXXXXXXXX.
211515 38. .  O.  .  .  .  .  .  .  .  .  .  .  .XXXXXXX.
211530 39. .  O.  .  .  .  .  .  .  .  .  .  .  LXXXXXXXXXX.
211545 40. . O .  .  .  .  .  .  .  .  .  .  .  . XXXXXXX.
```

211600 41. .....O.....LXXXXXXXXXX.
211615 42. . O . . . . XXXXXXX.
211630 43. . O . . . . XXXXXXXXXX.
211645 44. . O . . . . XXXXXX.
211700 45. . O . . . . .XXXXXXXXX.
211715 46. . O . . . . XXXXXX.
211730 47. .O . . . . .XXXXXXXX.
211745 48. .O . . . . XXXXX.
211800 49. O . . . . .XXXXXXXX.
211815 50. O . . . . XXXXX.
211830 51. ....O.....XXXXXXXX.
211845 52. .O . . . . XXXXX.
211900 53. O . . . . .XXXXXXXX.
211915 54. O . . . . XXXXX.
211930 55. O . . . . XXXXXX.
211945 56. O . . . . XXXXX.
212000 57. O. . . . . XXXXXX.
212015 58. O. . . . . XXXXX.
212030 59. O. . . . . XXXXXX.
212045 60. O. . . . . XXXXX.
212100 61. ....O.....XXXXXXX.
212115 62. O. . . . . LXXXX.
212130 63. O. . . . . XXXXXX.
212145 64. O. . . . . XXXX.
212200 65. O. . . . . LXXXXX.
212215 66. O. . . . . XXXX.
212230 67. O. . . . . XXXXX.
212245 68. O. . . . . XXXX.
212300 69. O. . . . . XXXXX.
212315 70. O. . . . . XXXX.
212330 71. ....O.....XXXXX.
212345 72. O. . . . . XXXX.
220000 73. O. . . . . XXXXX.
220015 74. O. . . . . XXXX.
220030 75. O . . . . XXXXX.
220045 76. O. . . . . XXXXXXXXXX.
220100 77. .O . . . . X.
220115 78. O. . . . . X.
220130 79. O . . . . XXXXX.
220145 80. O . . . . XXX.
220200 81. ...O.....XXXXX.
220215 82. O . . . . XXX.
220230 83. O . . . . XXXXX.
220245 84. O . . . . XXX.
220300 85. O . . . . XXXXX.
220315 86. O . . . . XXX.
220330 87. O . . . . XXXXX.
220345 88. O . . . . XXX.

220400 89. O . . . . . XXXXX.
220415 90. O . . . . . XXX.
220430 91. . . O . . . . . XXXX.
220445 92. O . . . . . XXX.
220500 93. O . . . . . XXXX.
220515 94. O . . . . . XXX.
220530 95. O . . . . . XXXX.
220545 96. O . . . . . XXXX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101.O. . . . . .
220715 102.O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105O . . . . . .
220815 106O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O. . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.

1 STATION COMB



211630 43. . .O . . . . . .
211645 44. . .O . . . . . .
211700 45. . O . . . . . .
211715 46. . O. . . . . .
211730 47. . O. . . . . .
211745 48. . O . . . . . .
211800 49. . O . . . . . .
211815 50. . O . . . . . .
211830 51. . . . . O . . . . . .
211845 52. . O . . . . . .
211900 53. . O . . . . . .
211915 54. . O . . . . . .
211930 55. . O . . . . . .
211945 56. . O . . . . . .
212000 57. . O . . . . . .
212015 58. . O . . . . . .
212030 59. . O . . . . . .
212045 60. . O . . . . . .
212100 61. . . . . O . . . . . .
212115 62. . O . . . . . .
212130 63. . O . . . . . .
212145 64. . O . . . . . .
212200 65. . O . . . . . .
212215 66. . O . . . . . .
212230 67. . O . . . . . .
212245 68. . O . . . . . .
212300 69. . O . . . . . .
212315 70. . O . . . . . .
212330 71. . . . . O . . . . . .
212345 72. . O . . . . . .
220000 73. . O . . . . . .
220015 74. . O . . . . . .
220030 75. . O . . . . . .
220045 76. . O . . . . . .
220100 77. . O . . . . . .
220115 78. . O . . . . . .
220130 79. O . . . . . .
220145 80. O. . . . . .
220200 81. . . . O. . . . . .
220215 82. O. . . . . .
220230 83. O . . . . . .
220245 84. O . . . . . .
220300 85. O . . . . . .
220315 86. O . . . . . .
220330 87. O . . . . . .
220345 88. O . . . . . .
220400 89. O . . . . . .
220415 90. O. . . . . .

220430 91. . . . .O. . . . . .
220445 92. O. . . . . .
220500 93. O. . . . . .
220515 94. O. . . . . .
220530 95. O. . . . . .
220545 96. O. . . . . .
220600 97. O. . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. .O. . . . . .
220715 102. O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105.O . . . . . .
220815 106.O . . . . . .
220830 107.O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O———.———.———.———.———.———.———.———.———.———.

1

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT									
SUB A	1.	8.00	0.	0.	0.	.00			
HYDROGRAPH AT									
SUB B	2.	8.25	1.	0.	0.	.00			
HYDROGRAPH AT									
SUB C	4.	8.25	2.	1.	1.	.00			
HYDROGRAPH AT									
SUB D	6.	8.25	2.	1.	1.	.01			
HYDROGRAPH AT									
SUB E	2.	8.00	1.	0.	0.	.00			
2 COMBINED AT									
COMB	8.	8.25	3.	2.	1.	.01			

*** NORMAL END OF HEC-1 ***

APPENDIX A-2

HEC-1 INPUT/OUTPUT SUBBASIN 1
100-YEAR STORM

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

****

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

1 HEC-1 INPUT PAGE 1

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  KINEMATIC WAVE MODEL 900 AREA ASPHALT SUBBASIN
    2     ID  RUNOFF EVALUATION 100-YR RETURN 24 HOUR DURATION STORM
    3     ID  MULTIPLE BASINS WITH OVERLAND FLOW AND GUTTER FLOW
    4     ID
    5     IT   15 21MAR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC  .0346 .0653 .1098 .1421 .2054 .2547 .3276 .3736 .4506 .5021
   12     PC  .5792 .6304 .7063 .7357 .8402 .8983 .9874 1.049 1.145 1.213
   13     PC  1.322 1.400 1.520 1.604 1.745 1.865 1.990 2.090 2.263 2.402
   14     PC  2.838 3.220 3.613 3.773 3.980 4.104 4.263 4.357 4.489 4.575
   15     PC  4.695 4.771 4.884 4.957 5.061 5.128 5.218 5.278 5.367 5.428
   16     PC  5.522 5.580 5.667 5.724 5.807 5.861 5.942 5.996 6.075 6.128
   17     PC  6.206 6.257 6.333 6.383 6.457 6.506 6.578 6.626 6.696 6.743
   18     PC  6.811 6.856 6.923 6.967 7.032 7.155 7.164 7.180 7.241 7.281
   19     PC  7.341 7.380 7.437 7.475 7.531 7.568 7.622 7.657 7.710 7.744
   20     PC  7.794 7.827 7.876 7.908 7.954 8.000    0    0    0    0
   21     LS   0   98    0    0   85    0
   22     BA .00065
   23     UK   100  .008  .13   80
   24     UK   100  .008  .08   20
   25     RK   130  .004  .13       TRAP    0   20
   26     RK   160  .004  .13       TRAP    0   20

   27     KK  SUB B
   28     KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN B
   29     LS   0   98    0    0   85    0
   30     BA .0017
   31     UK   170  .008  .13   80
   32     UK   170  .008  .08   20
   33     RK   160  .004  .13       TRAP    0   20
   34     RK   160  .004  .13       TRAP    0   20   YES
```

```
35    KK  SUB C
36    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN C
37    LS    0   98    0    0   85    0
38    BA  .0024
39    UK   210  .008  .13   80
40    UK   210  .008  .08   20
41    RK   160  .004  .13       TRAP    0   20
42    RK   160  .004  .13       TRAP    0   20   YES

43    KK  SUB D
44    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN D
45    LS    0   98    0    0   85    0
46    BA  .0024
47    UK   240  .008  .13   80
48    UK   240  .008  .08   20
49    RK   160  .004  .13       TRAP    0   20
50    RK   160  .004  .13       TRAP    0   20   YES
1                        HEC-1 INPUT                        PAGE  2

LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

51    KK  SUB E
52    KM  COMPUTING THE OUTFLOW HYDROGRAPH FOR RUNOFF FROM SUBBASIN E
53    LS    0   98    0    0   85    0
54    BA  .0025
55    UK   240  .008  .13   80
56    UK   240  .008  .08   20
57    RK   160  .004  .13       TRAP    0   20

58    KK  COMB 1
59    KM  COMBINING THE RUNOFF HYDROGRAPHS FROM PREVIOUS BASINS WITH SUBBASIN E
60    HC    2
61    ZZ
```

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT
LINE (V) ROUTING (---->) DIVERSION OR PUMP FLOW

NO. (.) CONNECTOR (<----) RETURN OF DIVERTED OR PUMPED FLOW

8 SUB A
V
V
27 SUB B ***
V
V
35 SUB C ***
V
V
43 SUB D ***
.
.
51 . SUB E
. .
. .
58 COMB .....

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
****

KINEMATIC WAVE MODEL 900 AREA ASPHALT SUBBASIN
RUNOFF EVALUATION 100-YR RETURN 24 HOUR DURATION STORM
MULTIPLE BASINS WITH OVERLAND FLOW AND GUTTER FLOW

6 IO OUTPUT CONTROL VARIABLES
IPRNT 5 PRINT CONTROL
IPLOT 2 PLOT CONTROL
QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA
NMIN 15 MINUTES IN COMPUTATION INTERVAL
IDATE 21MAR89 STARTING DATE
ITIME 0600 STARTING TIME
NQ 120 NUMBER OF HYDROGRAPH ORDINATES

NDTIME 1145 ENDING TIME

COMPUTATION INTERVAL .25 HOURS
TOTAL TIME BASE 29.75 HOURS

1 STATION SUB A

(O) OUTFLOW

.0 .1 .2 .3 .4 .5 .6 .7 .0 .0 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .0 .6 .4 .2 .0

DAHRMN PER

```
210600 1O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
210615 2O          .          .          .          .          .          .          .          .          .          LL.
210630 3O          .          .          .          .          .          .          .          .          .          LL.
210645 4O          .          .          .          .          .          .          .          .          .          LL.
210700 5O          .          .          .          .          .          .          .          .          .          LLX.
210715 6O          .          .          .          .          .          .          .          .          .          LX.
210730 7. O        .          .          .          .          .          .          .          .          .          LLXX.
210745 8.  O       .          .          .          .          .          .          .          .          .          XX.
210800 9.   O      .          .          .          .          .          .          .          .          .          LXXX.
210815 10.   O     .          .          .          .          .          .          .          .          .          LXX.
210830 11....O.....................................................................LXXX.
210845 12.   O     .          .          .          .          .          .          .          .          .          LXX.
210900 13.   O     .          .          .          .          .          .          .          .          .          LXXX.
210915 14.   O     .          .          .          .          .          .          .          .          .          X.
210930 15.   O     .          .          .          .          .          .          .          .          .          LXXXX.
210945 16.   O.    .          .          .          .          .          .          .          .          .          LXX.
211000 17.    O    .          .          .          .          .          .          .          .          .          XXXX.
211015 18.    .O   .          .          .          .          .          .          .          .          .          XXX.
211030 19.    .O   .          .          .          .          .          .          .          .          .          LXXXX.
211045 20.    . O  .          .          .          .          .          .          .          .          .          XXX.
211100 21.....O.....................................................................XXXXX.
211115 22.    . O  .          .          .          .          .          .          .          .          .          XXXX.
211130 23.    . O  .          .          .          .          .          .          .          .          .          LXXXXX.
211145 24.    . O  .          .          .          .          .          .          .          .          .          XXXX.
211200 25.    . O  .          .          .          .          .          .          .          .          .          XXXXXXX.
211215 26.    .  O .          .          .          .          .          .          .          .          .          XXXXXX.
211230 27.    .  O.          .          .          .          .          .          .          .          .          XXXXXX.
211245 28.    .  O.          .          .          .          .          .          .          .          .          XXXXX.
211300 29.    .  O.          .          .          .          .          .          .          .          .          LXXXXXXXX.
211315 30.    .   .O         .          .          .          .          .          .          .          .          XXXXXXX.
211330 31..............O.....................................................LXXXXXXXXXXXXXXXXXXXXX.
211345 32.    .   .   .   .  O   .          .          .          .          .LXXXXXXXXXXXXXXXXXX.
211400 33.    .   .   .   .   .  .O         .          .          .          LXXXXXXXXXXXXXXXXXXX.
211415 34.    .   .   .   .   .  O          .          .          .          .  XXXXXXXX.
211430 35.    .   .   .   .O  .  .          .          .          .          .  XXXXXXXXXX.
211445 36.    .   .   .O  .   .  .          .          .          .          .  XXXXXX.
211500 37.    .   .  O .   .   .  .          .          .          .          .  XXXXXXXX.
211515 38.    .   . O  .   .   .  .          .          .          .          .  XXXXX.
211530 39.    .   .O   .   .   .  .          .          .          .          .  LXXXXXX.
211545 40.    .   O.   .   .   .  .          .          .          .          .  XXXX.
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211600 41. . . . . O . . . . . XXXXXX.
211615 42. . O . . . . . XXXX.
211630 43. . O . . . . . XXXXXX.
211645 44. . O . . . . . XXXX.
211700 45. . O . . . . . XXXXX.
211715 46. . O . . . . . XXX.
211730 47. . O . . . . . LXXXX.
211745 48. . O . . . . . XXX.
211800 49. . O . . . . . XXXX.
211815 50. . O . . . . . XXX.
211830 51. . . . . O . . . . . XXXXX.
211845 52. . O . . . . . XXX.
211900 53. . O . . . . . XXXX.
211915 54. . O . . . . . XXX.
211930 55. . O . . . . . XXXX.
211945 56. . O . . . . . XXX.
212000 57. . O . . . . . XXXX.
212015 58. . O . . . . . XXX.
212030 59. . O . . . . . XXXX.
212045 60. . O . . . . . XXX.
212100 61. . . . . O . . . . . XXXX.
212115 62. . O . . . . . XXX.
212130 63. . O . . . . . XXXX.
212145 64. . O . . . . . XX.
212200 65. O . . . . . XXXX.
212215 66. O . . . . . XX.
212230 67. O . . . . . XXXX.
212245 68. O . . . . . XX.
212300 69. O . . . . . LXXX.
212315 70. O . . . . . XX.
212330 71. . . . . O . . . . . XXX.
212345 72. O . . . . . XX.
220000 73. O. . . . . XXX.
220015 74. O. . . . . XX.
220030 75. O. . . . . XXX.
220045 76. O . . . . . XXXXXX.
220100 77. . O . . . . . .
220115 78. . O . . . . . X.
220130 79. O . . . . . XXX.
220145 80. O . . . . . XX.
220200 81. . . O . . . . . XXX.
220215 82. O . . . . . XX.
220230 83. O . . . . . XXX.
220245 84. O . . . . . XX.
220300 85. O . . . . . XXX.
220315 86. O . . . . . XX.
220330 87. O . . . . . XXX.
220345 88. O . . . . . XX.

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220415 90.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220430 91. . . .O. . . . . .LXX.
220445 92.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220500 93.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220515 94.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220530 95.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220545 96.   O .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
220600 97.   O .  .  .  .  .  .  .  .  .  .  .  .  .  .
220615 98.  O .  .  .  .  .  .  .  .  .  .  .  .  .  .
220630 99. O  .  .  .  .  .  .  .  .  .  .  .  .  .  .
220645 100.O  .  .  .  .  .  .  .  .  .  .  .  .  .  .
220700 101.O. . . . . .
220715 102O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220730 103O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220745 104O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220800 105O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220815 106O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220830 107O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220845 108O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220900 109O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220915 110O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
220930 111O . . . . . .
220945 112O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221000 113O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221015 114O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221030 115O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221045 116O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221100 117O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221115 118O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221130 119O   .  .  .  .  .  .  .  .  .  .  .  .  .  .
221145 120O———————.———————.———————.———————.———————.———————.———————.———————.———————.
```

1 STATION SUB B

(O) OUTFLOW

.0 .4 .8 1.2 1.6 2.0 2.4 .0 .0 .0 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .0 .6 .4 .2 .0

```
DAHRMN PER
210600 1O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
210615 2O          .          .          .          .          .          .          .          .          .          .  LL.
210630 3O          .          .          .          .          .          .          .          .          .          .  LL.
210645 4O          .          .          .          .          .          .          .          .          .          .  LL.
210700 5O          .          .          .          .          .          .          .          .          .          .  LLX.
210715 6O          .          .          .          .          .          .          .          .          .          .  LX.
210730 7.O         .          .          .          .          .          .          .          .          .          .  LLXX.
210745 8. O        .          .          .          .          .          .          .          .          .          .  XX.
210800 9. O        .          .          .          .          .          .          .          .          .          .  LXXX.
210815 10.  O      .          .          .          .          .          .          .          .          .          .  LXX.
210830 11.. O.....................................................................  LXXX.
210845 12.  O      .          .          .          .          .          .          .          .          .          .  LXX.
210900 13.  O      .          .          .          .          .          .          .          .          .          .  LXXX.
210915 14.  O      .          .          .          .          .          .          .          .          .          .  X.
210930 15.  O      .          .          .          .          .          .          .          .          .          .  LXXXX.
210945 16.  O.     .          .          .          .          .          .          .          .          .          .  LXX.
211000 17.  O.     .          .          .          .          .          .          .          .          .          .  XXXX.
211015 18.  O      .          .          .          .          .          .          .          .          .          .  XXX.
211030 19.  O      .          .          .          .          .          .          .          .          .          .  LXXXX.
211045 20.  O      .          .          .          .          .          .          .          .          .          .  XXX.
211100 21.....O.....................................................................XXXXX.
211115 22.  .O     .          .          .          .          .          .          .          .          .          .  XXXX.
211130 23.  .O     .          .          .          .          .          .          .          .          .          .  LXXXXX.
211145 24.  . O    .          .          .          .          .          .          .          .          .          .  XXXX.
211200 25.  .  O   .          .          .          .          .          .          .          .          .          .  XXXXXXX.
211215 26.  .   O  .          .          .          .          .          .          .          .          .          .  XXXXXX.
211230 27.  .   O  .          .          .          .          .          .          .          .          .          .  XXXXXX.
211245 28.  .   O  .          .          .          .          .          .          .          .          .          .  XXXXX.
211300 29.  .   O  .          .          .          .          .          .          .          .          .          .  LXXXXXXXX.
211315 30.  .    O.           .          .          .          .          .          .          .          .          .  XXXXXXX.
211330 31.............O.....................................................  LXXXXXXXXXXXXXXXXXXXXX.
211345 32.  .          .          .    .O    .          .          .          .          .          .  LXXXXXXXXXXXXXXXXXX.
211400 33.  .          .          .          .    .O    .          .          .          .          .  LXXXXXXXXXXXXXXXXXXX.
211415 34.  .          .          .          .    .O    .          .          .          .          .  XXXXXXXX.
211430 35.  .          .          .    .O    .          .          .          .          .          .  XXXXXXXXXX.
211445 36.  .          .     .O   .          .          .          .          .          .          .  XXXXXX.
211500 37.  .          .  O  .          .          .          .          .          .          .          .  XXXXXXXX.
211515 38.  .          . O   .          .          .          .          .          .          .          .  XXXXX.
211530 39.  .          O.    .          .          .          .          .          .          .          .  LXXXXXX.
211545 40.  .          O.    .          .          .          .          .          .          .          .  XXXX.
```

211600 41. . . . . O . . . . . XXXXXX.
211615 42. . O . . . . . XXXX.
211630 43. . O . . . . . XXXXXX.
211645 44. . O . . . . . XXXX.
211700 45. . O . . . . . XXXXX.
211715 46. . O . . . . . XXX.
211730 47. . O . . . . . LXXXX.
211745 48. . O . . . . . XXX.
211800 49. . O . . . . . XXXX.
211815 50. .O . . . . . XXX.
211830 51. . . . . O. . . . . XXXXX.
211845 52. .O . . . . . XXX.
211900 53. .O . . . . . XXXX.
211915 54. .O . . . . . XXX.
211930 55. .O . . . . . XXXX.
211945 56. .O . . . . . XXX.
212000 57. O . . . . . XXXX.
212015 58. O . . . . . XXX.
212030 59. O . . . . . XXXX.
212045 60. O . . . . . XXX.
212100 61. . . . . O . . . . . XXXX.
212115 62. O . . . . . XXX.
212130 63. O . . . . . XXXX.
212145 64. O . . . . . XX.
212200 65. O . . . . . XXXX.
212215 66. O. . . . . XX.
212230 67. O. . . . . XXXX.
212245 68. O. . . . . XX.
212300 69. O. . . . . LXXX.
212315 70. O. . . . . XX.
212330 71. . . . . O. . . . . XXX.
212345 72. O. . . . . XX.
220000 73. O. . . . . XXX.
220015 74. O. . . . . XX.
220030 75. O. . . . . XXX.
220045 76. O. . . . . XXXXXX.
220100 77. .O . . . . . .
220115 78. O . . . . . X.
220130 79. O . . . . . XXX.
220145 80. O . . . . . XX.
220200 81. . . O . . . . . XXX.
220215 82. O . . . . . XX.
220230 83. O . . . . . XXX.
220245 84. O . . . . . XX.
220300 85. O . . . . . XXX.
220315 86. O . . . . . XX.
220330 87. O . . . . . XXX.
220345 88. O . . . . . XX.

220415 90. O . . . . . XX.
220430 91. . . O . . . . . LXX.
220445 92. O . . . . . XX.
220500 93. O . . . . . XX.
220515 94. O . . . . . XX.
220530 95. O . . . . . XX.
220545 96. O . . . . . XX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101.O. . . . . .
220715 102.O . . . . . .
220730 103.O . . . . . .
220745 104O . . . . . .
220800 105O . . . . . .
220815 106O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.

1 STATION SUB C

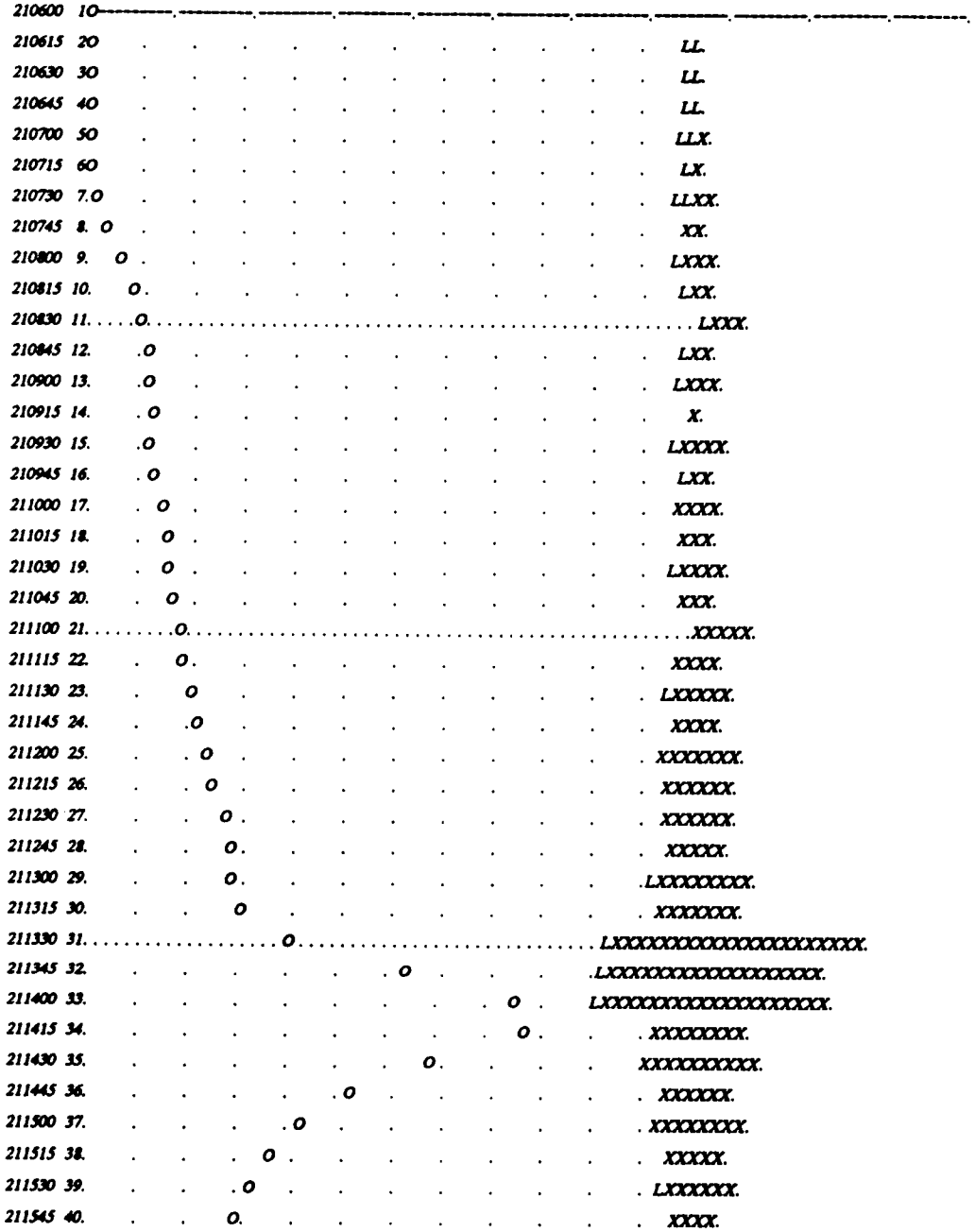
(O) OUTFLOW

.0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .0 .6 .4 .2 .0

DAHRMN PER



211600 41. .....O.....XXXXXX.
211615 42. . . O . . . . . XXXX.
211630 43. . . O . . . . . XXXXXX.
211645 44. . . O . . . . . XXXX.
211700 45. . . O . . . . . XXXXX.
211715 46. . .O . . . . . XXX.
211730 47. . .O . . . . . LXXXX.
211745 48. . O . . . . . XXX.
211800 49. . O. . . . . XXXX.
211815 50. . O. . . . . XXX.
211830 51. .....O.....XXXXX.
211845 52. . O. . . . . XXX.
211900 53. . O. . . . . XXXX.
211915 54. . O. . . . . XXX.
211930 55. . O. . . . . XXXX.
211945 56. . O. . . . . XXX.
212000 57. . O. . . . . XXXX.
212015 58. . O. . . . . XXX.
212030 59. . O. . . . . XXXX.
212045 60. . O. . . . . XXX.
212100 61. .....O.....XXXX.
212115 62. . O. . . . . XXX.
212130 63. . O. . . . . XXXX.
212145 64. . O. . . . . XX.
212200 65. . O. . . . . XXXX.
212215 66. . O. . . . . XX.
212230 67. . O. . . . . XXXX.
212245 68. . O. . . . . XX.
212300 69. . O. . . . . LXXX.
212315 70. . O. . . . . XX.
212330 71. .....O.....XXX.
212345 72. . O. . . . . XX.
220000 73. . O. . . . . XXX.
220015 74. . O. . . . . XX.
220030 75. . O. . . . . XXX.
220045 76. . O. . . . . XXXXXX.
220100 77. . O. . . . . .
220115 78. . O. . . . . X.
220130 79. .O. . . . . XXX.
220145 80. O. . . . . XX.
220200 81. .....O.....XXX.
220215 82. .O. . . . . XX.
220230 83. .O. . . . . XXX.
220245 84. . O. . . . . XX.
220300 85. .O. . . . . XXX.
220315 86. .O. . . . . XX.
220330 87. .O. . . . . XXX.
220345 88. .O. . . . . XX.

220400 89. .O . . . . . XXX.
220415 90. .O . . . . . XX.
220430 91. . . . . O . . . . . LXX.
220445 92. O . . . . . XX.
220500 93. O . . . . . XX.
220515 94. O . . . . . XX.
220530 95. O . . . . . XX.
220545 96. O . . . . . XX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. O . . . . . .
220715 102. O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105.O . . . . . .
220815 106.O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.

1 STATION SUB D

(O) OUTFLOW

0. 1. 2. 3. 4. 5. 6. 7. 0. 0. 0. 0. 0.

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .0 .6 .4 .2 .0

DAHRMN PER

```
210600 10----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
210615 20          .          .          .          .          .          .          .          .          .          .          .          .  LL.
210630 30          .          .          .          .          .          .          .          .          .          .          .          .  LL.
210645 40          .          .          .          .          .          .          .          .          .          .          .          .  LL.
210700 50          .          .          .          .          .          .          .          .          .          .          .          .  LLX.
210715 60          .          .          .          .          .          .          .          .          .          .          .          .  LX.
210730 70          .          .          .          .          .          .          .          .          .          .          .          .  LLXX.
210745 8. O        .          .          .          .          .          .          .          .          .          .          .          .  XX.
210800 9. O        .          .          .          .          .          .          .          .          .          .          .          .  LXXX.
210815 10.  O      .          .          .          .          .          .          .          .          .          .          .          .  LXX.
210830 11....O.....................................................................................................LXXX.
210845 12.   O     .          .          .          .          .          .          .          .          .          .          .          .  LXX.
210900 13.   O     .          .          .          .          .          .          .          .          .          .          .          .  LXXX.
210915 14.   O.    .          .          .          .          .          .          .          .          .          .          .          .  X.
210930 15.   O     .          .          .          .          .          .          .          .          .          .          .          .  LXXXX.
210945 16.   O.    .          .          .          .          .          .          .          .          .          .          .          .  LXX.
211000 17.    O    .          .          .          .          .          .          .          .          .          .          .          .  XXXX.
211015 18.    .O   .          .          .          .          .          .          .          .          .          .          .          .  XXX.
211030 19.    .O   .          .          .          .          .          .          .          .          .          .          .          .  LXXXX.
211045 20.    . O  .          .          .          .          .          .          .          .          .          .          .          .  XXX.
211100 21.....O.....................................................................................................XXXXX.
211115 22.    . O  .          .          .          .          .          .          .          .          .          .          .          .  XXXX.
211130 23.    . O  .          .          .          .          .          .          .          .          .          .          .          .  LXXXXX.
211145 24.    . O  .          .          .          .          .          .          .          .          .          .          .          .  XXXX.
211200 25.    .  O .          .          .          .          .          .          .          .          .          .          .          .  XXXXXXX.
211215 26.    .  O.          .          .          .          .          .          .          .          .          .          .          .  XXXXXX.
211230 27.    .   O          .          .          .          .          .          .          .          .          .          .          .  XXXXXX.
211245 28.    .  .O          .          .          .          .          .          .          .          .          .          .          .  XXXXX.
211300 29.    .  .O          .          .          .          .          .          .          .          .          .          .          .  LXXXXXXXX.
211315 30.    .  . O         .          .          .          .          .          .          .          .          .          .          .  XXXXXXX.
211330 31.............O.....................................LXXXXXXXXXXXXXXXXXXXXX.
211345 32.    .    .    .  .  O  .          .          .          .          .          .  LXXXXXXXXXXXXXXXXX.
211400 33.    .    .    .  .  .  .O         .          .          .          .          .  LXXXXXXXXXXXXXXXXXX.
211415 34.    .    .    .  .  .  .  .O       .          .          .          .          .  .XXXXXXXX.
211430 35.    .    .    .  .  .O .  .          .          .          .          .          .  XXXXXXXXXX.
211445 36.    .    .    .  .O .  .  .          .          .          .          .          .  .XXXXXX.
211500 37.    .    .  . O .  .  .  .          .          .          .          .          .  .XXXXXXX.
211515 38.    .    .  O.  .  .  .  .          .          .          .          .          .  .XXXXX.
211530 39.    .    . O .  .  .  .  .          .          .          .          .          .  .LXXXXX.
211545 40.    .    . O .  .  .  .  .          .          .          .          .          .  .XXXX.
```

211600 41. .....O.....xxxxxx.
211615 42. . O. . . . . xxxx.
211630 43. . O. . . . . xxxxxx.
211645 44. . O. . . . . xxxx.
211700 45. . O. . . . . xxxxx.
211715 46. . O. . . . . xxx.
211730 47. . O. . . . . Lxxxx.
211745 48. . O. . . . . xxx.
211800 49. . O. . . . . xxxx.
211815 50. . O. . . . . xxx.
211830 51. .....O.....xxxxx.
211845 52. . O. . . . . xxx.
211900 53. . O. . . . . xxxx.
211915 54. . O. . . . . xxx.
211930 55. . O. . . . . xxxx.
211945 56. . O. . . . . xxx.
212000 57. . O. . . . . xxxx.
212015 58. . O. . . . . xxx.
212030 59. . O. . . . . xxxx.
212045 60. . O. . . . . xxx.
212100 61. .....O.....xxxx.
212115 62. . O. . . . . xxx.
212130 63. . O. . . . . xxxx.
212145 64. . O. . . . . xx.
212200 65. .O. . . . . xxxx.
212215 66. .O. . . . . xx.
212230 67. .O. . . . . xxxx.
212245 68. .O. . . . . xx.
212300 69. .O. . . . . Lxxx.
212315 70. .O. . . . . xx.
212330 71. .....O.....xxx.
212345 72. .O. . . . . xx.
220000 73. O. . . . . xxx.
220015 74. O. . . . . xx.
220030 75. O. . . . . xxx.
220045 76. .O. . . . . xxxxxx.
220100 77. . O. . . . . .
220115 78. . O. . . . . x.
220130 79. O. . . . . xxx.
220145 80. O. . . . . xx.
220200 81. ...O.....xxx.
220215 82. O. . . . . xx.
220230 83. O. . . . . xxx.
220245 84. O. . . . . xx.
220300 85. O. . . . . xxx.
220315 86. O. . . . . xx.
220330 87. O. . . . . xxx.
220345 88. O. . . . . xx.

220400 89. O . . . . . XXX.
220415 90. O . . . . . XX.
220430 91. . . . O . . . . . LXX.
220445 92. O . . . . . XX.
220500 93. O . . . . . XX.
220515 94. O . . . . . XX.
220530 95. O . . . . . XX.
220545 96. O . . . . . XX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101. O . . . . . .
220715 102. O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105.O . . . . . .
220815 106.O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O———.———.———.———.———.———.———.———.———.———.

1 STATION SUB E

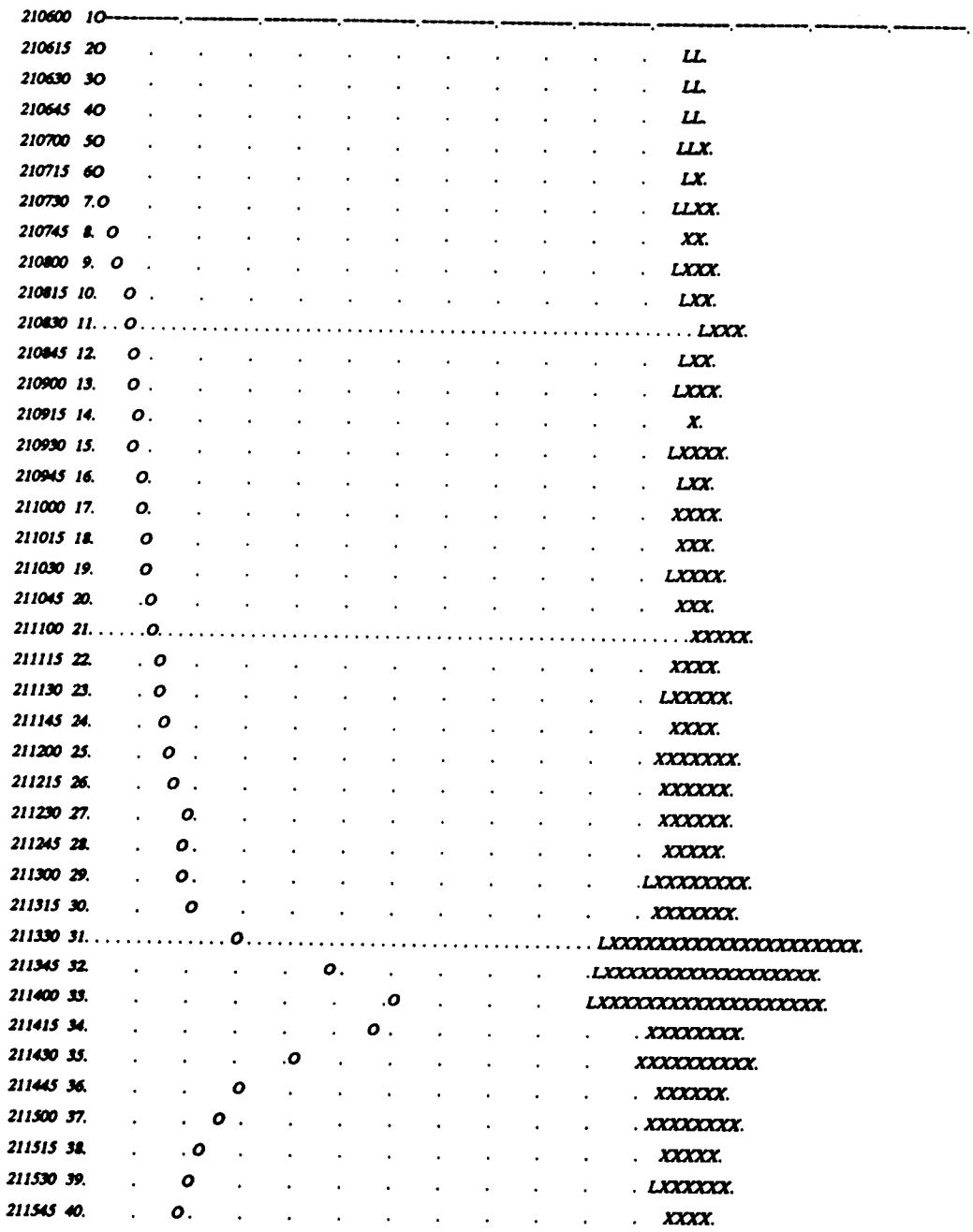
(O) OUTFLOW

.0 .4 .8 1.2 1.6 2.0 2.4 2.8 .0 .0 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .0 .6 .4 .2 .0

DAHRMN PER

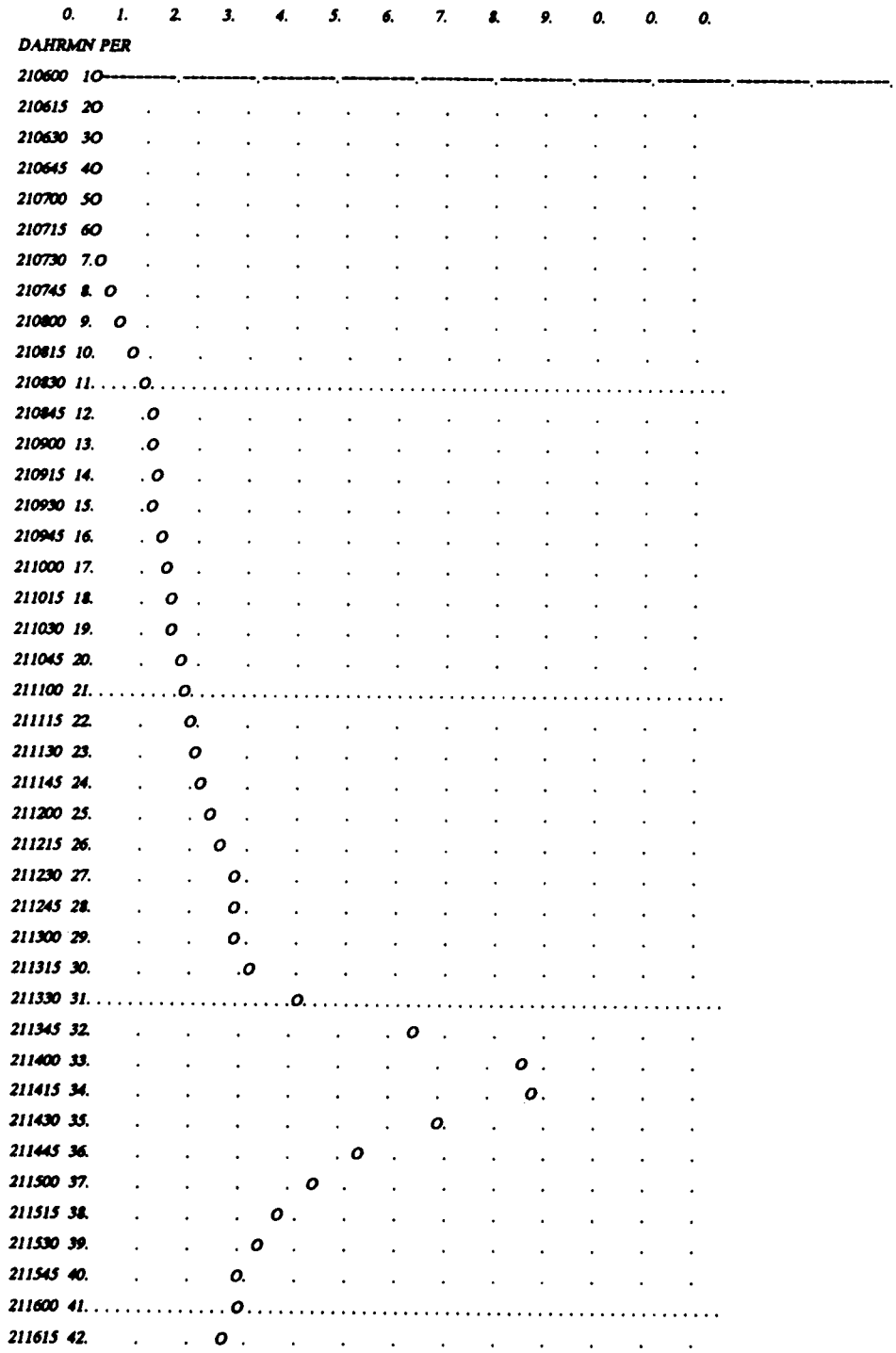


211615 42. . O . . . . . XXXX.
211630 43. . O . . . . . XXXXXX.
211645 44. . O . . . . . XXXX.
211700 45. . O . . . . . XXXXX.
211715 46. . O . . . . . XXX.
211730 47. . O . . . . . LXXXX.
211745 48. . O . . . . . XXX.
211800 49. . O . . . . . XXXX.
211815 50. . O . . . . . XXX.
211830 51. . . . . O . . . . . XXXXX.
211845 52. . O . . . . . XXX.
211900 53. . O . . . . . XXXX.
211915 54. . O . . . . . XXX.
211930 55. . O . . . . . XXXX.
211945 56. . O . . . . . XXX.
212000 57. . O . . . . . XXXX.
212015 58. . O . . . . . XXX.
212030 59. O . . . . . XXXX.
212045 60. . O . . . . . XXX.
212100 61. . . . . O . . . . . XXXX.
212115 62. O . . . . . XXX.
212130 63. O . . . . . XXXX.
212145 64. O . . . . . XX.
212200 65. O . . . . . XXXX.
212215 66. O . . . . . XX.
212230 67. O. . . . . XXXX.
212245 68. O . . . . . XX.
212300 69. O. . . . . LXXX.
212315 70. O. . . . . XX.
212330 71. . . . . O. . . . . XXX.
212345 72. O. . . . . XX.
220000 73. O. . . . . XXX.
220015 74. O. . . . . XX.
220030 75. O. . . . . XXX.
220045 76. O . . . . . XXXXXX.
220100 77. . O . . . . . .
220115 78. O. . . . . X.
220130 79. O . . . . . XXX.
220145 80. O . . . . . XX.
220200 81. . . . O. . . . . XXX.
220215 82. O. . . . . XX.
220230 83. O . . . . . XXX.
220245 84. O. . . . . XX.
220300 85. O . . . . . XXX.
220315 86. O. . . . . XX.
220330 87. O . . . . . XXX.
220345 88. O . . . . . XX.

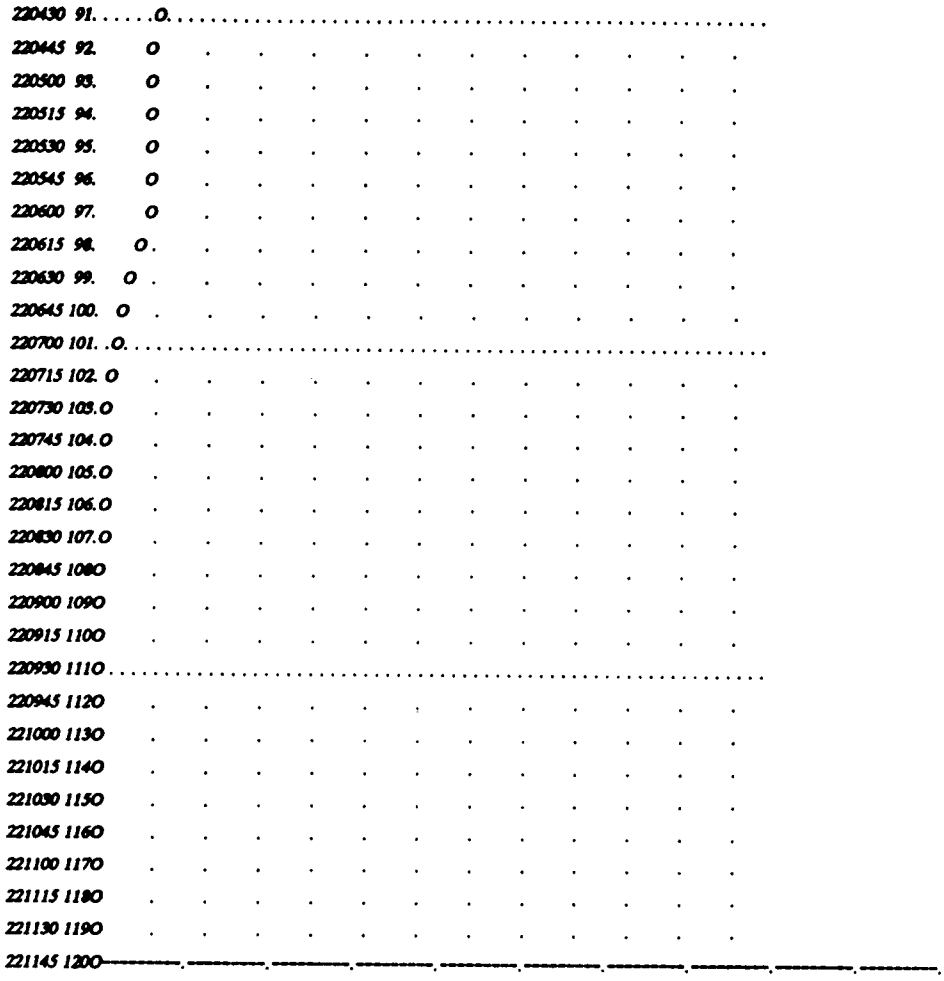
220400 89. O . . . . . XXX.
220415 90. O . . . . . XX.
220430 91. . . . O. . . . . LXX.
220445 92. O . . . . . XX.
220500 93. O . . . . . XX.
220515 94. O . . . . . XX.
220530 95. O . . . . . XX.
220545 96. O . . . . . XX.
220600 97. O . . . . . .
220615 98. O . . . . . .
220630 99. O . . . . . .
220645 100. O . . . . . .
220700 101.O. . . . . .
220715 102.O . . . . . .
220730 103.O . . . . . .
220745 104.O . . . . . .
220800 105O . . . . . .
220815 106O . . . . . .
220830 107O . . . . . .
220845 108O . . . . . .
220900 109O . . . . . .
220915 110O . . . . . .
220930 111O . . . . . .
220945 112O . . . . . .
221000 113O . . . . . .
221015 114O . . . . . .
221030 115O . . . . . .
221045 116O . . . . . .
221100 117O . . . . . .
221115 118O . . . . . .
221130 119O . . . . . .
221145 120O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.

1 STATION COMB

(O) OUTFLOW



211630 43. . . O . . . . . .
211645 44. . . O . . . . . .
211700 45. . . O . . . . . .
211715 46. . . O . . . . . .
211730 47. . .O . . . . . .
211745 48. . O . . . . . .
211800 49. . O. . . . . .
211815 50. . O. . . . . .
211830 51. .....O.....
211845 52. . O. . . . . .
211900 53. . O. . . . . .
211915 54. . O. . . . . .
211930 55. . O . . . . . .
211945 56. . O . . . . . .
212000 57. . O . . . . . .
212015 58. . O . . . . . .
212030 59. . O . . . . . .
212045 60. . O . . . . . .
212100 61. .....O.....
212115 62. . O . . . . . .
212130 63. . O . . . . . .
212145 64. . O . . . . . .
212200 65. . O . . . . . .
212215 66. . O . . . . . .
212230 67. . O . . . . . .
212245 68. . O . . . . . .
212300 69. . O . . . . . .
212315 70. . O . . . . . .
212330 71. .....O.....
212345 72. . O . . . . . .
220000 73. . O . . . . . .
220015 74. . O . . . . . .
220030 75. . O . . . . . .
220045 76. . O . . . . . .
220100 77. . O. . . . . .
220115 78. . O . . . . . .
220130 79. .O . . . . . .
220145 80. O . . . . . .
220200 81. .....O.....
220215 82. .O . . . . . .
220230 83. .O . . . . . .
220245 84. . O . . . . . .
220300 85. .O . . . . . .
220315 86. . O . . . . . .
220330 87. .O . . . . . .
220345 88. .O . . . . . .
220400 89. .O . . . . . .
220415 90. .O . . . . . .


220430 91.
220445 92.
220500 93.
220515 94.
220530 95.
220545 96.
220600 97.
220615 98.
220630 99.
220645 100.
220700 101.
220715 102.
220730 103.
220745 104.
220800 105.
220815 106.
220830 107.
220845 108
220900 109
220915 110
220930 111
220945 112
221000 113
221015 114
221050 115
221045 116
221100 117
221115 118
221130 119
221145 120

1

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT									
SUB A	1.	8.00	0.	0.	0.	.00			
HYDROGRAPH AT									
SUB B	2.	8.00	1.	0.	0.	.00			
HYDROGRAPH AT									
SUB C	4.	8.25	2.	1.	1.	.00			
HYDROGRAPH AT									
SUB D	6.	8.25	3.	1.	1.	.01			
HYDROGRAPH AT									
SUB E	2.	8.00	1.	0.	0.	.00			
2 COMBINED AT									
COMB	9.	8.25	4.	2.	2.	.01			

*** NORMAL END OF HEC-1 ***

APPENDIX A-3

HEC-1 INPUT/OUTPUT SUBBASIN 2 AND 3
1-YEAR STORM

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

HEC-1 INPUT

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
    2     ID  COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
    3     ID  1 YEAR STORM WITH 24 HOUR RAINFALL DISTRUBUTION
    4     ID
    5     IT   30 3APR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC  .0173  .0326  .0549  .0710  .1027  .1274  .1638  .1878  .2253  .2510
   12     PC  .2896  .3152  .3532  .3788  .4201  .4492  .4937  .5243  .5724  .6064
   13     PC  .6612  .7000  .7600  .8020  .8723  .9226  .9951  1.045  1.132  1.20
   14     PC  1.429  1.610  1.807  1.887  1.990  2.052  2.132  2.178  2.245  2.287
   15     PC  2.347  2.385  2.442  2.478  2.531  2.564  2.609  2.639  2.684  2.714
   16     PC  2.761  2.790  2.834  2.862  2.903  2.931  2.971  2.998  3.038  3.064
   17     PC  3.103  3.128  3.166  3.191  3.229  3.253  3.289  3.313  3.348  3.371
   18     PC  3.406  3.428  3.462  3.484  3.516  3.577  3.582  3.590  3.620  3.641
   19     PC  3.670  3.690  3.719  3.738  3.766  3.784  3.811  3.829  3.855  3.872
   20     PC  3.897  3.914  3.938  3.954  3.977  4.000
   21     BA   .03
   22     LS    0   80    0
   23     UD  1.50

   24     KK  SUB B
   25     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN B
   26     BA   .005
   27     LS    0   85    3
   28     UD   .50

   29     KK  COM 1
   30     KM  COMBINING HYDROGRAPHS FROM SUBBASINS A AND B
   31     HC    2

   32     KK  ROUTE
   33     KM  ROUTING HYDROGRAPH THROUGH CHANNEL TO RESERVOIR
   34     RM    1   .5   .2
   35     ZZ
```

1

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT

LINE (V) ROUTING (---->) DIVERSION OR PUMP FLOW

NO. (.) CONNECTOR (<----) RETURN OF DIVERTED OR PUMPED FLOW

8 SUB A

.

.

24 . SUB B

. .

. .

29 COM 1.....

V

V

32 ROUTE

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

****

SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF

COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE

1 YEAR STORM WITH 24 HOUR RAINFALL DISTRUBUTION

6 IO OUTPUT CONTROL VARIABLES

IPRNT 5 PRINT CONTROL

IPLOT 2 PLOT CONTROL

QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA

NMIN 30 MINUTES IN COMPUTATION INTERVAL

IDATE 3APR89 STARTING DATE

ITIME 0600 STARTING TIME

NQ 120 NUMBER OF HYDROGRAPH ORDINATES

NDDATE 5APR89 ENDING DATE

NDTIME 1730 ENDING TIME

COMPUTATION INTERVAL .50 HOURS

TOTAL TIME BASE 59.50 HOURS

ENGLISH UNITS

1 STATION SUB A

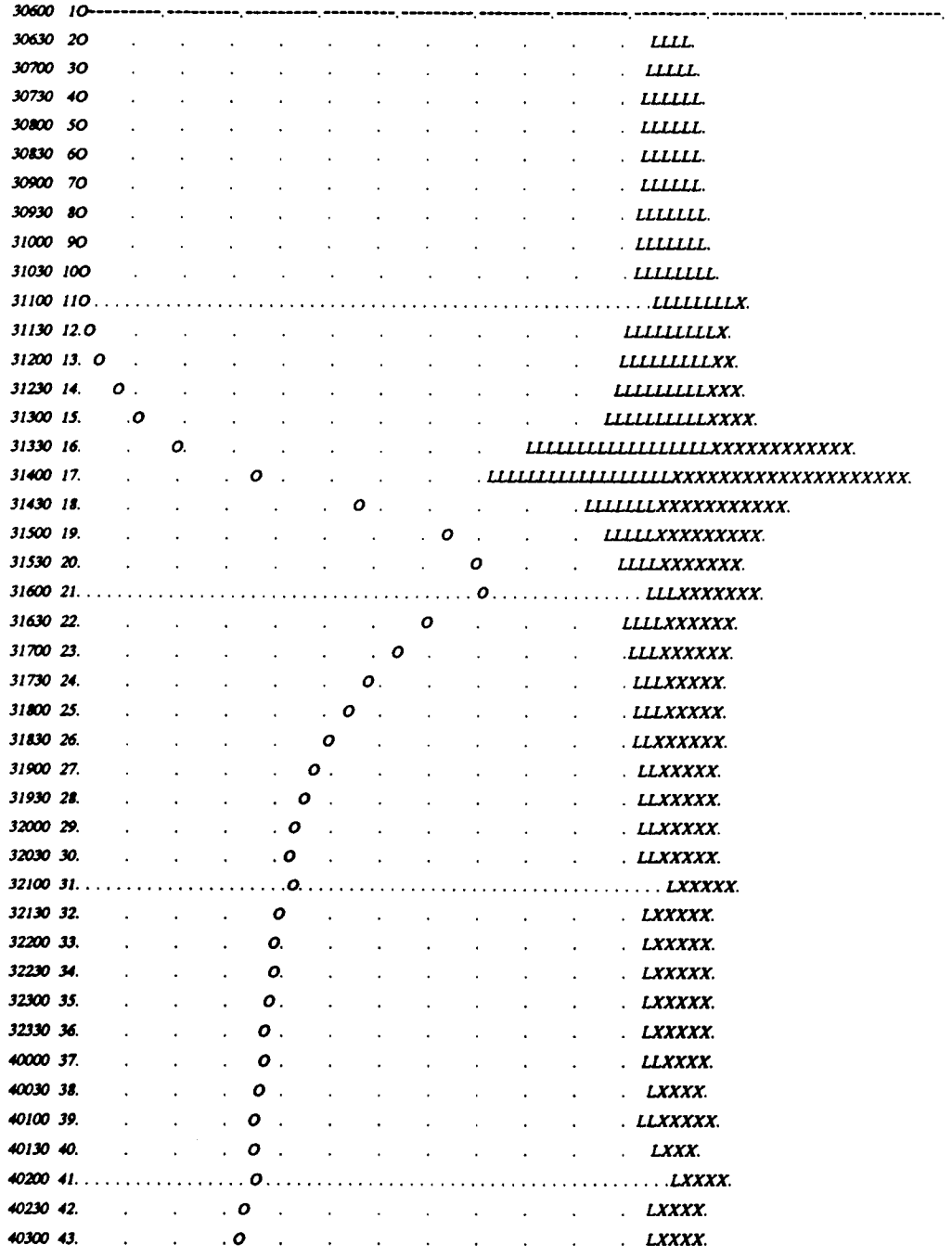
(O) OUTFLOW

.0 .5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .4 .3 .2 .1 .0

DAHRMN PER



40330 44. . . .O . . . . LXXXX.
40400 45. . . O . . . . XXXX.
40430 46. . . O . . . . LXXX.
40500 47. . . O. . . . . LXXX.
40530 48. . . O. . . . . LXXX.
40600 49. . . O . . . . XX.
40630 50. . . O . . . .
40700 51. . . . . O . . . . . .
40730 52. . O . . . .
40800 53. O. . . . .
40830 54. O . . . .
40900 55. O . . . .
40930 56. O . . . .
41000 57.O . . . .
41030 58.O . . . .
41100 59.O . . . .
41130 60O . . . .
41200 61O . . . . . .
41230 62O . . . .
41300 63O . . . .
41330 64O . . . .
41400 65O . . . .
41430 66O . . . .
41500 67O . . . .
41530 68O . . . .
41600 69O . . . .
41630 70O . . . .
41700 71O . . . . . .
41730 72O . . . .
41800 73O . . . .
41830 74O . . . .
41900 75O . . . .
41930 76O . . . .
42000 77O . . . .
42030 78O . . . .
42100 79O . . . .
42130 80O . . . .
42200 81O . . . . . .
42230 82O . . . .
42300 83O . . . .
42330 84O . . . .
50000 85O . . . .
50030 86O . . . .
50100 87O . . . .
50130 88O . . . .
50200 89O . . . .
50230 90O . . . .
50300 91O . . . . . .
50330 92O . . . .
50400 93O . . . .
50430 94O . . . .
50500 95O . . . .

50530 96O . . . . . .
50600 97O . . . . . .
50630 98O . . . . . .
50700 99O . . . . . .
50730 100O . . . . . .
50800 101O . . . . . .
50830 102O . . . . . .
50900 103O . . . . . .
50930 104O . . . . . .
51000 105O . . . . . .
51030 106O . . . . . .
51100 107O . . . . . .
51130 108O . . . . . .
51200 109O . . . . . .
51230 110O . . . . . .
51300 111O . . . . . .
51330 112O . . . . . .
51400 113O . . . . . .
51430 114O . . . . . .
51500 115O . . . . . .
51530 116O . . . . . .
51600 117O . . . . . .
51630 118O . . . . . .
51700 119O . . . . . .
51730 120O----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
1

1 STATION SUB B

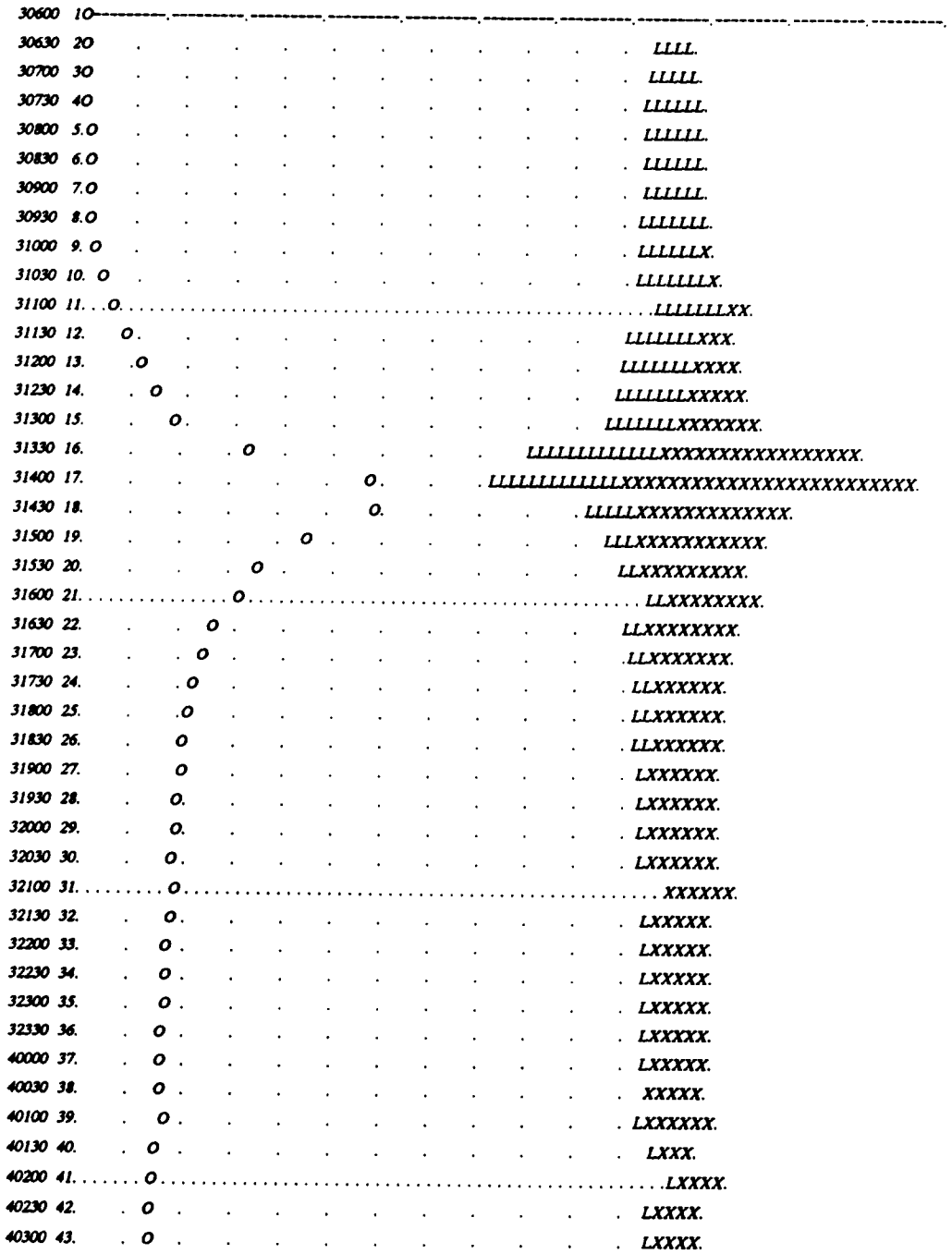
(O) OUTFLOW

.0 .2 .4 .6 .8 1.0 1.2 .0 .0 .0 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .4 .3 .2 .1 .0

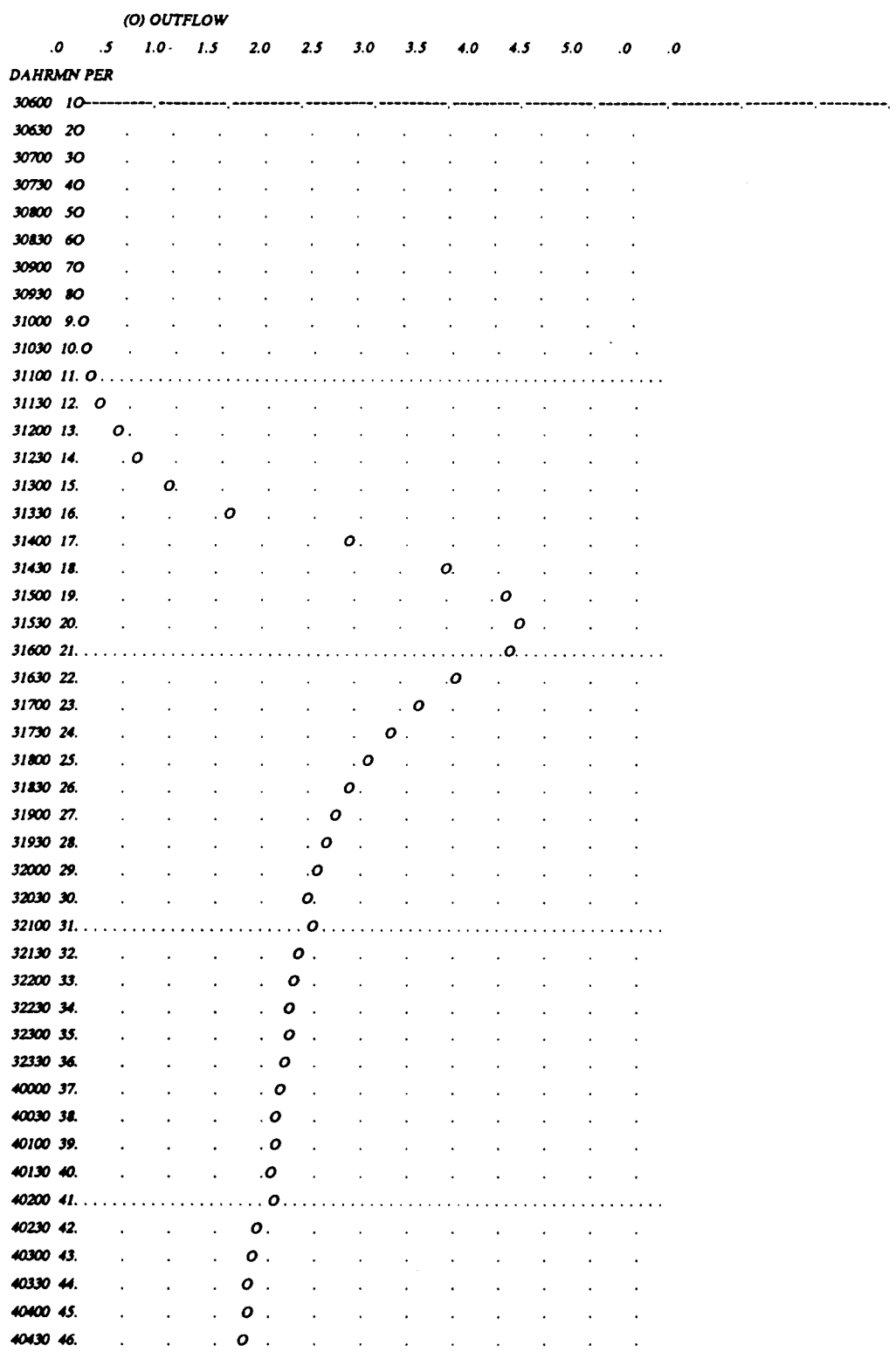
DAHRMN PER

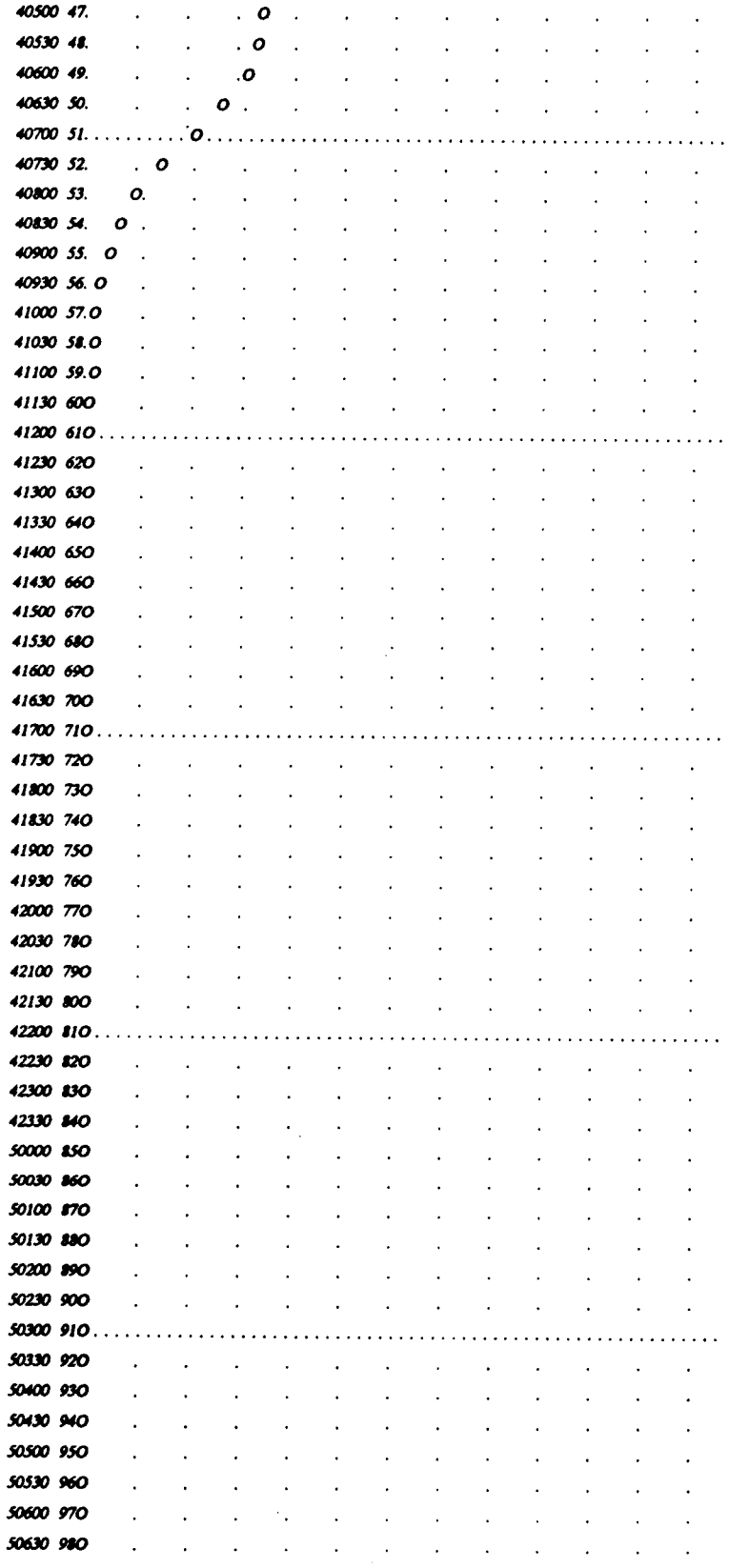


```
40330 44.      . O  .  .  .  .  .  .  .  .  .  .  .  .  .  LXXXX.
40400 45.      . O  .  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40430 46.      . O  .  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40500 47.      . O  .  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40530 48.      . O  .  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
40600 49.      O    .  .  .  .  .  .  .  .  .  .  .  .  .  XX.
40630 50.   O  .    .  .  .  .  .  .  .  .  .  .  .  .  .  .
40700 51. O ..........................................................
40730 52.O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40800 53O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40830 54O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40900 55O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40930 56O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41000 57O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41030 58O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41100 59O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41130 60O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41200 61O ..........................................................
41230 62O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41300 63O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41330 64O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41400 65O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41430 66O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41500 67O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41530 68O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41600 69O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41630 70O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41700 71O ..........................................................
41730 72O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41800 73O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41830 74O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41900 75O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41930 76O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42000 77O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42030 78O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42100 79O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42130 80O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42200 81O ..........................................................
42230 82O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42300 83O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42330 84O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50000 85O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50030 86O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50100 87O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50130 88O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50200 89O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50230 90O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50300 91O ..........................................................
50330 92O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50400 93O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50430 94O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50500 95O      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
```

50530 960 . . . . . .
50600 970 . . . . . .
50630 980 . . . . . .
50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 . . . . . .
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .
51130 1080 . . . . . .
51200 1090 . . . . . .
51230 1100 . . . . . .
51300 1110 . . . . . .
51330 1120 . . . . . .
51400 1130 . . . . . .
51430 1140 . . . . . .
51500 1150 . . . . . .
51530 1160 . . . . . .
51600 1170 . . . . . .
51630 1180 . . . . . .
51700 1190 . . . . . .
51730 1200----------.----------.----------.----------.----------.----------.----------.----------.----------.

1 STATION COM 1




40500 47.
40530 48.
40600 49.
40630 50.
40700 51.
40730 52.
40800 53.
40830 54.
40900 55.
40930 56.
41000 57.
41030 58.
41100 59.
41130 60
41200 61
41230 62
41300 63
41330 64
41400 65
41430 66
41500 67
41530 68
41600 69
41630 70
41700 71
41730 72
41800 73
41830 74
41900 75
41930 76
42000 77
42030 78
42100 79
42130 80
42200 81
42230 82
42300 83
42330 84
50000 85
50030 86
50100 87
50130 88
50200 89
50230 90
50300 91
50330 92
50400 93
50430 94
50500 95
50530 96
50600 97
50630 98

50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 .....
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .
51130 1080 . . . . . .
51200 1090 . . . . . .
51230 1100 . . . . . .
51300 1110 .....
51330 1120 . . . . . .
51400 1130 . . . . . .
51430 1140 . . . . . .
51500 1150 . . . . . .
51530 1160 . . . . . .
51600 1170 . . . . . .
51630 1180 . . . . . .
51700 1190 . . . . . .
51730 1200 ----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.

1 STATION ROUTE

(I) INFLOW, (O) OUTFLOW

```
     0.    1.    2.    3.    4.    5.    0.    0.    0.    0.    0.    0.    0.
DAHRMN PER
30600 11---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
30630 21 .  .  .  .  .  .  .  .  .  .  .  .  .
30700 31 .  .  .  .  .  .  .  .  .  .  .  .  .
30730 41 .  .  .  .  .  .  .  .  .  .  .  .  .
30800 51 .  .  .  .  .  .  .  .  .  .  .  .  .
30830 61 .  .  .  .  .  .  .  .  .  .  .  .  .
30900 71 .  .  .  .  .  .  .  .  .  .  .  .  .
30930 81 .  .  .  .  .  .  .  .  .  .  .  .  .
31000 91 .  .  .  .  .  .  .  .  .  .  .  .  .
31030 10OI .  .  .  .  .  .  .  .  .  .  .  .  .
31100 11.I. . . . . .
31130 12.OI .  .  .  .  .  .  .  .  .  .  .  .  .
31200 13. O I .  .  .  .  .  .  .  .  .  .  .  .  .
31230 14.  O I .  .  .  .  .  .  .  .  .  .  .  .  .
31300 15.   O I.  .  .  .  .  .  .  .  .  .  .  .  .
31330 16.    O  I .  .  .  .  .  .  .  .  .  .  .  .
31400 17.     . O .  I.  .  .  .  .  .  .  .  .  .  .
31430 18.     .  .  O.  I  .  .  .  .  .  .  .  .  .
31500 19.     .  .  .  O.  I .  .  .  .  .  .  .  .  .
31530 20.     .  .  .  . O I .  .  .  .  .  .  .  .  .
31600 21. . . . . .IO. . . . . .
31630 22.     .  .  .  I O  .  .  .  .  .  .  .  .  .
31700 23.     .  .  . I O  .  .  .  .  .  .  .  .  .
31730 24.     .  .  . I O .  .  .  .  .  .  .  .  .  .
31800 25.     .  .  .I O  .  .  .  .  .  .  .  .  .  .
31830 26.     .  .  I.O  .  .  .  .  .  .  .  .  .  .
31900 27.     .  .  IO.  .  .  .  .  .  .  .  .  .  .
31930 28.     .  .  I O. .  .  .  .  .  .  .  .  .  .
32000 29.     .  .  IO .  .  .  .  .  .  .  .  .  .  .
32030 30.     .  .  IO .  .  .  .  .  .  .  .  .  .  .
32100 31. . . . . IO. . . . . .
32130 32.     .  . I .  .  .  .  .  .  .  .  .  .  .
32200 33.     .  . IO .  .  .  .  .  .  .  .  .  .  .
32230 34.     .  . I .  .  .  .  .  .  .  .  .  .  .
32300 35.     .  . IO .  .  .  .  .  .  .  .  .  .  .
32330 36.     .  . I .  .  .  .  .  .  .  .  .  .  .
40000 37.     .  .IO .  .  .  .  .  .  .  .  .  .  .
40030 38.     .  .I .  .  .  .  .  .  .  .  .  .  .
40100 39.     .  .I .  .  .  .  .  .  .  .  .  .  .
40130 40.     .  .I .  .  .  .  .  .  .  .  .  .  .
40200 41. . . . . I. . . . . .
40230 42.     .  IO .  .  .  .  .  .  .  .  .  .  .
40300 43.     .  I. .  .  .  .  .  .  .  .  .  .  .
40330 44.     .  IO. .  .  .  .  .  .  .  .  .  .  .
40400 45.     .  I. .  .  .  .  .  .  .  .  .  .  .
40430 46.     .  IO .  .  .  .  .  .  .  .  .  .  .
```

```
40500 47.      .  I .  .  .  .  .  .  .  .  .  .  .  .  .  .
40530 48.      .  IO .  .  .  .  .  .  .  .  .  .  .  .  .  .
40600 49.      .  IO .  .  .  .  .  .  .  .  .  .  .  .  .  .
40630 50.      . I O .  .  .  .  .  .  .  .  .  .  .  .  .  .
40700 51.....I.O.....
40730 52.   I O  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40800 53.  I O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40830 54. I O  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40900 55. IO   .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40930 56.IO    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41000 57.I     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41030 58IO     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41100 59I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41130 60I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41200 61I.....
41230 62I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41300 63I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41330 64I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41400 65I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41430 66I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41500 67I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41530 68I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41600 69I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41630 70I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41700 71I.....
41730 72I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41800 73I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41830 74I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41900 75I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41930 76I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42000 77I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42030 78I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42100 79I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42130 80I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42200 81I.....
42230 82I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42300 83I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42330 84I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50000 85I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50030 86I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50100 87I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50130 88I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50200 89I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50230 90I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50300 91I.....
50330 92I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50400 93I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50430 94I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50500 95I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50530 96I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50600 97I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50630 98I      .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
```

```
50700 99I    .    .    .    .    .    .    .    .    .    .    .    .
50730 100I   .    .    .    .    .    .    .    .    .    .    .    .
50800 101I.....................................................
50830 102I   .    .    .    .    .    .    .    .    .    .    .    .
50900 103I   .    .    .    .    .    .    .    .    .    .    .    .
50930 104I   .    .    .    .    .    .    .    .    .    .    .    .
51000 105I   .    .    .    .    .    .    .    .    .    .    .    .
51030 106I   .    .    .    .    .    .    .    .    .    .    .    .
51100 107I   .    .    .    .    .    .    .    .    .    .    .    .
51130 108I   .    .    .    .    .    .    .    .    .    .    .    .
51200 109I   .    .    .    .    .    .    .    .    .    .    .    .
51230 110I   .    .    .    .    .    .    .    .    .    .    .    .
51300 111I.....................................................
51330 112I   .    .    .    .    .    .    .    .    .    .    .    .
51400 113I   .    .    .    .    .    .    .    .    .    .    .    .
51430 114I   .    .    .    .    .    .    .    .    .    .    .    .
51500 115I   .    .    .    .    .    .    .    .    .    .    .    .
51530 116I   .    .    .    .    .    .    .    .    .    .    .    .
51600 117I   .    .    .    .    .    .    .    .    .    .    .    .
51630 118I   .    .    .    .    .    .    .    .    .    .    .    .
51700 119I   .    .    .    .    .    .    .    .    .    .    .    .
51730 120I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1
1
```

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT									
+	SUB A	4.	9.50	3.	2.	1.	.03		
HYDROGRAPH AT									
+	SUB B	1.	8.50	1.	0.	0.	.00		
2 COMBINED AT									
+	COM 1	5.	9.50	4.	2.	1.	.04		
ROUTED TO									
+	ROUTE	5.	10.00	4.	2.	1.	.04		

**** NORMAL END OF HEC-1 ****

APPENDIX A-4

HEC-1 INPUT/OUTPUT SUBBASIN 2 AND 3
5-YEAR STORM

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

HEC-1 INPUT PAGE 1

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
    2     ID  COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
    3     ID  5 YEAR STORM WITH 24 HOUR RAINFALL DISTRIBUTION
    4     ID
    5     IT   30 3APR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC .0281  .053 .0892 .1154 .1669  .207 .2662 .3052 .3661 .4079
   12     PC .4706 .5122 .5739 .6156 .6826 .7299 .8022 .8520 .9302 .9653
   13     PC 1.075 1.138 1.235 1.303 1.418 1.499 1.617 1.698 1.839 1.951
   14     PC 2.306 2.617 2.936 3.066 3.234 3.334 3.464 3.540 3.648 3.717
   15     PC 3.815 3.876 3.968 4.027 4.112 4.166 4.239 4.288 4.361  4.41
   16     PC 4.487 4.533 4.605 4.651 4.718 4.762 4.828 4.872 4.936 4.979
   17     PC 5.042 5.084 5.145 5.186 5.246 5.286 5.345 5.383 5.441 5.478
   18     PC 5.534 5.571 5.625 5.661 5.714 5.813 5.821 5.853 5.883 5.916
   19     PC 5.964 5.996 6.043 6.074 6.119 6.149 6.193 6.222 6.264 6.292
   20     PC 6.333 6.360 6.399 6.425 6.463   6.5
   21     BA   .03
   22     LS    0   80    0
   23     UD  1.50

   24     KK  SUB B
   25     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN B
   26     BA   .005
   27     LS    0   87    3
   28     UD   .50

   29     KK  COM 1
   30     KM  COMBINING HYDROGRAPHS FROM SUBBASINS A AND B
   31     HC    2

   32     KK  ROUTE
   33     KM  ROUTING HYDROGRAPHS FROM SUBBASINS A AND B
   34     RM    1   .5   .2
   35     ZZ
```

```
1
          SCHEMATIC DIAGRAM OF STREAM NETWORK
INPUT
LINE    (V) ROUTING        (---->) DIVERSION OR PUMP FLOW

NO.     (.) CONNECTOR      (<----) RETURN OF DIVERTED OR PUMPED FLOW

  8     SUB A
          .
          .
 24         .    SUB B
          .        .
          .        .
 29     COM 1.....
          V
          V
 32     ROUTE

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION
1                                    ****
                FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
          U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                     ****



                SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
                COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
                5 YEAR STORM WITH 24 HOUR RAINFALL DISTRIBUTION


 6 IO       OUTPUT CONTROL VARIABLES
              IPRNT       5  PRINT CONTROL
              IPLOT       2  PLOT CONTROL
              QSCAL       0.  HYDROGRAPH PLOT SCALE

 IT         HYDROGRAPH TIME DATA
              NMIN       30  MINUTES IN COMPUTATION INTERVAL
              IDATE    3APR89  STARTING DATE
              ITIME      0600  STARTING TIME
                NQ        120  NUMBER OF HYDROGRAPH ORDINATES
             NDDATE     5APR89  ENDING DATE
             NDTIME      1730  ENDING TIME

           COMPUTATION INTERVAL     .50 HOURS
             TOTAL TIME BASE   59.50 HOURS

      ENGLISH UNITS
```

1 STATION SUB A

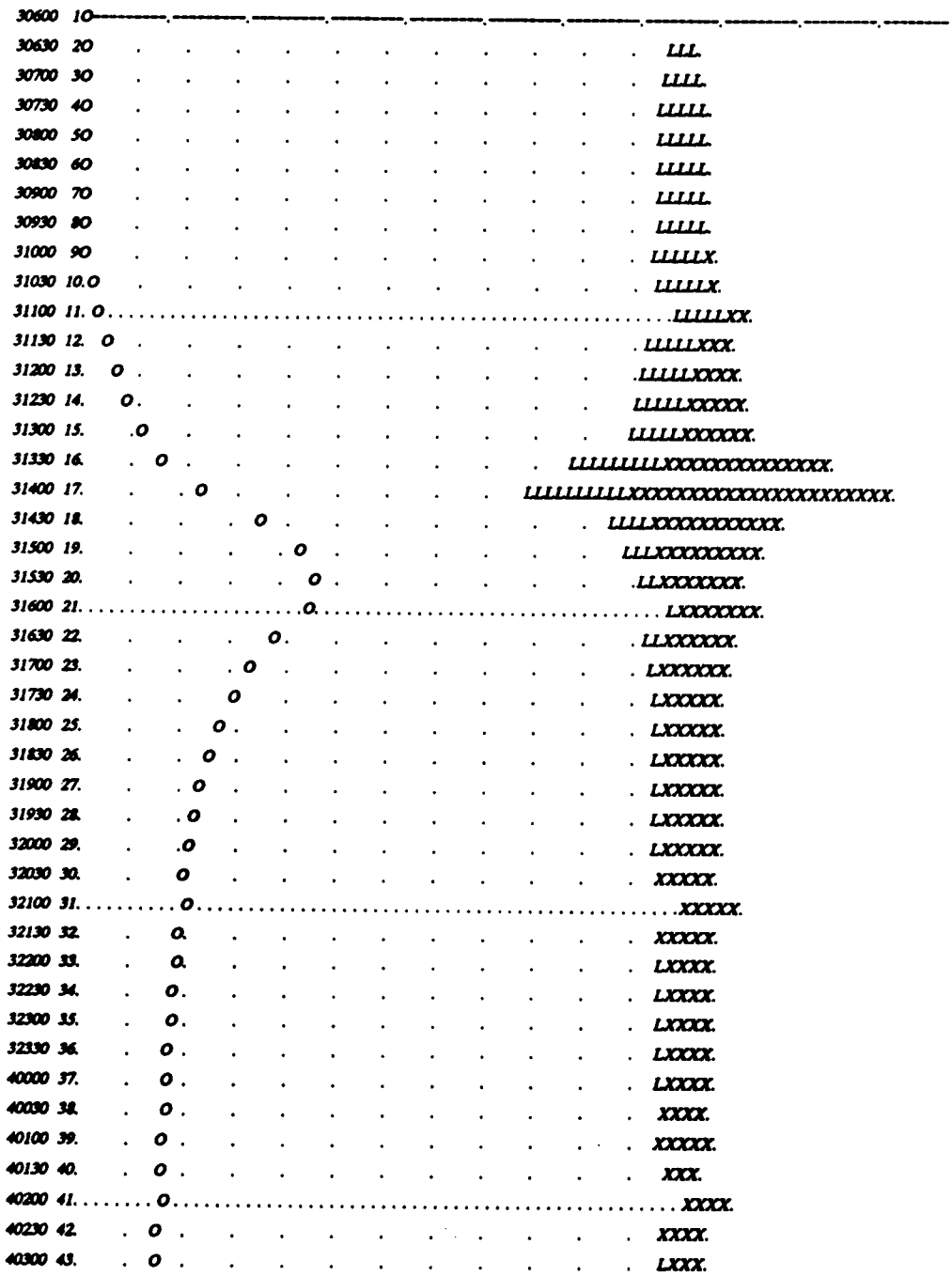
(O) OUTFLOW

0. 2. 4. 6. 8. 10. 0. 0. 0. 0. 0. 0. 0.

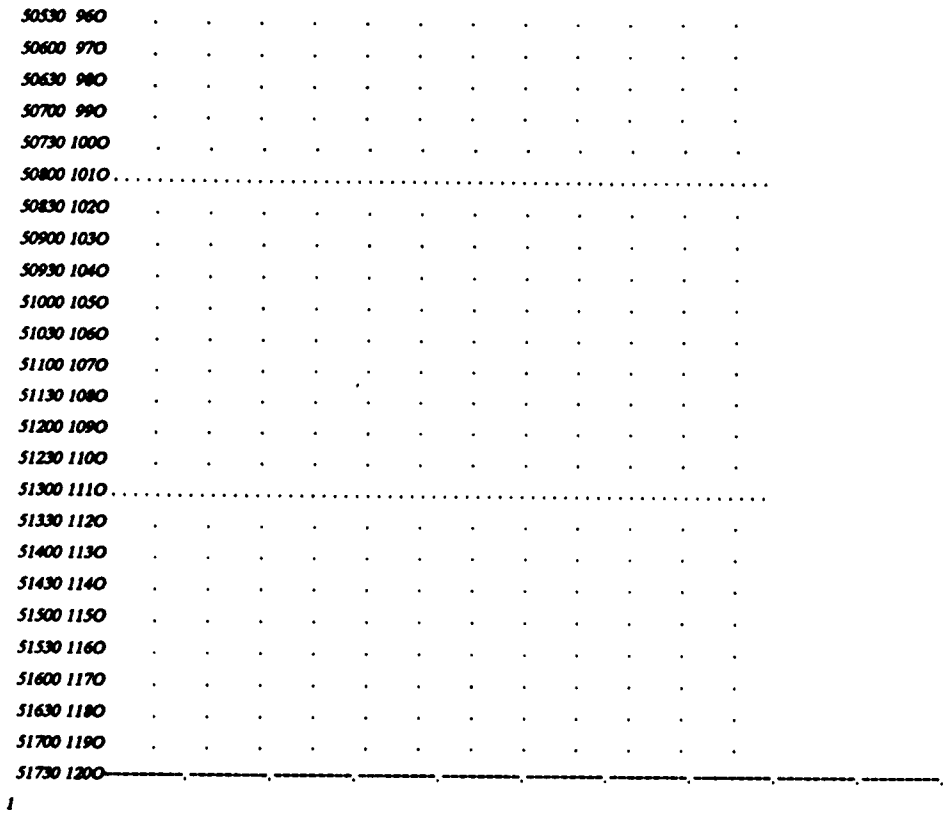
(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .8 .6 .4 .2 .0

DAHRMN PER



40400 45. . O . . . . . LXXX.
40430 46. . O . . . . . XXX.
40500 47. . O . . . . . XXX.
40530 48. . O . . . . . XXX.
40600 49. . O . . . . . XX.
40630 50. .O . . . . . .
40700 51. . . . .O. . . . . .
40730 52. O . . . . . .
40800 53. O . . . . . .
40830 54. O . . . . . .
40900 55. O . . . . . .
40930 56.O . . . . . .
41000 57.O . . . . . .
41030 58O . . . . . .
41100 59O . . . . . .
41130 60O . . . . . .
41200 61O . . . . . .
41230 62O . . . . . .
41300 63O . . . . . .
41330 64O . . . . . .
41400 65O . . . . . .
41430 66O . . . . . .
41500 67O . . . . . .
41530 68O . . . . . .
41600 69O . . . . . .
41630 70O . . . . . .
41700 71O . . . . . .
41730 72O . . . . . .
41800 73O . . . . . .
41830 74O . . . . . .
41900 75O . . . . . .
41930 76O . . . . . .
42000 77O . . . . . .
42030 78O . . . . . .
42100 79O . . . . . .
42130 80O . . . . . .
42200 81O . . . . . .
42230 82O . . . . . .
42300 83O . . . . . .
42330 84O . . . . . .
50000 85O . . . . . .
50030 86O . . . . . .
50100 87O . . . . . .
50130 88O . . . . . .
50200 89O . . . . . .
50230 90O . . . . . .
50300 91O . . . . . .
50330 92O . . . . . .
50400 93O . . . . . .
50430 94O . . . . . .
50500 95O . . . . . .


50530 96O
50600 97O
50630 98O
50700 99O
50730 100O
50800 101O
50830 102O
50900 103O
50930 104O
51000 105O
51030 106O
51100 107O
51130 108O
51200 109O
51230 110O
51300 111O
51330 112O
51400 113O
51430 114O
51500 115O
51530 116O
51600 117O
51630 118O
51700 119O
51730 120O
1

1 STATION SUB B

(O) OUTFLOW

.0 .4 .8 1.2 1.6 2.0 2.4 2.8 .0 .0 .0 .0 .0

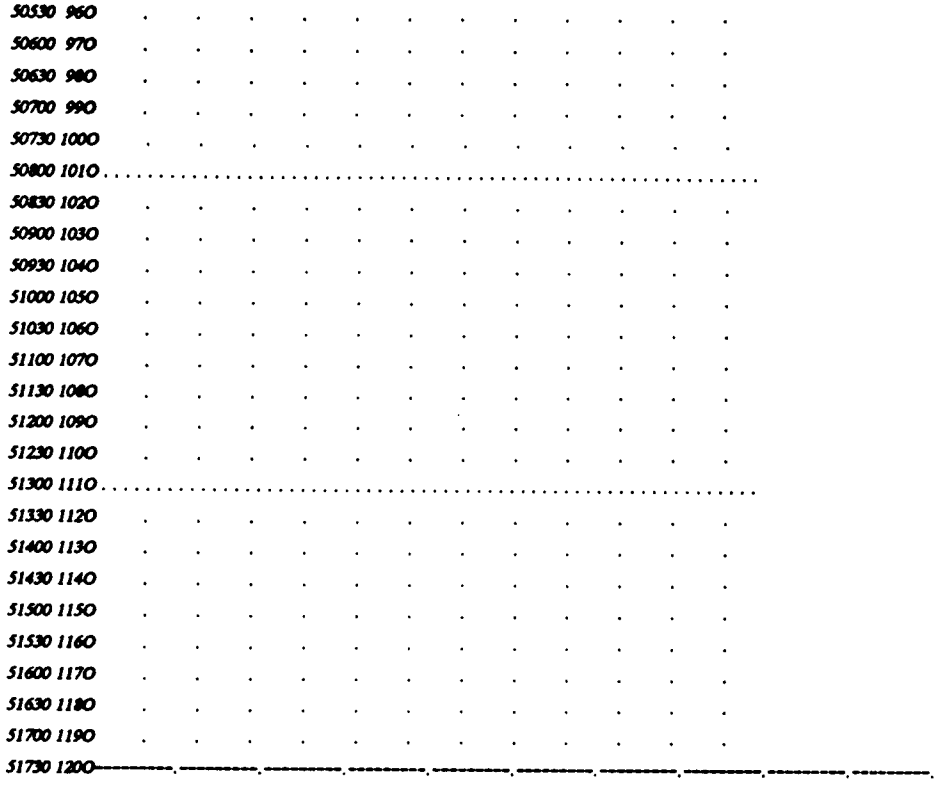
(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .8 .6 .4 .2 .0

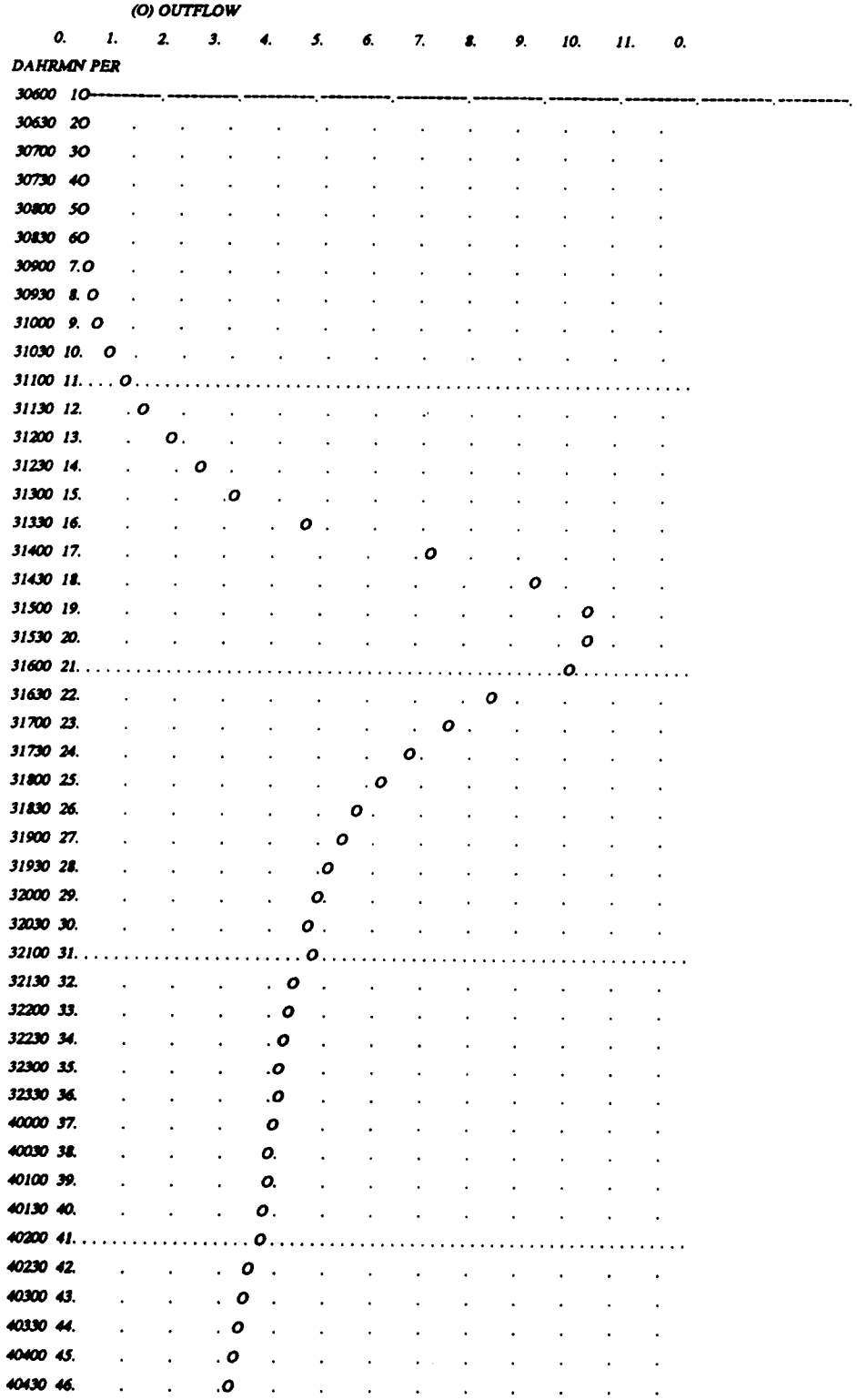
DAHRMN PER

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30600 1O----------.---------.---------.---------.---------.---------.---------.---------.---------.---------.-------
30630 2O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLL.
30700 3O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLL.
30730 4O  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLL.
30800 5.O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLL.
30830 6.O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLX.
30900 7. O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLX.
30930 8. O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLXX.
31000 9.  O .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLXX.
31030 10.  O.  .  .  .  .  .  .  .  .  .  .  .  .  LLLXXX.
31100 11.....O.....................................................LLLXXXX.
31130 12.  . O  .  .  .  .  .  .  .  .  .  .  .  .  LLLXXXXX.
31200 13.  .  O .  .  .  .  .  .  .  .  .  .  .  .  LLLXXXXXX.
31230 14.  .  O.  .  .  .  .  .  .  .  .  .  .  .  LLLXXXXXXX.
31300 15.  .  . O  .  .  .  .  .  .  .  .  .  .  .  LLLXXXXXXXX.
31330 16.  .  .  .  O.  .  .  .  .  .  .  .  .  .  LLLLXXXXXXXXXXXXXXXXXXX.
31400 17.  .  .  .  .  .  .  O  .  .  LLLLLXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
31430 18.  .  .  .  .  .  .  O  .  .  .  .  LLXXXXXXXXXXXXX.
31500 19.  .  .  .  .  O  .  .  .  .  .  .  LLXXXXXXXXXX.
31530 20.  .  .  .  O  .  .  .  .  .  .  .  .  LXXXXXXXX.
31600 21.............O.....................................................XXXXXXXX.
31630 22.  .  .  O  .  .  .  .  .  .  .  .  .  LXXXXXXX.
31700 23.  .  . O  .  .  .  .  .  .  .  .  .  .  XXXXXXX.
31730 24.  .  .O  .  .  .  .  .  .  .  .  .  .  XXXXXX.
31800 25.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXXX.
31830 26.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXXX.
31900 27.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXXX.
31930 28.  .  O.  .  .  .  .  .  .  .  .  .  .  LXXXXX.
32000 29.  .  O.  .  .  .  .  .  .  .  .  .  .  LXXXXX.
32030 30.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
32100 31.....O.....................................................XXXXX.
32130 32.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
32200 33.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
32230 34.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
32300 35.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
32330 36.  .  O.  .  .  .  .  .  .  .  .  .  .  LXXXX.
40000 37.  .  O.  .  .  .  .  .  .  .  .  .  .  LXXXX.
40030 38.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXX.
40100 39.  .  O.  .  .  .  .  .  .  .  .  .  .  XXXXX.
40130 40.  . O.  .  .  .  .  .  .  .  .  .  .  .  XXX.
40200 41.....O.....................................................XXXX.
40230 42.  . O.  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40300 43.  . O.  .  .  .  .  .  .  .  .  .  .  .  XXXX.
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40330 44. .O . . . . . XXXX.
40400 45. .O . . . . . LXXX.
40430 46. .O . . . . . XXX.
40500 47. .O . . . . . XXX.
40530 48. O . . . . . XXX.
40600 49. O. . . . . XX.
40630 50. O . . . . . .
40700 51. O.....
40730 52.O . . . . . .
40800 53O . . . . . .
40830 54O . . . . . .
40900 55O . . . . . .
40930 56O . . . . . .
41000 57O . . . . . .
41030 58O . . . . . .
41100 59O . . . . . .
41130 60O . . . . . .
41200 61O.....
41230 62O . . . . . .
41300 63O . . . . . .
41330 64O . . . . . .
41400 65O . . . . . .
41430 66O . . . . . .
41500 67O . . . . . .
41530 68O . . . . . .
41600 69O . . . . . .
41630 70O . . . . . .
41700 71O.....
41730 72O . . . . . .
41800 73O . . . . . .
41830 74O . . . . . .
41900 75O . . . . . .
41930 76O . . . . . .
42000 77O . . . . . .
42030 78O . . . . . .
42100 79O . . . . . .
42130 80O . . . . . .
42200 81O.....
42230 82O . . . . . .
42300 83O . . . . . .
42330 84O . . . . . .
50000 85O . . . . . .
50030 86O . . . . . .
50100 87O . . . . . .
50130 88O . . . . . .
50200 89O . . . . . .
50230 90O . . . . . .
50300 91O.....
50330 92O . . . . . .
50400 93O . . . . . .
50430 94O . . . . . .
50500 95O . . . . . .


50530 960
50600 970
50630 980
50700 990
50730 1000
50800 1010
50830 1020
50900 1030
50930 1040
51000 1050
51030 1060
51100 1070
51130 1080
51200 1090
51230 1100
51300 1110
51330 1120
51400 1130
51430 1140
51500 1150
51530 1160
51600 1170
51630 1180
51700 1190
51730 1200

1 STATION COM 1



40500 47. . . O . . . . . .
40530 48. . . O. . . . . .
40600 49. . . O. . . . . .
40630 50. . . O . . . . . .
40700 51. . . . . O . . . . . .
40730 52. . O . . . . . .
40800 53. O . . . . . .
40830 54. O . . . . . .
40900 55. O . . . . . .
40930 56. O . . . . . .
41000 57.O . . . . . .
41030 58.O . . . . . .
41100 59O . . . . . .
41130 60O . . . . . .
41200 61O . . . . . .
41230 62O . . . . . .
41300 63O . . . . . .
41330 64O . . . . . .
41400 65O . . . . . .
41430 66O . . . . . .
41500 67O . . . . . .
41530 68O . . . . . .
41600 69O . . . . . .
41630 70O . . . . . .
41700 71O . . . . . .
41730 72O . . . . . .
41800 73O . . . . . .
41830 74O . . . . . .
41900 75O . . . . . .
41930 76O . . . . . .
42000 77O . . . . . .
42030 78O . . . . . .
42100 79O . . . . . .
42130 80O . . . . . .
42200 81O . . . . . .
42230 82O . . . . . .
42300 83O . . . . . .
42330 84O . . . . . .
50000 85O . . . . . .
50030 86O . . . . . .
50100 87O . . . . . .
50130 88O . . . . . .
50200 89O . . . . . .
50230 90O . . . . . .
50300 91O . . . . . .
50330 92O . . . . . .
50400 93O . . . . . .
50430 94O . . . . . .
50500 95O . . . . . .
50530 96O . . . . . .
50600 97O . . . . . .
50630 98O . . . . . .

50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 . . . . . .
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .
51130 1080 . . . . . .
51200 1090 . . . . . .
51230 1100 . . . . . .
51300 1110 . . . . . .
51330 1120 . . . . . .
51400 1130 . . . . . .
51430 1140 . . . . . .
51500 1150 . . . . . .
51530 1160 . . . . . .
51600 1170 . . . . . .
51630 1180 . . . . . .
51700 1190 . . . . . .
51730 1200 ---------- ---------- ---------- ---------- ---------- ---------- ---------- ---------- ----------

1

1 STATION ROUTE

(I) INFLOW, (O) OUTFLOW

```
     0.    2.    4.    6.    8.   10.   12.    0.    0.    0.    0.    0.    0.
DAHRMN PER
30600 1I----------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
30630 2I          .         .         .         .         .         .         .         .         .         .
30700 3I          .         .         .         .         .         .         .         .         .         .
30730 4I          .         .         .         .         .         .         .         .         .         .
30800 5I          .         .         .         .         .         .         .         .         .         .
30830 6I          .         .         .         .         .         .         .         .         .         .
30900 7OI         .         .         .         .         .         .         .         .         .         .
30930 8.I         .         .         .         .         .         .         .         .         .         .
31000 9.OI        .         .         .         .         .         .         .         .         .         .
31030 10. OI      .         .         .         .         .         .         .         .         .         .
31100 11. .OI.....................................................................
31130 12.  O I    .         .         .         .         .         .         .         .         .         .
31200 13.   O I.  .         .         .         .         .         .         .         .         .         .
31230 14.    O. I .         .         .         .         .         .         .         .         .         .
31300 15.     . O I .         .         .         .         .         .         .         .         .         .
31330 16.       .  O  .  I    .         .         .         .         .         .         .         .         .
31400 17.       .     .  O  .   I .         .         .         .         .         .         .         .
31430 18.       .     .     .  O  .   I .         .         .         .         .         .         .
31500 19.       .     .     .     .  O  .  I .         .         .         .         .         .
31530 20.       .     .     .     .     .O I .         .         .         .         .         .
31600 21.....................I.O.....................................
31630 22.       .     .     .     . I  O .         .         .         .         .         .         .
31700 23.       .     .     .    I. O    .         .         .         .         .         .         .
31730 24.       .     .     .  I  O .         .         .         .         .         .         .
31800 25.       .     .    .I O    .         .         .         .         .         .         .
31830 26.       .     .    I.O     .         .         .         .         .         .         .
31900 27.       .     .   I O.     .         .         .         .         .         .         .
31930 28.       .     .   IO .     .         .         .         .         .         .         .
32000 29.       .     .   IO .     .         .         .         .         .         .         .
32030 30.       .     .   IO .     .         .         .         .         .         .         .
32100 31.............IO.....................................................
32130 32.       .     . IO .     .         .         .         .         .         .         .
32200 33.       .     . I  .     .         .         .         .         .         .         .
32230 34.       .     .IO  .     .         .         .         .         .         .         .
32300 35.       .     .I   .     .         .         .         .         .         .         .
32330 36.       .     IO   .     .         .         .         .         .         .         .
40000 37.       .     I    .     .         .         .         .         .         .         .
40030 38.       .     IO   .     .         .         .         .         .         .         .
40100 39.       .     IO   .     .         .         .         .         .         .         .
40130 40.       .     I.   .     .         .         .         .         .         .         .
40200 41.........IO.....................................................
40230 42.       .     I.   .     .         .         .         .         .         .         .
40300 43.       .     IO.  .     .         .         .         .         .         .         .
40330 44.       .     IO.  .     .         .         .         .         .         .         .
40400 45.       .     I .  .     .         .         .         .         .         .         .
40430 46.       .     I .  .     .         .         .         .         .         .         .
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40500 47. . IO . . . . . .
40530 48. . I . . . . . .
40600 49. . IO . . . . . .
40630 50. . I O . . . . . .
40700 51. . . . . I. O . . . . . .
40730 52. I O. . . . . .
40800 53. I O . . . . . .
40830 54. IO . . . . . .
40900 55. IO . . . . . .
40930 56.IO . . . . . .
41000 57.I . . . . . .
41030 58IO . . . . . .
41100 59I . . . . . .
41130 60I . . . . . .
41200 61I . . . . . .
41230 62I . . . . . .
41300 63I . . . . . .
41330 64I . . . . . .
41400 65I . . . . . .
41430 66I . . . . . .
41500 67I . . . . . .
41530 68I . . . . . .
41600 69I . . . . . .
41630 70I . . . . . .
41700 71I . . . . . .
41730 72I . . . . . .
41800 73I . . . . . .
41830 74I . . . . . .
41900 75I . . . . . .
41930 76I . . . . . .
42000 77I . . . . . .
42030 78I . . . . . .
42100 79I . . . . . .
42130 80I . . . . . .
42200 81I . . . . . .
42230 82I . . . . . .
42300 83I . . . . . .
42330 84I . . . . . .
50000 85I . . . . . .
50030 86I . . . . . .
50100 87I . . . . . .
50130 88I . . . . . .
50200 89I . . . . . .
50230 90I . . . . . .
50300 91I . . . . . .
50330 92I . . . . . .
50400 93I . . . . . .
50430 94I . . . . . .
50500 95I . . . . . .
50530 96I . . . . . .
50600 97I . . . . . .
50630 98I . . . . . .

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50700 99I  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50730 100I .  .  .  .  .  .  .  .  .  .  .  .  .  .
50800 101I.....................................................
50830 102I .  .  .  .  .  .  .  .  .  .  .  .  .  .
50900 103I .  .  .  .  .  .  .  .  .  .  .  .  .  .
50930 104I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51000 105I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51030 106I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51100 107I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51130 108I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51200 109I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51230 110I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51300 111I.....................................................
51330 112I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51400 113I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51430 114I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51500 115I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51530 116I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51600 117I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51630 118I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51700 119I .  .  .  .  .  .  .  .  .  .  .  .  .  .
51730 120I---------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1
1
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RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

		PEAK	TIME OF	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN	MAXIMUM	TIME OF
	OPERATION	STATION	FLOW	PEAK			AREA	STAGE	MAX STAGE
*				6-HOUR	24-HOUR	72-HOUR			
	HYDROGRAPH AT								
*	SUB A	9.	9.50	6.	3.	1.	.03		
	HYDROGRAPH AT								
*	SUB B	2.	8.00	1.	1.	0.	.00		
	2 COMBINED AT								
*	COM 1	11.	9.50	8.	4.	2.	.04		
	ROUTED TO								
*	ROUTE	10.	10.00	8.	4.	2.	.04		

*** NORMAL END OF HEC-1 ***

APPENDIX A-5

HEC-1 INPUT/OUTPUT SUBBASIN 2 AND 3
25-YEAR STORM

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

HEC-1 INPUT PAGE 1

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
    2     ID  COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
    3     ID  25 YEAR STORM WITH 24 HOUR RAINFALL DISTRUBUTION
    4     ID
    5     IT   30 3APR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC  .0302 .0571 .0960 .1243 .1798 .2229 .2867 .3287 .3943 .4393
   12     PC  .5068 .5516 .6180 .6630 .7251 .7860 .8639 .9175 1.002 1.061
   13     PC  1.157 1.225 1.330 1.403 1.527 1.615 1.742 1.829 1.980 2.101
   14     PC  2.483 2.818 3.162 3.302 3.483 3.591 3.730 3.812 3.928 4.003
   15     PC  4.108 4.175 4.273 4.337 4.429 4.487 4.565 4.618 4.696 4.749
   16     PC  4.832 4.882 4.959 5.009 5.081 5.128 5.199 5.246 5.316 5.362
   17     PC  5.430 5.475 5.541 5.585 5.650 5.693 5.756 5.798 5.859 5.900
   18     PC  5.960 5.999 6.058 6.096 6.153 6.261 6.269 6.282 6.336 6.371
   19     PC  6.423 6.457 6.508 6.541 6.590 6.622 6.669 6.700 6.746 6.776
   20     PC  6.820 6.849 6.891 6.919 6.960 7.000
   21     BA   .03
   22     LS    0   80    0
   23     UD  1.50

   24     KK  SUB B
   25     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN B
   26     BA  .005
   27     LS    0   85    3
   28     UD  .50

   29     KK  COM 1
   30     KM  COMBINING HYDROGRAPHS FROM SUBBASINS A AND B
   31     HC    2

   32     KK  ROUTE
   33     KM  ROUTING HYDROGRAPH THROUGH CHANNEL TO RESERVOIR
   34     RM    1   .5   .2
   35     ZZ
```

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT
LINE (V) ROUTING (---->) DIVERSION OR PUMP FLOW

NO. (.) CONNECTOR (<----) RETURN OF DIVERTED OR PUMPED FLOW

8 SUB A
.
.
24 . SUB B
. .
. .
29 COM 1.....
V
V
32 ROUTE

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
****

SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
25 YEAR STORM WITH 24 HOUR RAINFALL DISTRUBUTION

6 IO OUTPUT CONTROL VARIABLES
IPRNT 5 PRINT CONTROL
IPLOT 2 PLOT CONTROL
QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA
NMIN 30 MINUTES IN COMPUTATION INTERVAL
IDATE 3APR89 STARTING DATE
ITIME 0600 STARTING TIME
NQ 120 NUMBER OF HYDROGRAPH ORDINATES
NDDATE 5APR89 ENDING DATE
NDTIME 1730 ENDING TIME

COMPUTATION INTERVAL .50 HOURS
TOTAL TIME BASE 59.50 HOURS

ENGLISH UNITS

1 STATION SUB A

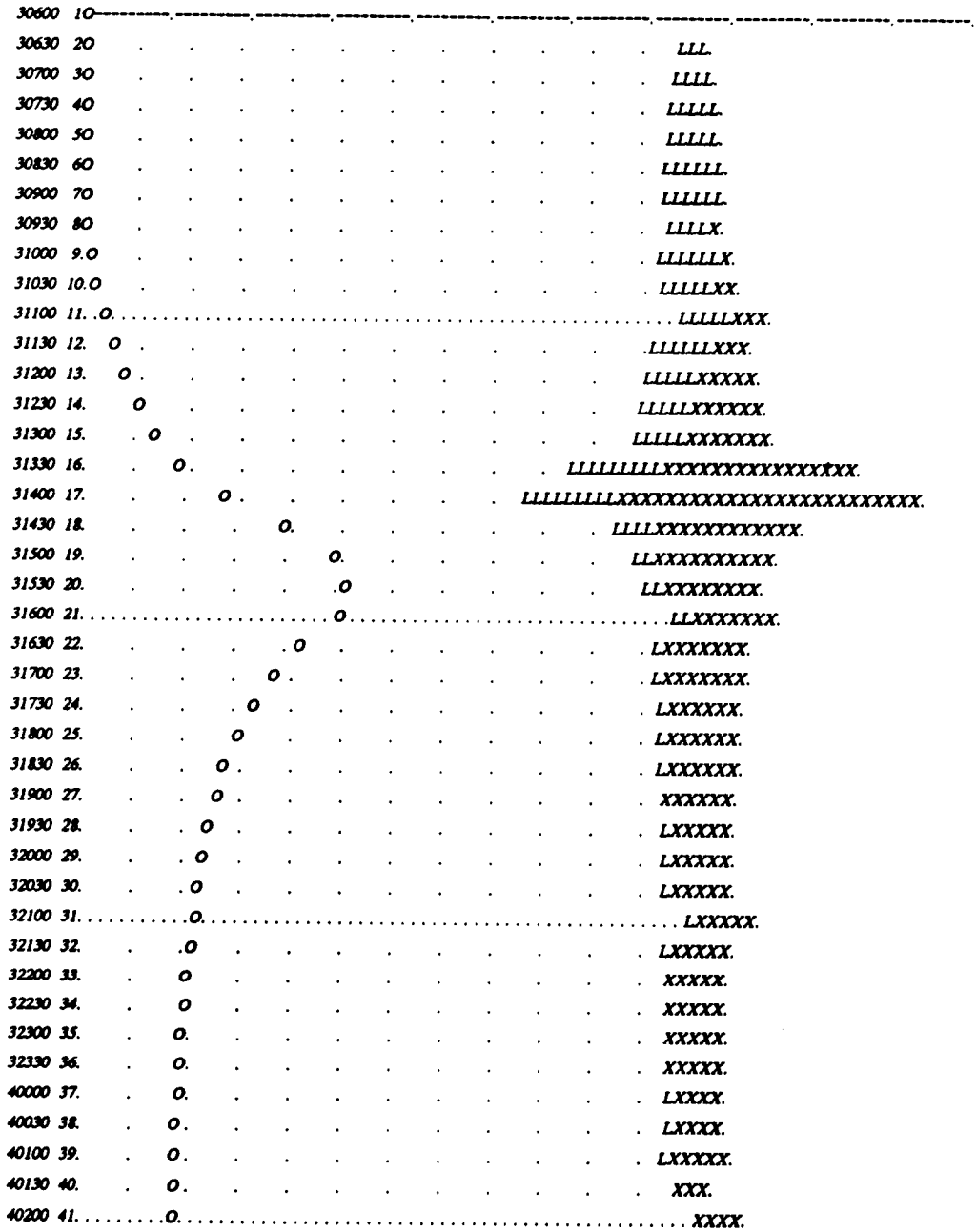
(O) OUTFLOW

0. 2. 4. 6. 8. 10. 12. 0. 0. 0. 0. 0. 0.

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .8 .6 .4 .2 .0

DAHRMN PER



```
40230 42.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40300 43.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40330 44.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40400 45.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XXXX.
40430 46.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
40500 47.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  LXXX.
40530 48.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XXX.
40600 49.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  XX.
40630 50.    .  O  .  .  .  .  .  .  .  .  .  .  .  .  .
40700 51. . . . O . . . . . .
40730 52.  O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40800 53.  O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40830 54.  O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40900 55. O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
40930 56.O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41000 57.O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41030 58O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41100 59O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41130 60O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41200 61O . . . . . .
41230 62O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41300 63O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41330 64O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41400 65O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41430 66O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41500 67O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41530 68O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41600 69O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41630 70O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41700 71O . . . . . .
41730 72O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41800 73O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41830 74O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41900 75O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
41930 76O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42000 77O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42030 78O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42100 79O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42130 80O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42200 81O . . . . . .
42230 82O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42300 83O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
42330 84O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50000 85O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50030 86O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50100 87O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50130 88O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50200 89O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50230 90O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
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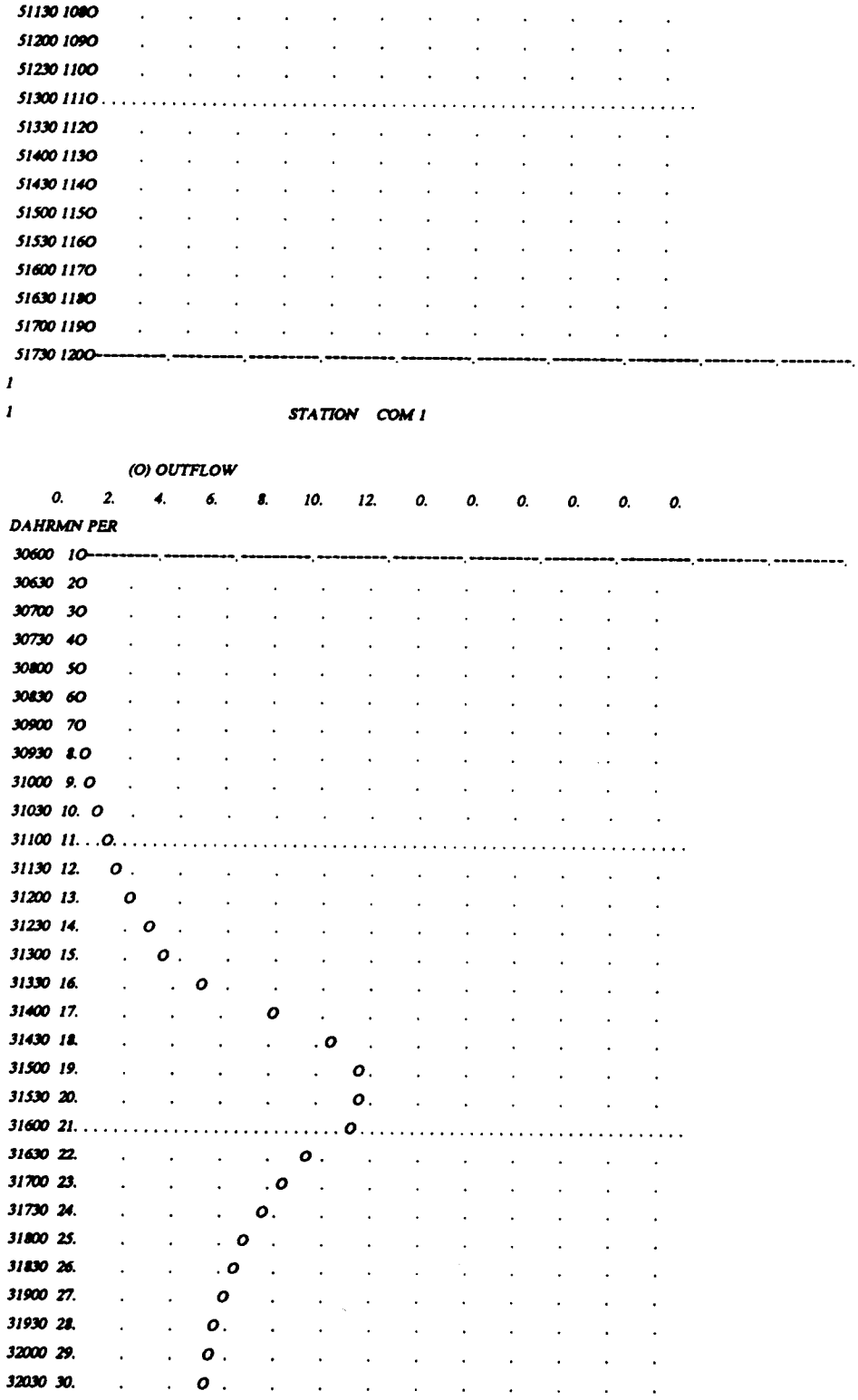
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50330 92O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50400 93O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50430 94O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50500 95O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50530 96O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50600 97O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50630 98O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50700 99O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50730 100O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50800 101O....................................................
50830 102O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50900 103O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
50930 104O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51000 105O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51030 106O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51100 107O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51130 108O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51200 109O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51230 110O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51300 111O....................................................
51330 112O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51400 113O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51430 114O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51500 115O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51530 116O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51600 117O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51630 118O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51700 119O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
51730 120O----------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1
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1                                   STATION   SUB B

                 (O) OUTFLOW
     .0    .4    .8    1.2   1.6   2.0   2.4   2.8   .0    .0    .0    .0    .0
                                                     (L) PRECIP,  (X) EXCESS
     .0    .0    .0    .0    .0    .0    .0    .0    .8    .6    .4    .2    .0
DAHRMN PER
30600  1O----------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
30630  2O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLL.
30700  3O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLL.
30730  4O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLL.
30800  5O     .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLL.
30830  6.O    .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLLX.
30900  7. O   .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLLX.
30930  8.  O  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLXX.
31000  9.   O .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  LLLLXXX.
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31030 10.   O .   .   .   .   .   .   .   .   .   .   .   . LLLLXXX.
31100 11.....O............................................ LLLLXXXX.
31130 12.   . O   .   .   .   .   .   .   .   .   .   .  .LLLLXXXXX.
31200 13.   .  O .   .   .   .   .   .   .   .   .   .   LLLLXXXXXX.
31230 14.   .   O   .   .   .   .   .   .   .   .   .   LLLLXXXXXXX.
31300 15.   .   . O   .   .   .   .   .   .   .   .   .   LLLLXXXXXXXX.
31330 16.   .   .   .   O.   .   .   .   .   .   . LLLLLLXXXXXXXXXXXXXXXXXXXXX.
31400 17.   .   .   .   .   .   .   . O   .   . LLLLLLXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX.
31430 18.   .   .   .   .   .   .   . O   .   .   .   . LLXXXXXXXXXXXXXXX.
31500 19.   .   .   .   .   .  O.   .   .   .   .   .   LXXXXXXXXXXXX.
31530 20.   .   .   .   O .   .   .   .   .   .   .   LXXXXXXXXXX.
31600 21..............O...................................LXXXXXXXXX.
31630 22.   .   .  O .   .   .   .   .   .   .   .   .   . LXXXXXXXX.
31700 23.   .   . O   .   .   .   .   .   .   .   .   .   . LXXXXXXXX.
31730 24.   .   . O   .   .   .   .   .   .   .   .   .   . LXXXXXXX.
31800 25.   .   .O   .   .   .   .   .   .   .   .   .   . LXXXXXXX.
31830 26.   .   O   .   .   .   .   .   .   .   .   .   . LXXXXXXX.
31900 27.   .   O   .   .   .   .   .   .   .   .   .   . XXXXXX.
31930 28.   .  O.   .   .   .   .   .   .   .   .   .   . XXXXXX.
32000 29.   .  O .   .   .   .   .   .   .   .   .   .   . LXXXXX.
32030 30.   .  O .   .   .   .   .   .   .   .   .   .   . LXXXXX.
32100 31.........O........................................ LXXXXX.
32130 32.   .  O .   .   .   .   .   .   .   .   .   .   . LXXXXX.
32200 33.   .  O .   .   .   .   .   .   .   .   .   .   . XXXXX.
32230 34.   .  O .   .   .   .   .   .   .   .   .   .   . XXXXX.
32300 35.   .  O .   .   .   .   .   .   .   .   .   .   . XXXXX.
32330 36.   .  O .   .   .   .   .   .   .   .   .   .   . XXXXX.
40000 37.   . O  .   .   .   .   .   .   .   .   .   .   . XXXXX.
40030 38.   . O  .   .   .   .   .   .   .   .   .   .   . LXXXX.
40100 39.   .  O .   .   .   .   .   .   .   .   .   .   . LXXXXX.
40130 40.   . O  .   .   .   .   .   .   .   .   .   .   .  XXX.
40200 41.......O..............................................XXXX.
40230 42.   . O  .   .   .   .   .   .   .   .   .   .   . XXXX.
40300 43.   . O  .   .   .   .   .   .   .   .   .   .   . XXXX.
40330 44.   . O  .   .   .   .   .   .   .   .   .   .   . XXXX.
40400 45.   . O  .   .   .   .   .   .   .   .   .   .   . XXXX.
40430 46.   . O  .   .   .   .   .   .   .   .   .   .   . XXXX.
40500 47.   .O   .   .   .   .   .   .   .   .   .   .   . LXXX.
40530 48.   .O   .   .   .   .   .   .   .   .   .   .   .  XXX.
40600 49.   O.   .   .   .   .   .   .   .   .   .   .   .  XX.
40630 50.  O .   .   .   .   .   .   .   .   .   .   .   .
40700 51. O...........................................................
40730 52.O   .   .   .   .   .   .   .   .   .   .   .   .
40800 53O    .   .   .   .   .   .   .   .   .   .   .   .
40830 54O    .   .   .   .   .   .   .   .   .   .   .   .
40900 55O    .   .   .   .   .   .   .   .   .   .   .   .
40930 56O    .   .   .   .   .   .   .   .   .   .   .   .
41000 57O    .   .   .   .   .   .   .   .   .   .   .   .
41030 58O    .   .   .   .   .   .   .   .   .   .   .   .
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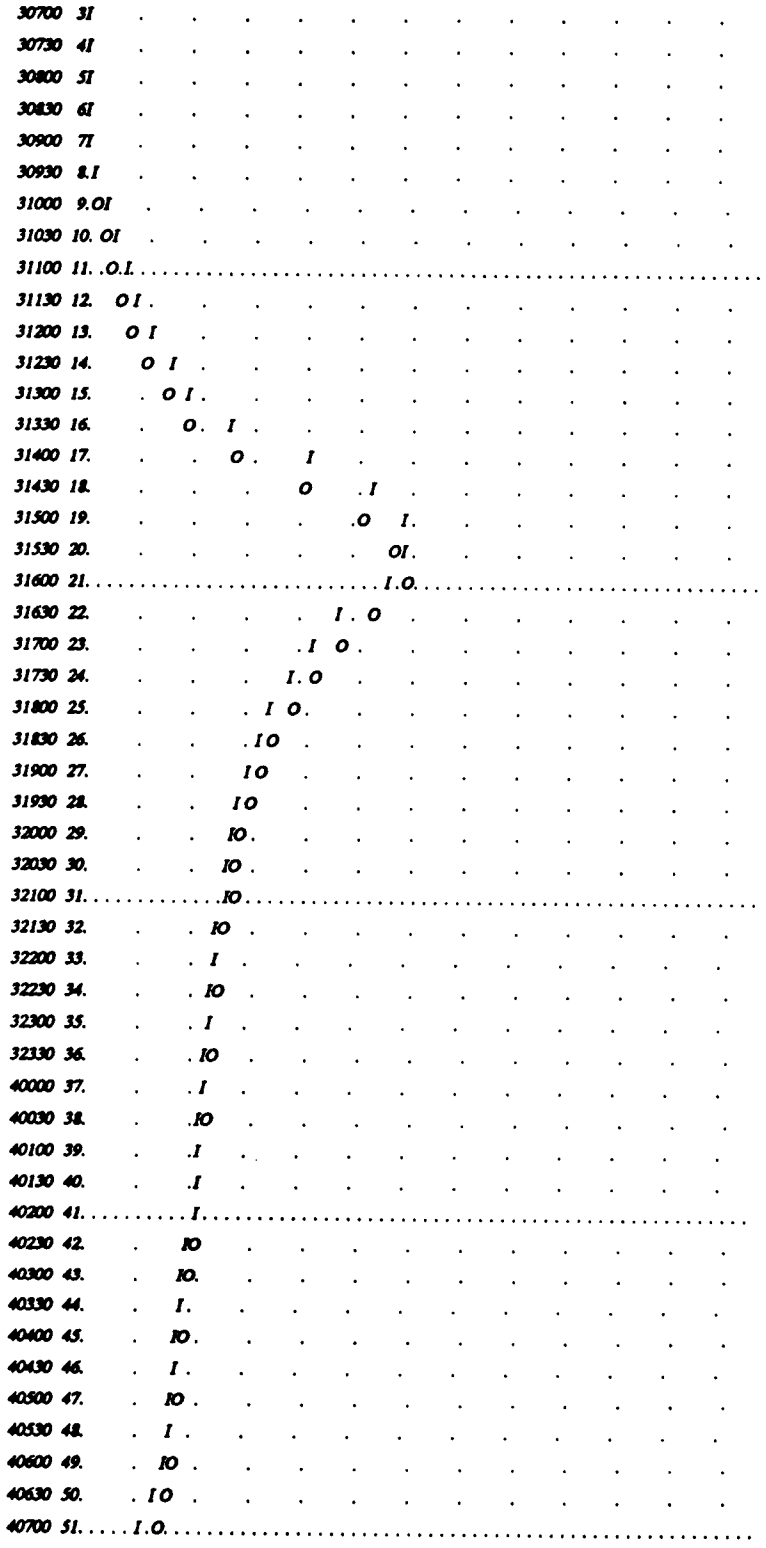
41100 590 . . . . . .
41130 600 . . . . . .
41200 610 . . . . . .
41230 620 . . . . . .
41300 630 . . . . . .
41330 640 . . . . . .
41400 650 . . . . . .
41430 660 . . . . . .
41500 670 . . . . . .
41530 680 . . . . . .
41600 690 . . . . . .
41630 700 . . . . . .
41700 710 . . . . . .
41730 720 . . . . . .
41800 730 . . . . . .
41830 740 . . . . . .
41900 750 . . . . . .
41930 760 . . . . . .
42000 770 . . . . . .
42030 780 . . . . . .
42100 790 . . . . . .
42130 800 . . . . . .
42200 810 . . . . . .
42230 820 . . . . . .
42300 830 . . . . . .
42330 840 . . . . . .
50000 850 . . . . . .
50030 860 . . . . . .
50100 870 . . . . . .
50130 880 . . . . . .
50200 890 . . . . . .
50230 900 . . . . . .
50300 910 . . . . . .
50330 920 . . . . . .
50400 930 . . . . . .
50430 940 . . . . . .
50500 950 . . . . . .
50530 960 . . . . . .
50600 970 . . . . . .
50630 980 . . . . . .
50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 . . . . . .
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .


51130 108O
51200 109O
51230 110O
51300 111O
51330 112O
51400 113O
51430 114O
51500 115O
51530 116O
51600 117O
51630 118O
51700 119O
51730 120O
1
1
STATION COM 1
(O) OUTFLOW
0. 2. 4. 6. 8. 10. 12. 0. 0. 0. 0. 0. 0.
DAHRMN PER
30600 1O
30630 2O
30700 3O
30730 4O
30800 5O
30830 6O
30900 7O
30930 8.O
31000 9. O
31030 10. O
31100 11. .O.
31130 12. O
31200 13. O
31230 14. O
31300 15. O
31330 16. O
31400 17. O
31430 18. O
31500 19. O
31530 20. O
31600 21. O
31630 22. O
31700 23. O
31730 24. O
31800 25. O
31830 26. O
31900 27. O
31930 28. O
32000 29. O
32030 30. O

32100 31. . . . . O. . . . . .
32130 32. . . O . . . . . .
32200 33. . . O . . . . . .
32230 34. . . O . . . . . .
32300 35. . . O . . . . . .
32330 36. . . O . . . . . .
40000 37. . . O . . . . . .
40030 38. . .O . . . . . .
40100 39. . .O . . . . . .
40130 40. . .O . . . . . .
40200 41. . . . . O. . . . . .
40230 42. . O. . . . . .
40300 43. . O. . . . . .
40330 44. . O. . . . . .
40400 45. . O . . . . . .
40430 46. . O . . . . . .
40500 47. . O . . . . . .
40530 48. . O . . . . . .
40600 49. . O . . . . . .
40630 50. . O . . . . . .
40700 51. . . . . O. . . . . .
40730 52. O . . . . . .
40800 53. O . . . . . .
40830 54. O . . . . . .
40900 55. O . . . . . .
40930 56.O . . . . . .
41000 57.O . . . . . .
41030 58O . . . . . .
41100 59O . . . . . .
41130 60O . . . . . .
41200 61O . . . . . .
41230 62O . . . . . .
41300 63O . . . . . .
41330 64O . . . . . .
41400 65O . . . . . .
41430 66O . . . . . .
41500 67O . . . . . .
41530 68O . . . . . .
41600 69O . . . . . .
41630 70O . . . . . .
41700 71O . . . . . .
41730 72O . . . . . .
41800 73O . . . . . .
41830 74O . . . . . .
41900 75O . . . . . .
41930 76O . . . . . .
42000 77O . . . . . .
42030 78O . . . . . .
42100 79O . . . . . .

```
42130 800 . . . . . .
42200 810 ..........
42230 820 . . . . . .
42300 830 . . . . . .
42330 840 . . . . . .
50000 850 . . . . . .
50030 860 . . . . . .
50100 870 . . . . . .
50130 880 . . . . . .
50200 890 . . . . . .
50230 900 . . . . . .
50300 910 ..........
50330 920 . . . . . .
50400 930 . . . . . .
50430 940 . . . . . .
50500 950 . . . . . .
50530 960 . . . . . .
50600 970 . . . . . .
50630 980 . . . . . .
50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 ..........
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .
51130 1080 . . . . . .
51200 1090 . . . . . .
51230 1100 . . . . . .
51300 1110 ..........
51330 1120 . . . . . .
51400 1130 . . . . . .
51430 1140 . . . . . .
51500 1150 . . . . . .
51530 1160 . . . . . .
51600 1170 . . . . . .
51630 1180 . . . . . .
51700 1190 . . . . . .
51730 1200----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
1
1                                    STATION   ROUTE

                    (I) INFLOW,  (O) OUTFLOW
     0.    2.    4.    6.    8.    10.   12.   0.    0.    0.    0.    0.    0.
DAHRMN PER
30600 1I----------.----------.----------.----------.----------.----------.----------.----------.----------.----------.
30630 2I . . . . . .
```



```
40730 52.   I O
40800 53.  IO
40830 54. I O
40900 55. IO
40930 56.IO
41000 57.I
41030 58IO
41100 59I
41130 60I
41200 61I
41230 62I
41300 63I
41330 64I
41400 65I
41430 66I
41500 67I
41530 68I
41600 69I
41630 70I
41700 71I
41730 72I
41800 73I
41830 74I
41900 75I
41930 76I
42000 77I
42030 78I
42100 79I
42130 80I
42200 81I
42230 82I
42300 83I
42330 84I
50000 85I
50030 86I
50100 87I
50130 88I
50200 89I
50230 90I
50300 91I
50330 92I
50400 93I
50430 94I
50500 95I
50530 96I
50600 97I
50630 98I
50700 99I
50730 100I
```

```
50800 101I.....................................................
50830 102I    .   .   .   .   .   .   .   .   .   .   .   .   .
50900 103I    .   .   .   .   .   .   .   .   .   .   .   .   .
50930 104I    .   .   .   .   .   .   .   .   .   .   .   .   .
51000 105I    .   .   .   .   .   .   .   .   .   .   .   .   .
51030 106I    .   .   .   .   .   .   .   .   .   .   .   .   .
51100 107I    .   .   .   .   .   .   .   .   .   .   .   .   .
51130 108I    .   .   .   .   .   .   .   .   .   .   .   .   .
51200 109I    .   .   .   .   .   .   .   .   .   .   .   .   .
51230 110I    .   .   .   .   .   .   .   .   .   .   .   .   .
51300 111I.....................................................
51330 112I    .   .   .   .   .   .   .   .   .   .   .   .   .
51400 113I    .   .   .   .   .   .   .   .   .   .   .   .   .
51430 114I    .   .   .   .   .   .   .   .   .   .   .   .   .
51500 115I    .   .   .   .   .   .   .   .   .   .   .   .   .
51530 116I    .   .   .   .   .   .   .   .   .   .   .   .   .
51600 117I    .   .   .   .   .   .   .   .   .   .   .   .   .
51630 118I    .   .   .   .   .   .   .   .   .   .   .   .   .
51700 119I    .   .   .   .   .   .   .   .   .   .   .   .   .
51730 120I----------.---------.---------.---------.---------.---------.---------.---------.---------.---------.
1
1
```

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

		PEAK	TIME OF	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN	MAXIMUM	TIME OF
OPERATION	STATION	FLOW	PEAK	6-HOUR	24-HOUR	72-HOUR	AREA	STAGE	MAX STAGE
HYDROGRAPH AT									
+	SUB A	10.	9.50	7.	4.	2.	.03		
HYDROGRAPH AT									
+	SUB B	3.	8.00	1.	1.	0.	.00		
2 COMBINED AT									
+	COM 1	12.	9.50	9.	4.	2.	.04		
ROUTED TO									
+	ROUTE	11.	10.00	8.	4.	2.	.04		

**** NORMAL END OF HEC-1 ****

APPENDIX A-6

HEC-1 INPUT/OUTPUT SUBBASIN 2 AND 3
100-YEAR STORM

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

HEC-1 INPUT PAGE 1

```
LINE      ID.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10

          *DIAGRAM
    1     ID  SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
    2     ID  COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
    3     ID  100 YEAR STORM WITH 24 HOUR RAINFALL DISTRIBUTION
    4     ID
    5     IT   30 3APR89  0600   120
    6     IO    5    2
    7     IN   15

    8     KK  SUB A
    9     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN A
   10     PB
   11     PC  .0346 .0653 .1098 .1421 .2054 .2547 .3276 .3756 .4506 .5021
   12     PC  .5792 .6304 .7063 .7577 .8402 .8983 .9874 1.049 1.145 1.213
   13     PC  1.322 1.400 1.520 1.604 1.745 1.845 1.990 2.090 2.263 2.402
   14     PC  2.838 3.220 3.614 3.773 3.980 4.104 4.263 4.357 4.489 4.575
   15     PC  4.695 4.771 4.884 4.957 5.061 5.128 5.218 5.278 5.367 5.428
   16     PC  5.522 5.580 5.667 5.724 5.807 5.861 5.942 5.996 6.075 6.128
   17     PC  6.206 6.257 6.333 6.383 6.457 6.506 6.578 6.626 6.696 6.743
   18     PC  6.811 6.856 6.923 6.967 7.032 7.155 7.164 7.180 7.241 7.281
   19     PC  7.341 7.380 7.437 7.475 7.531 7.568 7.622 7.657 7.710 7.744
   20     PC  7.794 7.827 7.876 7.908 7.954 8.000
   21     BA   .03
   22     LS    0   80    0
   23     UD  1.50

   24     KK  SUB B
   25     KM  COMPUTING OUTFLOW HYDROGRAPH FOR SUBBASIN B
   26     BA   .005
   27     LS    0   87    3
   28     UD   .50

   29     KK  COM 1
   30     KM  COMBINING HYDROGRAPHS FROM SUBBASINS A AND B
   31     HC    2

   32     KK  ROUTE
   33     KM  ROUTING HYDROGRAPHS FROM SUBBASINS A AND B
   34     RM    1   .5   .2
   35     ZZ
```

SCHEMATIC DIAGRAM OF STREAM NETWORK

INPUT
LINE (V) ROUTING (---->) DIVERSION OR PUMP FLOW

NO. (.) CONNECTOR (<----) RETURN OF DIVERTED OR PUMPED FLOW

8 SUB A
.
.
24 . SUB B
. .
. .
29 COM 1.....
V
V
32 ROUTE

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

1 ****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
****

SCS STORM HYDROGRAPH FOR 900 AREA RUNOFF
COMBINE 2 SUBBASINS FOR TOTAL DISCHARGE
100 YEAR STORM WITH 24 HOUR RAINFALL DISTRIBUTION

6 IO OUTPUT CONTROL VARIABLES
IPRNT 5 PRINT CONTROL
IPLOT 2 PLOT CONTROL
QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA
NMIN 30 MINUTES IN COMPUTATION INTERVAL
IDATE 3APR89 STARTING DATE
ITIME 0600 STARTING TIME
NQ 120 NUMBER OF HYDROGRAPH ORDINATES
NDDATE 5APR89 ENDING DATE
NDTIME 1730 ENDING TIME

COMPUTATION INTERVAL .50 HOURS
TOTAL TIME BASE 59.50 HOURS

ENGLISH UNITS

1 STATION SUB A

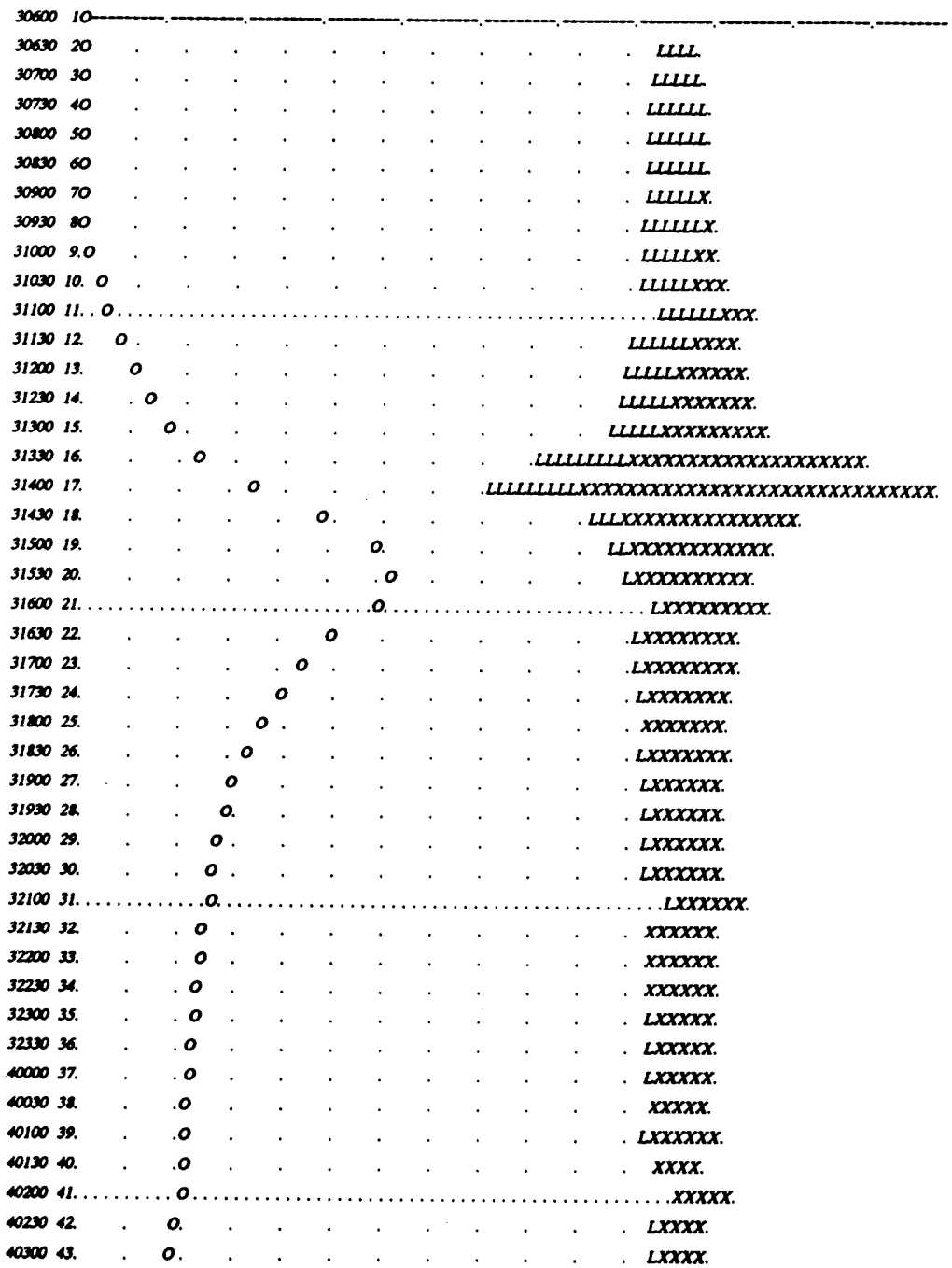
(O) OUTFLOW

0. 2. 4. 6. 8. 10. 12. 14. 0. 0. 0. 0. 0.

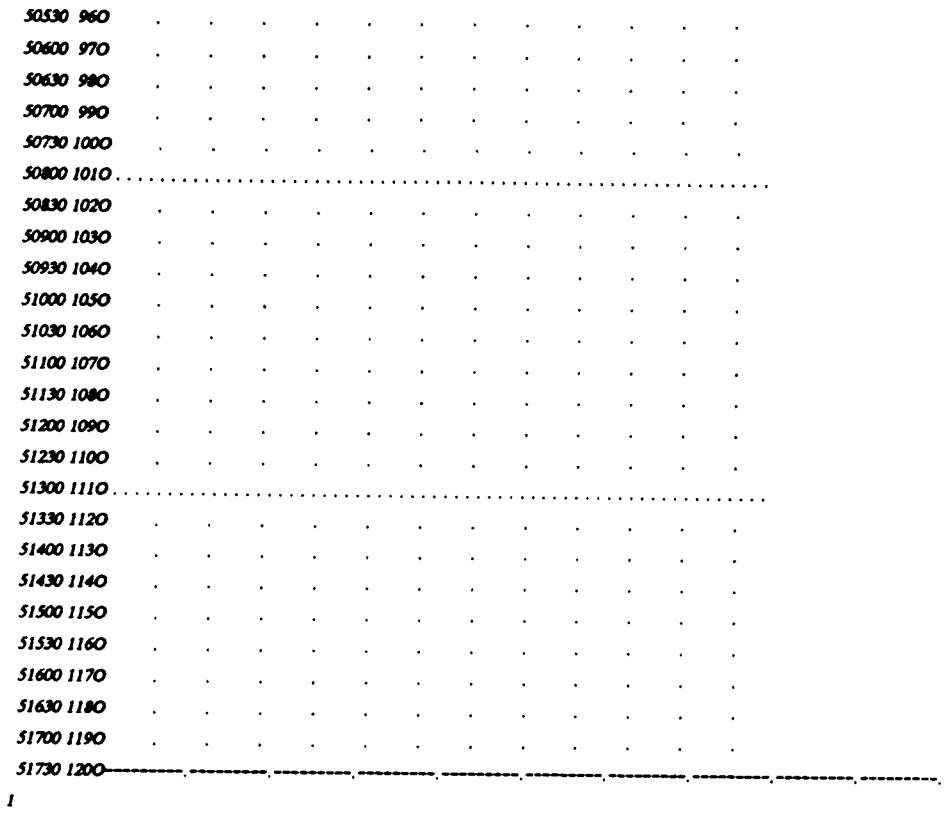
(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .8 .6 .4 .2 .0

DAHRMN PER



40330 44. . O. . . . . LXXXX.
40400 45. . O. . . . . XXXX.
40430 46. . O. . . . . XXXX.
40500 47. . O. . . . . XXXX.
40530 48. . O. . . . . XXXX.
40600 49. . O. . . . . XX.
40630 50. . O. . . . . .
40700 51. . . . . O. . . . . .
40730 52. O. . . . . .
40800 53. O. . . . . .
40830 54. O. . . . . .
40900 55. O. . . . . .
40930 56. O. . . . . .
41000 57. O. . . . . .
41030 58O. . . . . .
41100 59O. . . . . .
41130 60O. . . . . .
41200 61O. . . . . .
41230 62O. . . . . .
41300 63O. . . . . .
41330 64O. . . . . .
41400 65O. . . . . .
41430 66O. . . . . .
41500 67O. . . . . .
41530 68O. . . . . .
41600 69O. . . . . .
41630 70O. . . . . .
41700 71O. . . . . .
41730 72O. . . . . .
41800 73O. . . . . .
41830 74O. . . . . .
41900 75O. . . . . .
41930 76O. . . . . .
42000 77O. . . . . .
42030 78O. . . . . .
42100 79O. . . . . .
42130 80O. . . . . .
42200 81O. . . . . .
42230 82O. . . . . .
42300 83O. . . . . .
42330 84O. . . . . .
50000 85O. . . . . .
50030 86O. . . . . .
50100 87O. . . . . .
50130 88O. . . . . .
50200 89O. . . . . .
50230 90O. . . . . .
50300 91O. . . . . .
50330 92O. . . . . .
50400 93O. . . . . .
50430 94O. . . . . .
50500 95O. . . . . .


50530 96O
50600 97O
50630 98O
50700 99O
50730 100O
50800 101O
50830 102O
50900 103O
50930 104O
51000 105O
51030 106O
51100 107O
51130 108O
51200 109O
51230 110O
51300 111O
51330 112O
51400 113O
51430 114O
51500 115O
51530 116O
51600 117O
51630 118O
51700 119O
51730 120O
1

1 STATION SUB B

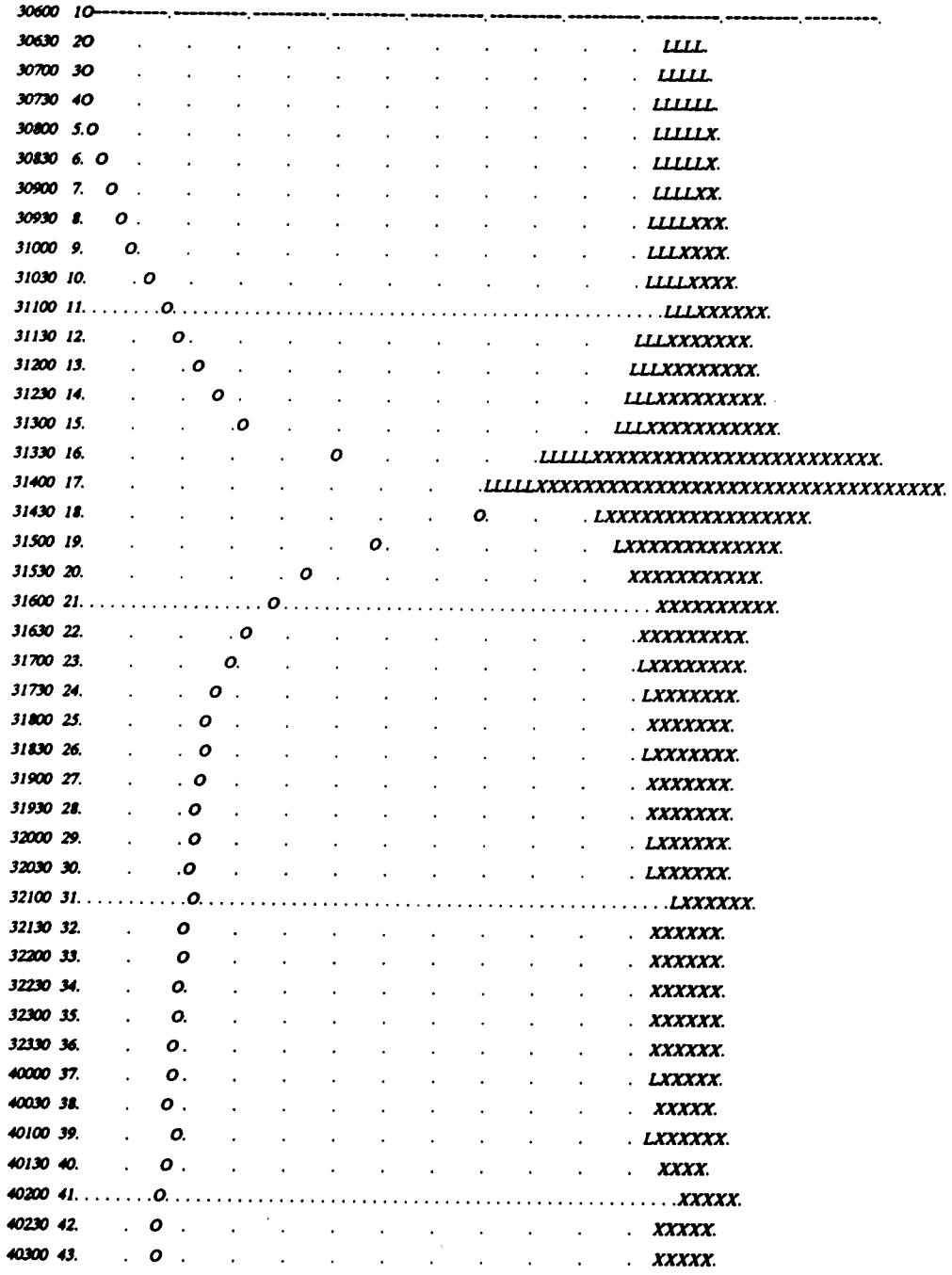
(O) OUTFLOW

.0 .4 .8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 .0 .0 .0

(L) PRECIP, (X) EXCESS

.0 .0 .0 .0 .0 .0 .0 .0 .8 .6 .4 .2 .0

DAHRMN PER



```
40330 44.      . O . . . . . . . . . . . . . LXXXX.
40400 45.      . O . . . . . . . . . . . . . XXXX.
40430 46.      . O . . . . . . . . . . . . . XXXX.
40500 47.      . O . . . . . . . . . . . . . XXXX.
40530 48.      . O . . . . . . . . . . . . . XXXX.
40600 49.      .O . . . . . . . . . . . . . XX.
40630 50.   O . . . . . . . . . . . . . . .
40700 51. O.....
40730 52.O     . . . . . . . . . . . . . .
40800 53O      . . . . . . . . . . . . . .
40830 54O      . . . . . . . . . . . . . .
40900 55O      . . . . . . . . . . . . . .
40930 56O      . . . . . . . . . . . . . .
41000 57O      . . . . . . . . . . . . . .
41030 58O      . . . . . . . . . . . . . .
41100 59O      . . . . . . . . . . . . . .
41130 60O      . . . . . . . . . . . . . .
41200 61O.....
41230 62O      . . . . . . . . . . . . . .
41300 63O      . . . . . . . . . . . . . .
41330 64O      . . . . . . . . . . . . . .
41400 65O      . . . . . . . . . . . . . .
41430 66O      . . . . . . . . . . . . . .
41500 67O      . . . . . . . . . . . . . .
41530 68O      . . . . . . . . . . . . . .
41600 69O      . . . . . . . . . . . . . .
41630 70O      . . . . . . . . . . . . . .
41700 71O.....
41730 72O      . . . . . . . . . . . . . .
41800 73O      . . . . . . . . . . . . . .
41830 74O      . . . . . . . . . . . . . .
41900 75O      . . . . . . . . . . . . . .
41930 76O      . . . . . . . . . . . . . .
42000 77O      . . . . . . . . . . . . . .
42030 78O      . . . . . . . . . . . . . .
42100 79O      . . . . . . . . . . . . . .
42130 80O      . . . . . . . . . . . . . .
42200 81O.....
42230 82O      . . . . . . . . . . . . . .
42300 83O      . . . . . . . . . . . . . .
42330 84O      . . . . . . . . . . . . . .
50000 85O      . . . . . . . . . . . . . .
50030 86O      . . . . . . . . . . . . . .
50100 87O      . . . . . . . . . . . . . .
50130 88O      . . . . . . . . . . . . . .
50200 89O      . . . . . . . . . . . . . .
50230 90O      . . . . . . . . . . . . . .
50300 91O.....
50330 92O      . . . . . . . . . . . . . .
50400 93O      . . . . . . . . . . . . . .
50430 94O      . . . . . . . . . . . . . .
50500 95O      . . . . . . . . . . . . . .
```

50530 960 . . . . . .
50600 970 . . . . . .
50630 980 . . . . . .
50700 990 . . . . . .
50730 1000 . . . . . .
50800 1010 . . . . . .
50830 1020 . . . . . .
50900 1030 . . . . . .
50930 1040 . . . . . .
51000 1050 . . . . . .
51030 1060 . . . . . .
51100 1070 . . . . . .
51130 1080 . . . . . .
51200 1090 . . . . . .
51230 1100 . . . . . .
51300 1110 . . . . . .
51330 1120 . . . . . .
51400 1130 . . . . . .
51430 1140 . . . . . .
51500 1150 . . . . . .
51530 1160 . . . . . .
51600 1170 . . . . . .
51630 1180 . . . . . .
51700 1190 . . . . . .
51730 1200 ---------.---------.---------.---------.---------.---------.---------.---------.---------.

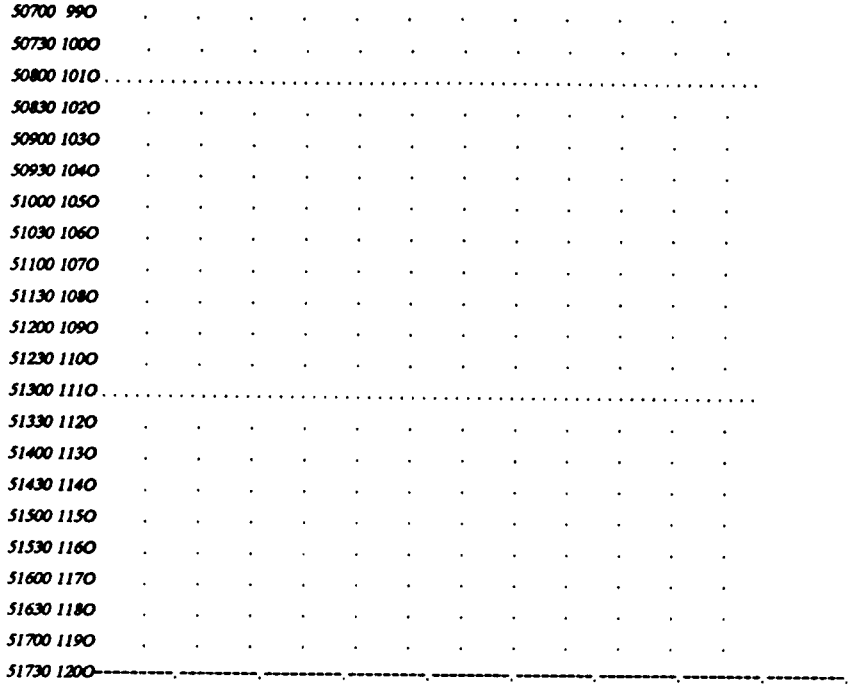
1

1 STATION COM 1

(O) OUTFLOW

	0.	2.	4.	6.	8.	10.	12.	14.	16.	0.	0.	0.	0.
DAHRMN PER													
30600 1	O												
30630 2	O												
30700 3	O												
30730 4	O												
30800 5	O												
30830 6.	O												
30900 7.	O												
30930 8.	O												
31000 9.	O												
31030 10.	O												
31100 11.	O												
31130 12.		O											
31200 13.		O											
31230 14.		O											
31300 15.		O											
31330 16.		O											
31400 17.						O							
31430 18.							O						
31500 19.								O					
31530 20.								O					
31600 21.								O					
31630 22.							O						
31700 23.						O							
31730 24.					O								
31800 25.					O								
31830 26.					O								
31900 27.					O								
31930 28.					O								
32000 29.					O								
32030 30.					O								
32100 31.					O								
32130 32.				O									
32200 33.				O									
32230 34.				O									
32300 35.				O									
32330 36.				O									
40000 37.				O									
40030 38.				O									
40100 39.				O									
40130 40.				O									
40200 41.				O									
40230 42.			O										
40300 43.			O										
40330 44.			O										
40400 45.			O										
40430 46.			O										

40500 47. . O.
40530 48. . O.
40600 49. . O .
40630 50. . O .
40700 51. . . . . O . . . . . .
40730 52. O .
40800 53. O .
40830 54. O .
40900 55. O .
40930 56. O .
41000 57. O .
41030 58O .
41100 59O .
41130 60O .
41200 61O . . . . . .
41230 62O .
41300 63O .
41330 64O .
41400 65O .
41430 66O .
41500 67O .
41530 68O .
41600 69O .
41630 70O .
41700 71O . . . . . .
41730 72O .
41800 73O .
41830 74O .
41900 75O .
41930 76O .
42000 77O .
42030 78O .
42100 79O .
42130 80O .
42200 81O . . . . . .
42230 82O .
42300 83O .
42330 84O .
50000 85O .
50030 86O .
50100 87O .
50130 88O .
50200 89O .
50230 90O .
50300 91O . . . . . .
50330 92O .
50400 93O .
50430 94O .
50500 95O .
50530 96O .
50600 97O .
50630 98O .


50700 990
50730 1000
50800 1010
50830 1020
50900 1030
50930 1040
51000 1050
51030 1060
51100 1070
51130 1080
51200 1090
51230 1100
51300 1110
51330 1120
51400 1130
51430 1140
51500 1150
51530 1160
51600 1170
51630 1180
51700 1190
51730 1200

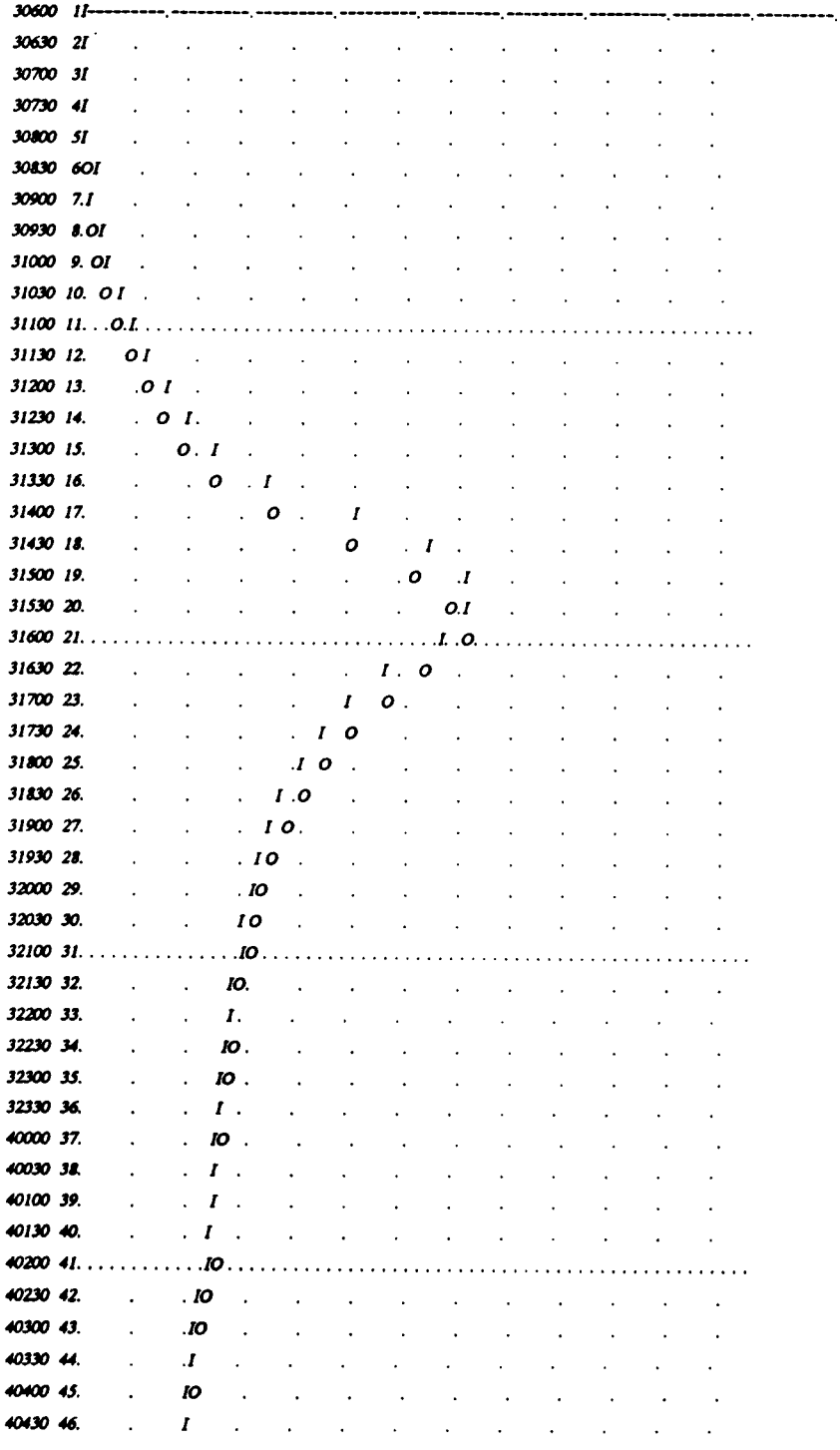
1

1 STATION ROUTE

(I) INFLOW, (O) OUTFLOW

0. 2. 4. 6. 8. 10. 12. 14. 16. 0. 0. 0. 0.

DAHRMN PER



40500 47. . IO . . . . . .
40530 48. . I. . . . . .
40600 49. . IO. . . . . .
40630 50. . I O . . . . . .
40700 51. . . . . I .O. . . . . .
40730 52. I .O . . . . . .
40800 53. I O. . . . . .
40830 54. I O . . . . . .
40900 55. IO . . . . . .
40930 56.IO . . . . . .
41000 57.I . . . . . .
41030 58IO . . . . . .
41100 59IO . . . . . .
41130 60I . . . . . .
41200 61I. . . . . .
41230 62I . . . . . .
41300 63I . . . . . .
41330 64I . . . . . .
41400 65I . . . . . .
41430 66I . . . . . .
41500 67I . . . . . .
41530 68I . . . . . .
41600 69I . . . . . .
41630 70I . . . . . .
41700 71I. . . . . .
41730 72I . . . . . .
41800 73I . . . . . .
41830 74I . . . . . .
41900 75I . . . . . .
41930 76I . . . . . .
42000 77I . . . . . .
42030 78I . . . . . .
42100 79I . . . . . .
42130 80I . . . . . .
42200 81I. . . . . .
42230 82I . . . . . .
42300 83I . . . . . .
42330 84I . . . . . .
50000 85I . . . . . .
50030 86I . . . . . .
50100 87I . . . . . .
50130 88I . . . . . .
50200 89I . . . . . .
50230 90I . . . . . .
50300 91I. . . . . .
50330 92I . . . . . .
50400 93I . . . . . .
50430 94I . . . . . .
50500 95I . . . . . .
50530 96I . . . . . .
50600 97I . . . . . .
50630 98I . . . . . .

```
50700 99I     .    .    .    .    .    .    .    .    .    .    .    .    .
50730 100I    .    .    .    .    .    .    .    .    .    .    .    .    .
50800 101I....................................................................
50830 102I    .    .    .    .    .    .    .    .    .    .    .    .    .
50900 103I    .    .    .    .    .    .    .    .    .    .    .    .    .
50930 104I    .    .    .    .    .    .    .    .    .    .    .    .    .
51000 105I    .    .    .    .    .    .    .    .    .    .    .    .    .
51030 106I    .    .    .    .    .    .    .    .    .    .    .    .    .
51100 107I    .    .    .    .    .    .    .    .    .    .    .    .    .
51130 108I    .    .    .    .    .    .    .    .    .    .    .    .    .
51200 109I    .    .    .    .    .    .    .    .    .    .    .    .    .
51230 110I    .    .    .    .    .    .    .    .    .    .    .    .    .
51300 111I....................................................................
51330 112I    .    .    .    .    .    .    .    .    .    .    .    .    .
51400 113I    .    .    .    .    .    .    .    .    .    .    .    .    .
51430 114I    .    .    .    .    .    .    .    .    .    .    .    .    .
51500 115I    .    .    .    .    .    .    .    .    .    .    .    .    .
51530 116I    .    .    .    .    .    .    .    .    .    .    .    .    .
51600 117I    .    .    .    .    .    .    .    .    .    .    .    .    .
51630 118I    .    .    .    .    .    .    .    .    .    .    .    .    .
51700 119I    .    .    .    .    .    .    .    .    .    .    .    .    .
51730 120I----------.---------.---------.---------.---------.---------.---------.---------.---------.---------
1
1
```

RUNOFF SUMMARY

FLOW IN CUBIC FEET PER SECOND

TIME IN HOURS, AREA IN SQUARE MILES

		PEAK	TIME OF	AVERAGE FLOW FOR MAXIMUM PERIOD			BASIN	MAXIMUM	TIME OF
	OPERATION	STATION	FLOW	PEAK	6-HOUR	24-HOUR	72-HOUR	AREA	STAGE	MAX STAGE
+	HYDROGRAPH AT	SUB A	12.	9.50	9.	4.	2.	.03		
+	HYDROGRAPH AT	SUB B	3.	8.00	2.	1.	0.	.00		
+	2 COMBINED AT	COM 1	14.	9.00	10.	5.	2.	.04		
+	ROUTED TO	ROUTE	14.	9.50	10.	5.	2.	.04		

*** NORMAL END OF HEC-1 ***

APPENDIX B

ELECTRON MICROGRAPHS PARTICLE ANALYSIS

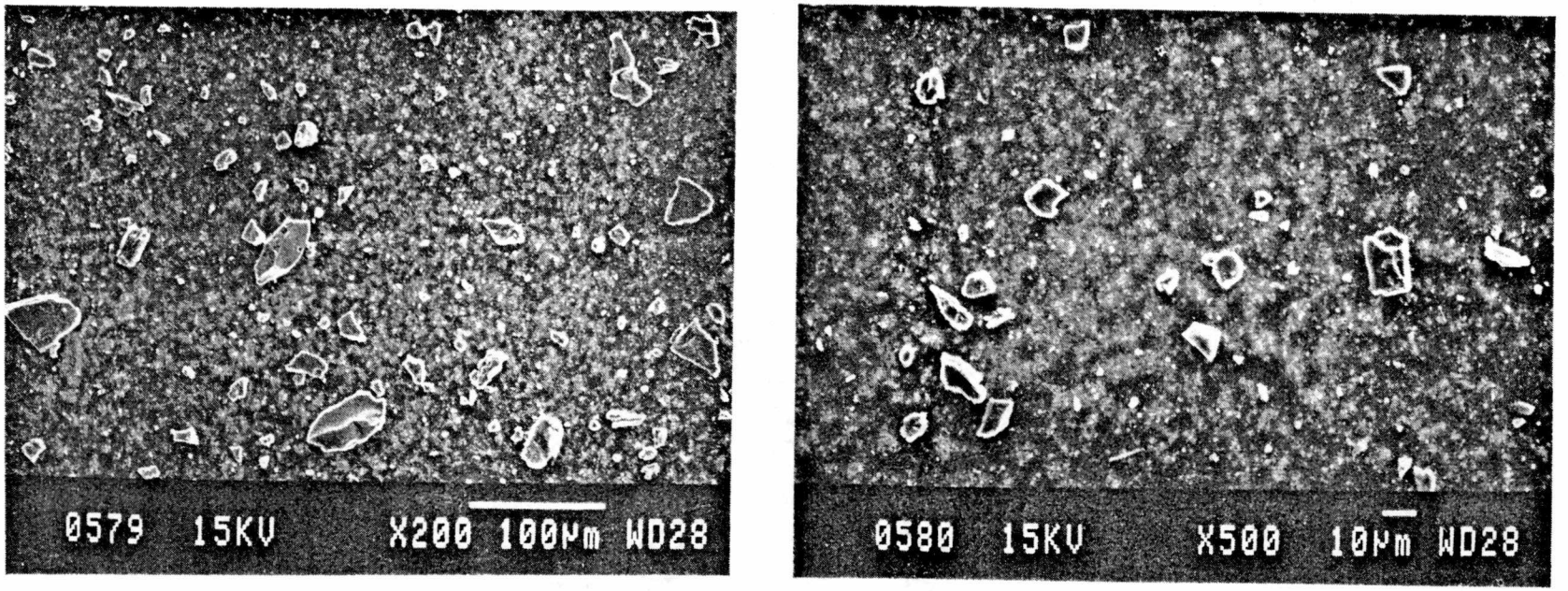


FIGURE B-1. SECONDARY ELECTRON IMAGES OF PARTICLES
FROM SITE 1 SURFACE SAMPLE (#26657)

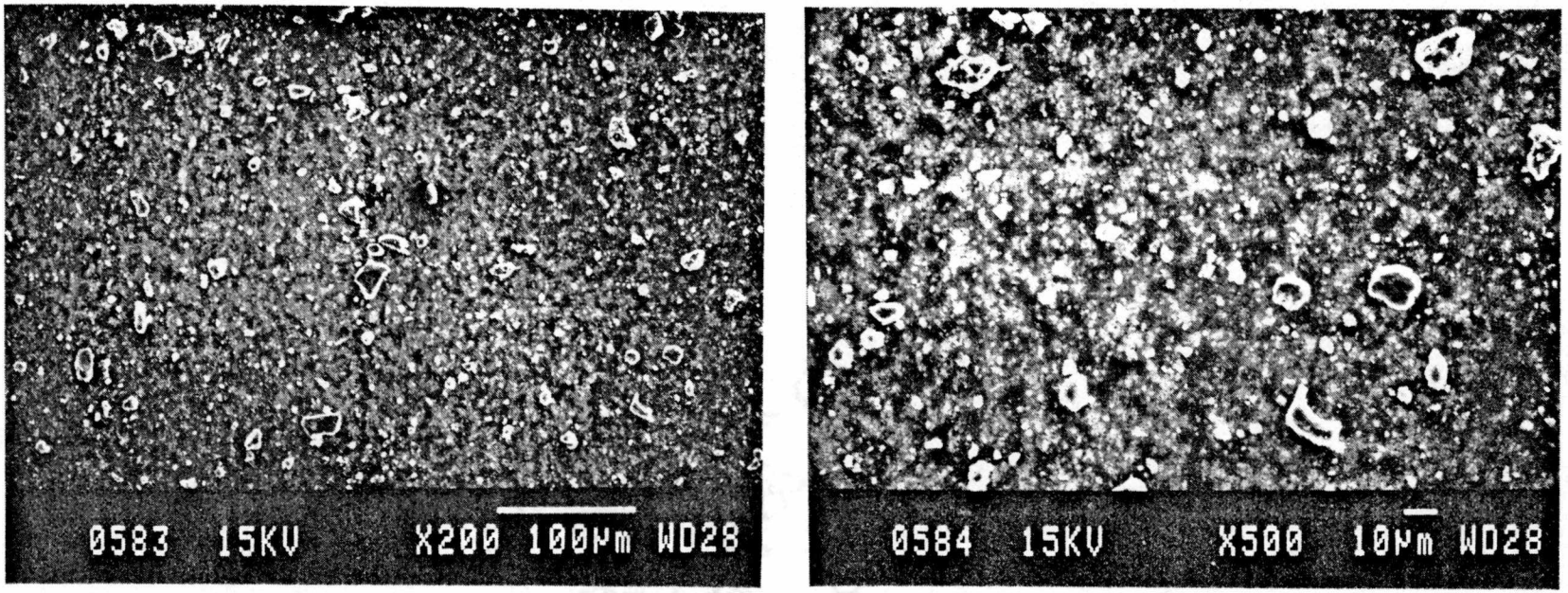


FIGURE B-2. SECONDARY ELECTRON IMAGES OF PARTICLES
FROM SITE 2 SURFACE SAMPLE (#26658)

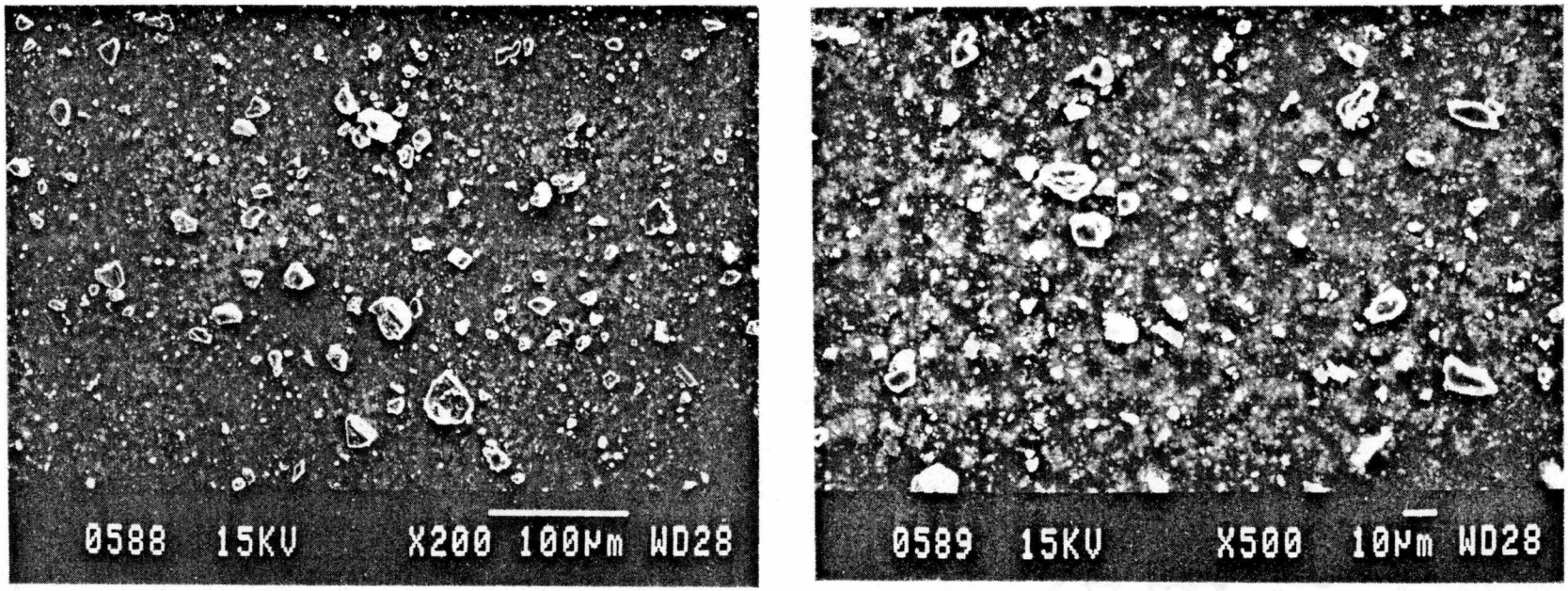


FIGURE B-3. SECONDARY ELECTRON IMAGES OF PARTICLES
FROM SITE 3 SURFACE SAMPLE (#26659)

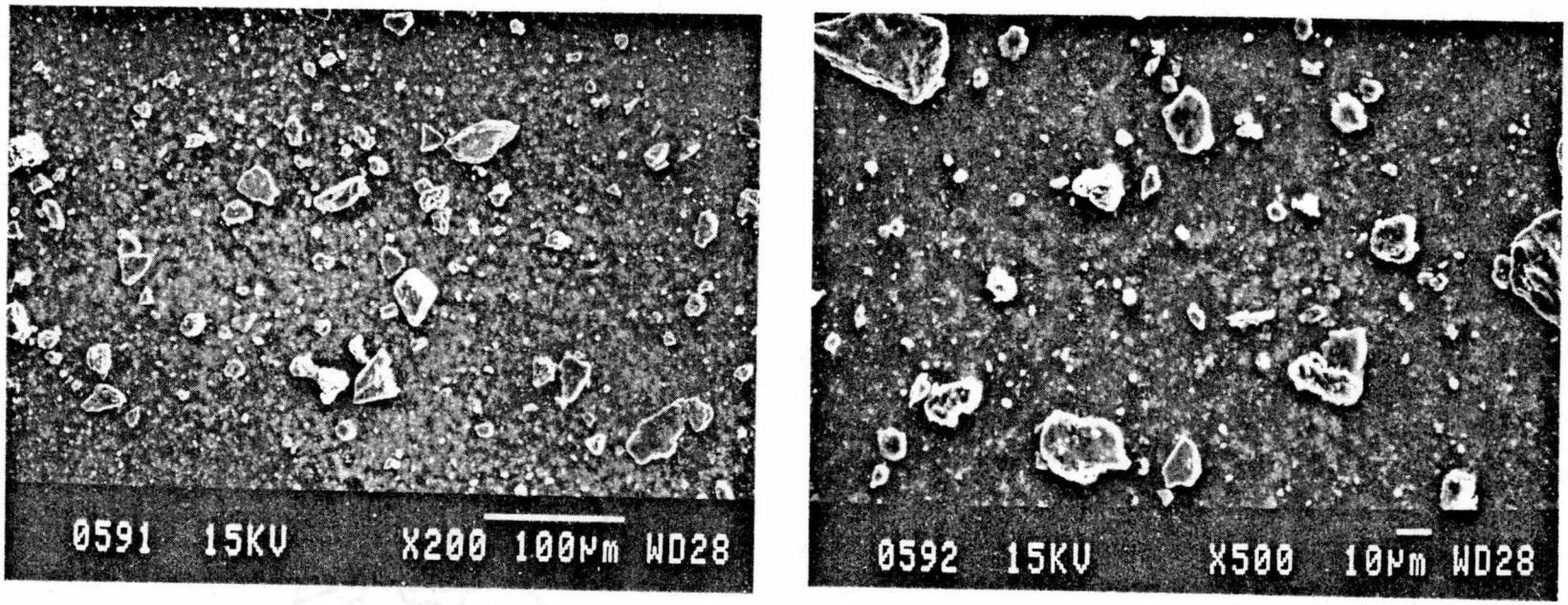


FIGURE B-4. SECONDARY ELECTRON IMAGES OF PARTICLES
FROM SITE 4 SURFACE SAMPLE (#26660)

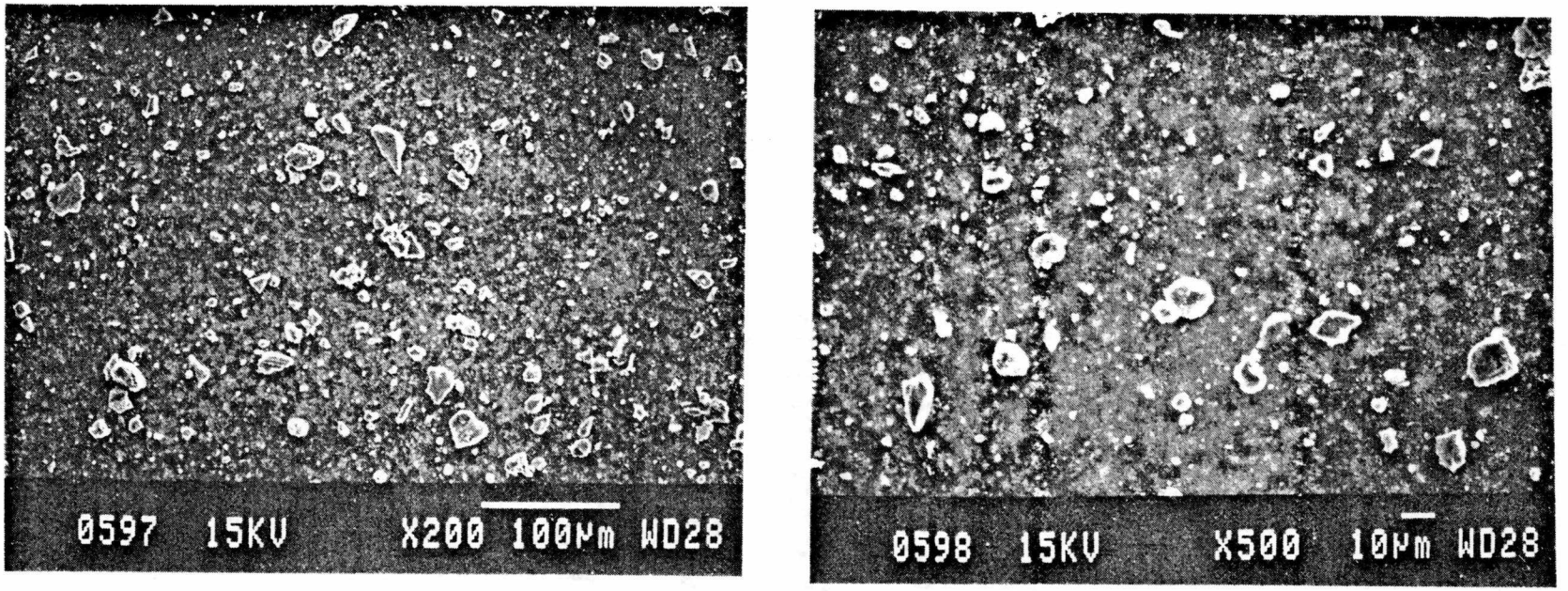


FIGURE B-5. SECONDARY ELECTRON IMAGES OF PARTICLES
FROM SITE 5 SURFACE SAMPLE (#26661)

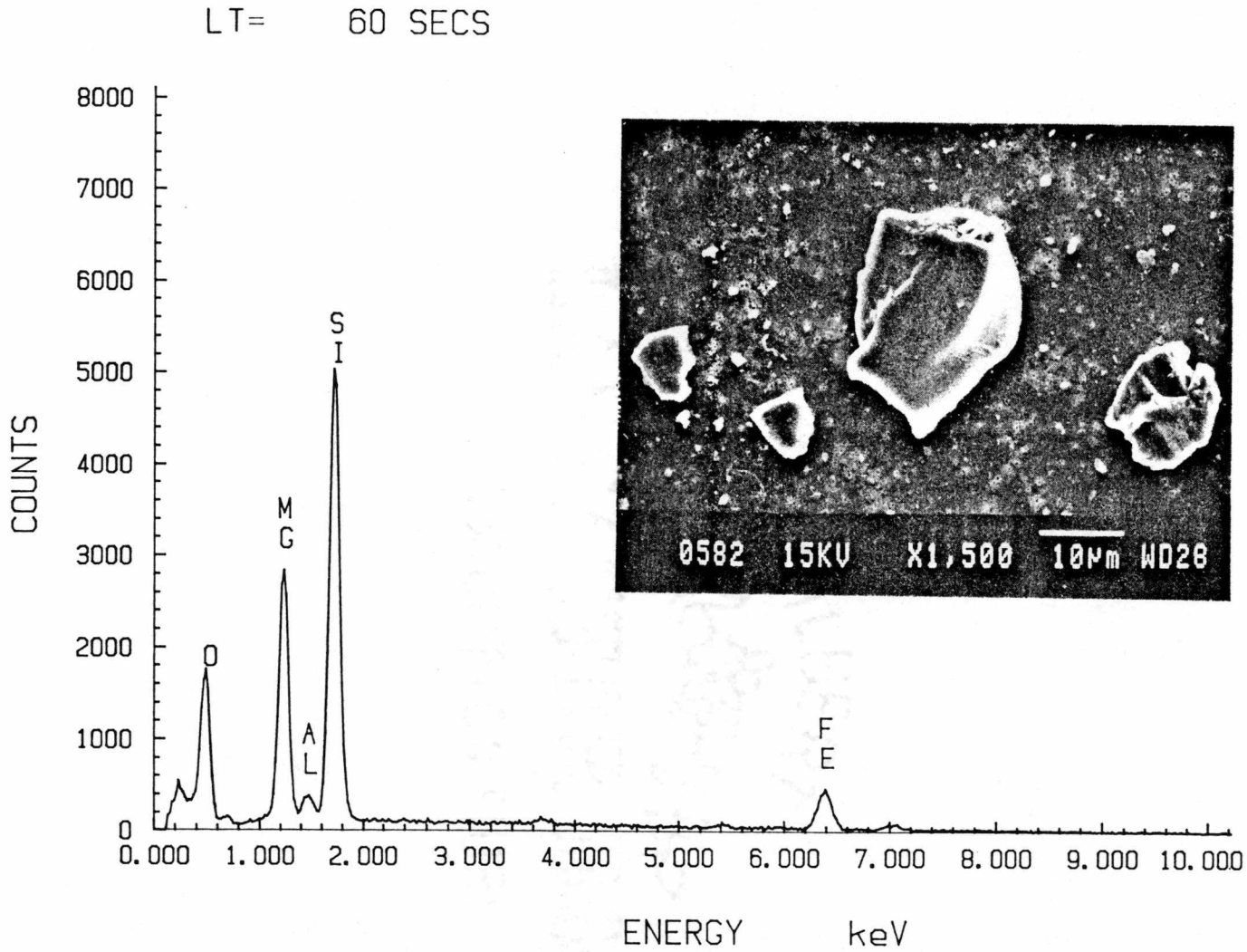


FIGURE B-6. SECONDARY ELECTRON IMAGE AND ELEMENTAL SPECTRUM OF SILICON-MAGNESIUM (Si-Mg). PARTICLE OBSERVED ON SITE 1 SURFACE SAMPLE

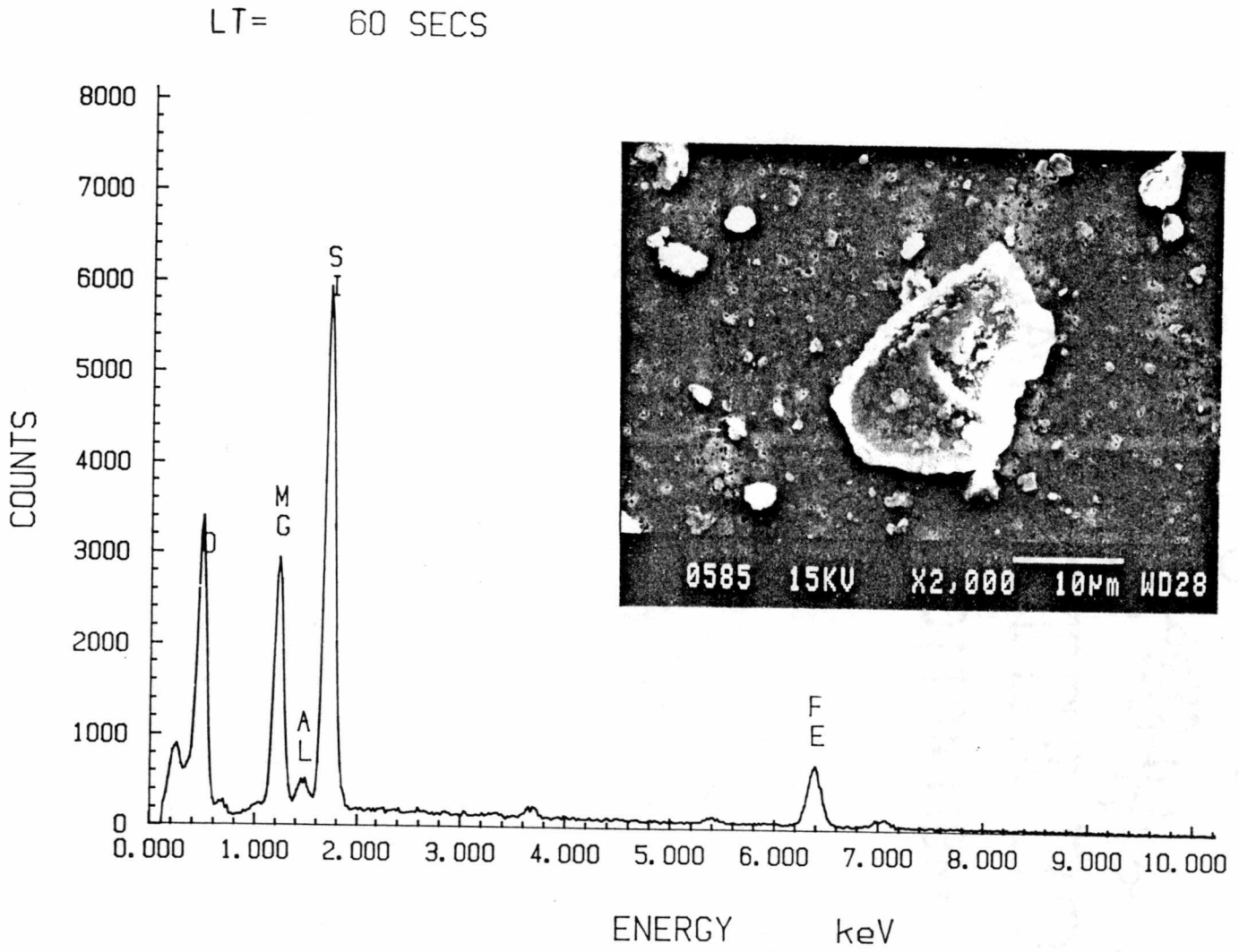


FIGURE B-7. SECONDARY ELECTRON IMAGE AND ELEMENTAL SPECTRUM OF SILICON-MAGNESIUM (Si-Mg). PARTICLE OBSERVED ON SITE 2 SURFACE SAMPLE

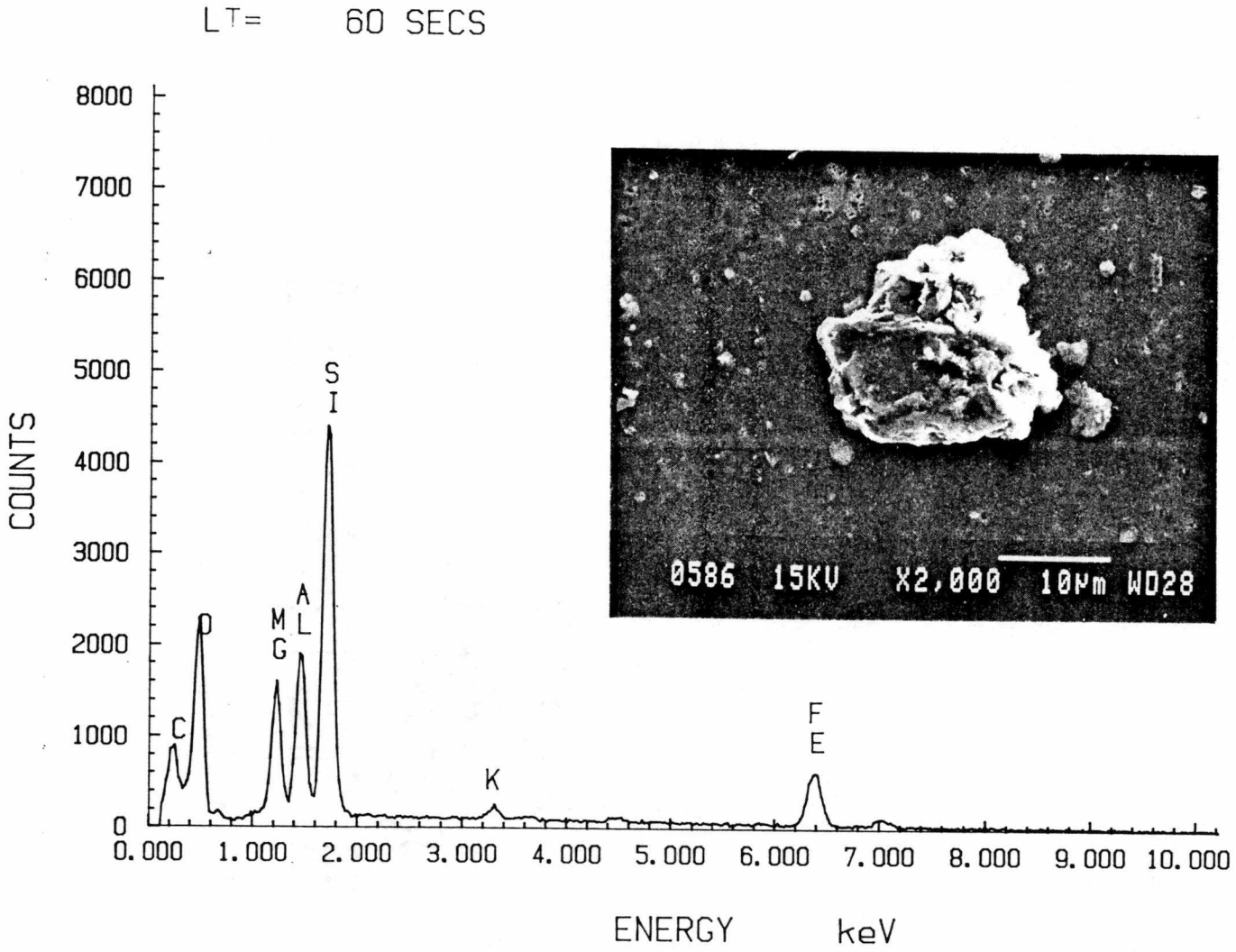


FIGURE B-8. SECONDARY ELECTRON IMAGE AND ELEMENTAL SPECTRUM OF SILICON-ALUMINUM-MAGNESIUM (Si-Al-Mg). PARTICLE OBSERVED ON SITE 2 SURFACE SAMPLE

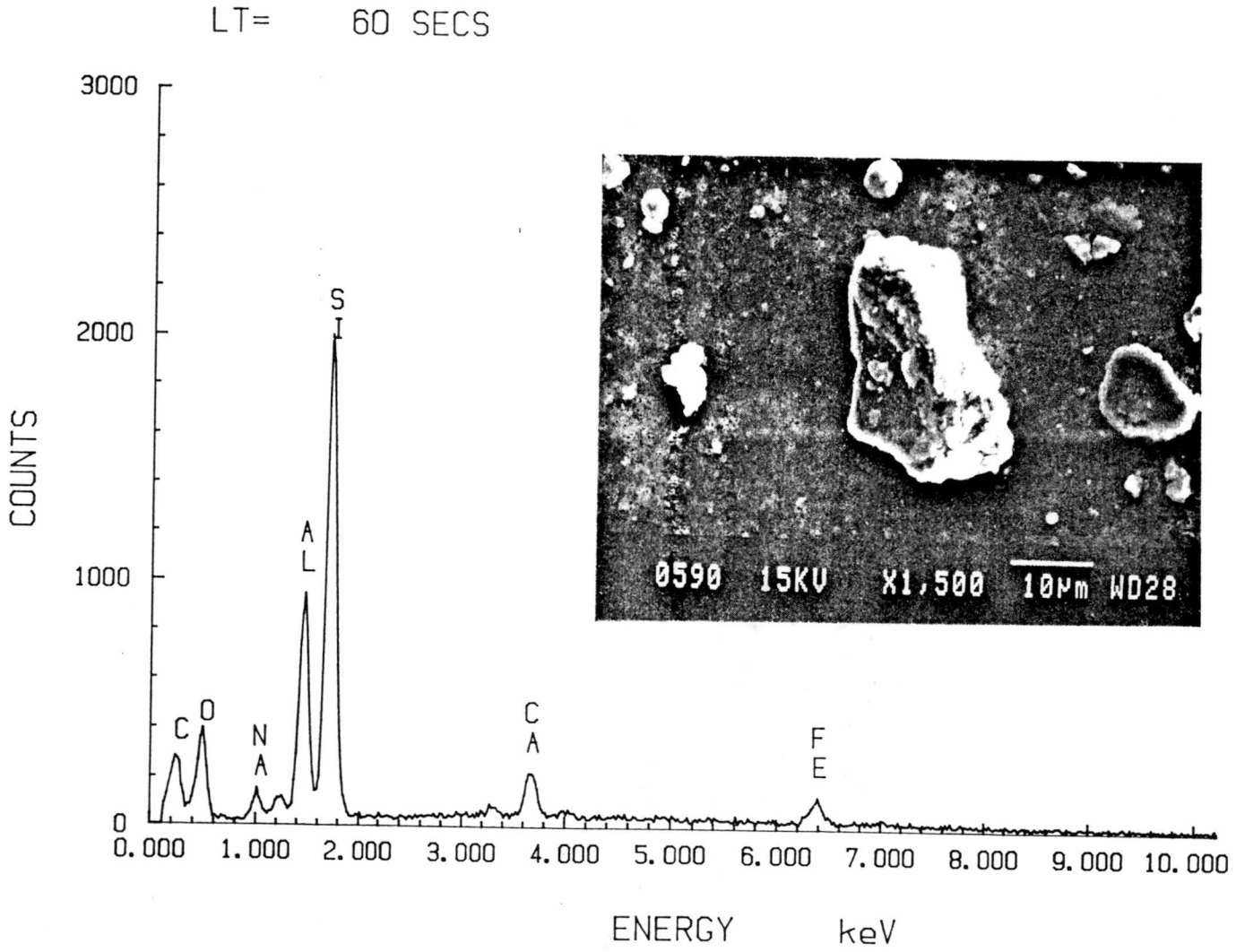


FIGURE B-9. SECONDARY ELECTRON IMAGE AND ELEMENTAL SPECTRUM OF SILICON-ALUMINUM (Si-Al). PARTICLE OBSERVED ON SITE 3 SURFACE SAMPLE

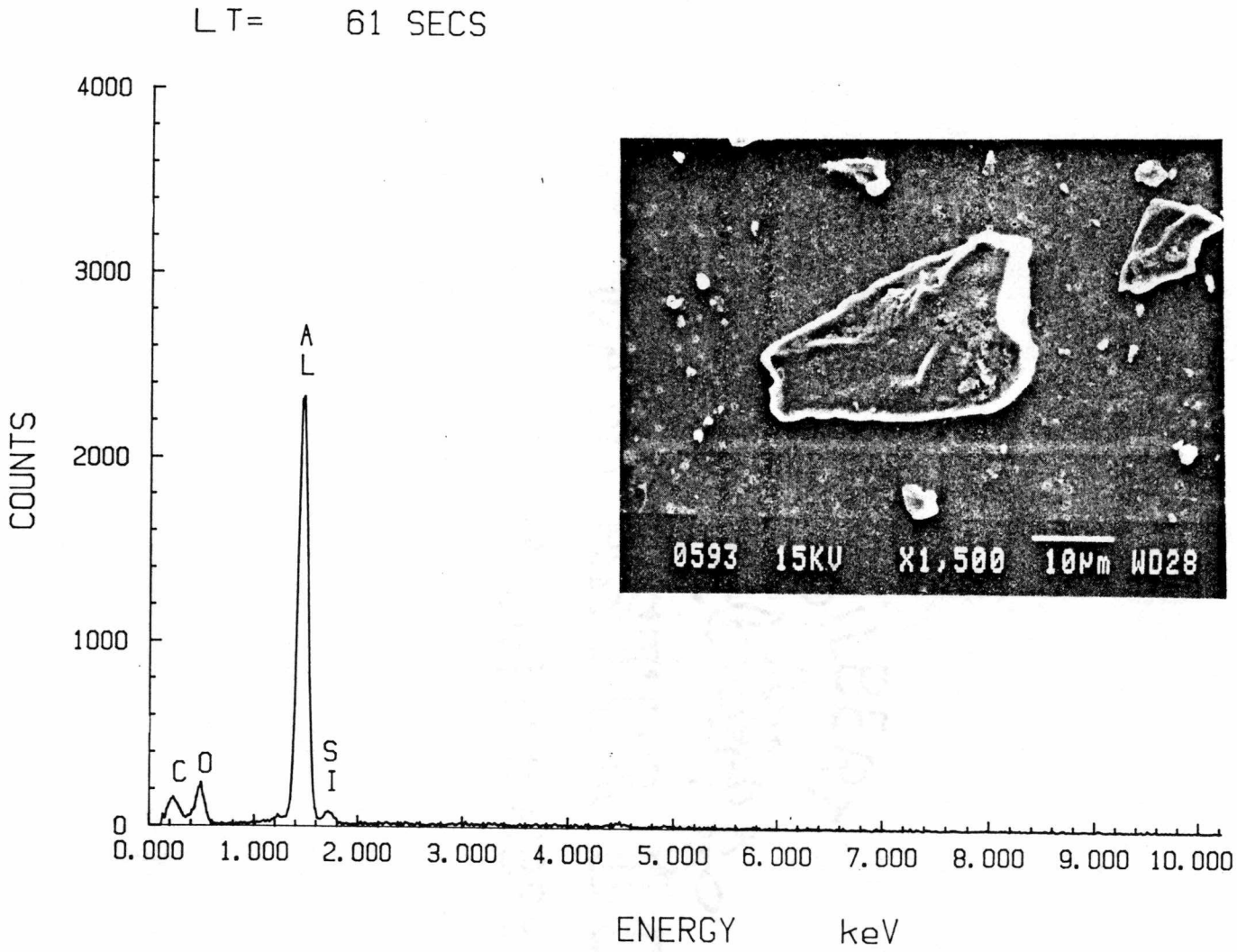


FIGURE B-10. SECONDARY ELECTRON IMAGE AND ELEMENTAL SPECTRUM OF ALUMINUM-RICH (AI-RICH). PARTICLE OBSERVED ON SITE 4 SURFACE SAMPLE

APPENDIX C

INPUT/OUTPUT HEC-6 MODEL

APPENDIX C-1

HEC-6 SEDIMENT TRANSPORT MODEL
DISCHARGE = .5 CFS @ .54 DAYS

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC  0     0   .0130
X1  170    3   0.0    40
GR 99.5   0.0  98.5    20  99.5    40
H   170  98.4  20.0    20
X1  330    3   0.0    40   160   160   160
GR 100     0    99    20   100    40
H   330  98.9  20.0    20
X1  490    3   0.0    40   160   160   160
GR 100.5   0   99.5    20 100.5    40
H   490  99.4  20.0    20
X1  650    3   0.0    40   160   160   160
GR 101     0   100    20   101    40
H   650  99.9  20.0    20
X1  810    3   0.0    40   160   160   160
GR 101.5   0  100.5    20 101.5    40
H   810 100.4  20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1        50    0    1
I3              1    1  1.80
I4         1    1    5  2.65
L  Q   .000   .10    1.0    100                    120
L SILT .0000  .0000   .000   .000
L  VFS .0000  .0000  .0000   .00
L  FS  .0000  .0000   .000   .00
L  MS  .0000  .0000   .000   .000
L  CS  .0000  .0000   .000   .00
L  VCS .0000  .0000  .0000   .0000
N 170  0    .067   0    .95        .011  .025  .21   .31
N      25   .08
N 330  0    .067   0    .95        .011  .025  .21   .31
N      .25  .08
N 490  0    .067   0    .95        .011  .025  .21   .31
N      .25  .08
N 650  0    .067   0    .95        .011  .025  .21   .31
N      .25  .08
N 810  0    .067   0    .95        .011  .025  .21   .31
0N     .25  .08
$HYD
*   B RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   .5
R  98.5
T   65
W   .54
$$END
```

T1 SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2 MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3 BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
P	0.050000	0.000000	1.000000	1.000000		1		

ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
		1.000000	1.000000				

SEC NO. 170.000

SEC NO. 330.000

SEC NO. 490.000

SEC NO. 650.000

SEC NO. 810.000

NO. OF CROSS SECTIONS READ IN = 5

NO. OF INPUT DATA MESSAGES= 0

END OF GEOMETRIC DATA
*1 SEDIMENT MODEL INCLUDES, SILT, AND SAND. TOTAL SAND LOAD IS DIVIDED
*2 INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3 BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4 TRANSPORT CAPACITY= USER SPECIFIED
*5 MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***

MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @		ELEVATIONS	
SEC NO.	SHAPE FACTOR	BED WIDTH	@ LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
2500000.000 8000000.000
N 330 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 490 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 650 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 810 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

```
*  B RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER   DISCHARGE=     0.50
      ELEVATION=    98.50
    TEMPERATURE=    65.00
FLOW DURATION(DAYS)    0.54
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE **       0.50       1.11     1.105171
                 *                  *                  *
ACCUMULATED AC-FT BY ENTRY *        SILT          *        SAND          *
  DAYS        POINT *  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW
                 *                  *                  *
  0.54       810.000*   0.00             *   0.00             *
    TOTAL=   170.000*   0.00    0.00    0.74*   0.00    0.00    0.67*
                 *                  *                  *


 SECTION  BED CHANGE  WS ELEV  THALWEG     Q    SEDIMENT LOAD IN TONS/DAY
 ID NO      FEET       FEET    EL FEET     CFS     SILT     SAND
 810.000    0.03     100.60    100.53      0.      1.       1.
 650.000    0.00     100.23    100.00      0.      1.       1.
 490.000    0.00      99.65     99.50      0.      1.       1.
 330.000    0.00      99.17     99.00      0.      0.       2.
 170.000    0.00      98.62     98.50      0.      0.       2.

END OF JOB
```

APPENDIX C-2

HEC-6 SEDIMENT TRANSPORT MODEL
DISCHARGE = 1.0 CFS @ .54 DAYS

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC  0     0   .0130
X1  170    3   0.0    40
GR 99.5   0.0  98.5    20  99.5    40
H   170  98.4  20.0    20
X1  330    3   0.0    40   160   160   160
GR 100     0    99    20   100    40
H   330  98.9  20.0    20
X1  490    3   0.0    40   160   160   160
GR 100.5   0   99.5    20 100.5    40
H   490  99.4  20.0    20
X1  650    3   0.0    40   160   160   160
GR 101     0   100    20   101    40
H   650  99.9  20.0    20
X1  810    3   0.0    40   160   160   160
GR 101.5   0  100.5    20 101.5    40
H   810 100.4  20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1        50     0     1
I3              1     1   1.80
I4         1     1     5   2.65
L  Q   .000   .10    1.0    100                    120
L SILT .0000   .0000   .000   .000
L  VFS .0000   .0000   .0000  .00
L  FS  .0000   .0000   .000   .00
L  MS  .0000   .0000   .000   .000
L  CS  .0000   .0000   .000   .00
L  VCS .0000  .0000  .0000    .0000
N 170   0     .067   0    .95        .011   .025   .21    .31
N      25    .08
N 330   0     .067   0    .95        .011   .025   .21    .31
N      .25   .08
N 490   0     .067   0    .95        .011   .025   .21    .31
N      .25   .08
N 650   0     .067   0    .95        .011   .025   .21    .31
N      .25   .08
N 810   0     .067   0    .95        .011   .025   .21    .31
0N     .25   .08
$HYD
*   B  RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   1
R  98.5
T   65
W   .54
$$END
```

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS


   ALER     ASEL      CE       CC       LFA      NR      TAN      CRL
P  0.050000 0.000000  1.000000 1.000000       1


   ALER     ASEL      CE       CC       LFA      NR      TAN      CRL
                     1.000000 1.000000


SEC NO.   170.000


SEC NO.   330.000


SEC NO.   490.000


SEC NO.   650.000


SEC NO.   810.000

NO. OF CROSS SECTIONS READ IN =    5

NO. OF INPUT DATA MESSAGES=    0

END OF GEOMETRIC DATA
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***


MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
```

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @	ELEVATIONS		
SEC NO.	SHAPE FACTOR	BED WIDTH @	LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
2500000.000 8000000.000
N 330 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 490 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 650 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 810 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

```
*  B RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER   DISCHARGE=     1.00
        ELEVATION=    98.50
     TEMPERATURE=     65.00
FLOW DURATION(DAYS)    0.54
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE **        1.00        1.11      1.105171
                  *                   *                   *
ACCUMULATED AC-FT BY ENTRY *         SILT          *        SAND          *
  DAYS          POINT *   INFLOW   OUTFLOW  TRAP EFF*   INFLOW   OUTFLOW  TRAP EFF*   INFLOW   OUTFLOW
                  *                   *                   *
  0.54         810.000*     0.00              *     0.00              *
    TOTAL=     170.000*     0.00      0.00    0.28*     0.00      0.00    0.45*
                  *                   *                   *


 SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD IN TONS/DAY
 ID NO       FEET        FEET     EL FEET      CFS      SILT      SAND
 810.000     0.02      100.68     100.52        1.       1.        3.
 650.000     0.00      100.29     100.00        1.       1.        2.
 490.000     0.00       99.74      99.50        1.       1.        1.
 330.000    -0.01       99.25      98.99        1.       1.        3.
 170.000     0.00       98.68      98.50        1.       1.        3.

END OF JOB
```

APPENDIX C-3

HEC-6 SEDIMENT TRANSPORT MODEL
DISCHARGE = 1.5 CFS @ .54 DAYS

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC   0     0   .0130
X1  170     3   0.0    40
GR 99.5   0.0  98.5    20  99.5    40
H   170   98.4  20.0    20
X1  330     3   0.0    40   160   160   160
GR 100      0    99    20   100    40
H   330   98.9  20.0    20
X1  490     3   0.0    40   160   160   160
GR 100.5    0   99.5    20 100.5    40
H   490   99.4  20.0    20
X1  650     3   0.0    40   160   160   160
GR 101      0   100    20   101    40
H   650   99.9  20.0    20
X1  810     3   0.0    40   160   160   160
GR 101.5    0  100.5    20 101.5    40
H   810  100.4  20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1        50     0     1
I3              1     1   1.80
I4         1     1     5   2.65
L  Q   .000   .10     1.0    100                    120
L SILT .0000   .0000   .000   .000
L  VFS .0000   .0000   .0000  .00
L  FS  .0000   .0000   .000   .00
L  MS  .0000   .0000   .000   .000
L  CS  .0000   .0000   .000   .00
L  VCS .0000   .0000  .0000    .0000
N 170   0     .067    0     .95          .011   .025   .21    .31
N      25    .08
N 330   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 490   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 650   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 810   0     .067    0     .95          .011   .025   .21    .31
0N     .25   .08
$HYD
*   B  RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   1.5
R   98.5
T   65
W   .54
$$END
```

T1 SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2 MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3 BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
P	0.050000	0.000000	1.000000	1.000000		1		

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
			1.000000	1.000000				

SEC NO. 170.000

SEC NO. 330.000

SEC NO. 490.000

SEC NO. 650.000

SEC NO. 810.000

NO. OF CROSS SECTIONS READ IN = 5

NO. OF INPUT DATA MESSAGES= 0

END OF GEOMETRIC DATA
*1 SEDIMENT MODEL INCLUDES, SILT, AND SAND. TOTAL SAND LOAD IS DIVIDED
*2 INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3 BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4 TRANSPORT CAPACITY= USER SPECIFIED
*5 MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***

MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @	ELEVATIONS		
SEC NO.	SHAPE FACTOR	BED WIDTH @	LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170	*0.000*	*0.067*	*0.000*	*0.950*	*0.000*	*0.011*	*0.025*	*0.210*	*0.310*
	2500000.000	*8000000.000*							
N 330	*0.000*	*0.067*	*0.000*	*0.950*	*0.000*	*0.011*	*0.025*	*0.210*	*0.310*
	0.250	*0.080*							
N 490	*0.000*	*0.067*	*0.000*	*0.950*	*0.000*	*0.011*	*0.025*	*0.210*	*0.310*
	0.250	*0.080*							
N 650	*0.000*	*0.067*	*0.000*	*0.950*	*0.000*	*0.011*	*0.025*	*0.210*	*0.310*
	0.250	*0.080*							
N 810	*0.000*	*0.067*	*0.000*	*0.950*	*0.000*	*0.011*	*0.025*	*0.210*	*0.310*
	0.250	*0.080*							

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

```
*  B  RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER   DISCHARGE=     1.50
        ELEVATION=    98.50
      TEMPERATURE=    65.00
FLOW DURATION(DAYS)    0.54
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE **       1.50       1.11      1.105171
                  *                   *                   *
ACCUMULATED AC-FT BY ENTRY *         SILT          *        SAND         *
  DAYS          POINT *  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW
                  *                   *                   *
  0.54         810.000*    0.00             *    0.00             *
    TOTAL=     170.000*    0.00     0.00    0.31*    0.00     0.00    0.37*
                  *                   *                   *


 SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD IN TONS/DAY
  ID NO      FEET        FEET     EL FEET      CFS      SILT      SAND
  810.000     0.02      100.73    100.52        1.        1.        2.
  650.000    -0.01      100.28     99.99        1.        1.        4.
  490.000     0.00       99.70     99.50        1.        1.        4.
  330.000     0.01       99.34     99.01        1.        1.        3.
  170.000    -0.01       98.71     98.49        1.        1.        3.

END OF JOB
```

APPENDIX C-4

HEC-6 SEDIMENT TRANSPORT MODEL
DISCHARGE = 2.0 CFS @ .54 DAYS

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC  0     0   .0130
X1  170     3   0.0    40
GR  99.5    0.0   98.5    20   99.5    40
H   170   98.4   20.0    20
X1  330     3   0.0    40   160   160   160
GR 100      0    99    20   100    40
H   330   98.9   20.0    20
X1  490     3   0.0    40   160   160   160
GR 100.5    0   99.5    20  100.5    40
H   490   99.4   20.0    20
X1  650     3   0.0    40   160   160   160
GR 101      0   100    20   101    40
H   650   99.9   20.0    20
X1  810     3   0.0    40   160   160   160
GR 101.5    0  100.5    20  101.5    40
H   810  100.4   20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1        50    0    1
I3              1    1   1.80
I4         1    1    5   2.65
L  Q   .000   .10    1.0    100                    120
L SILT .0000   .0000   .000   .000
L  VFS .0000   .0000   .0000   .00
L  FS  .0000   .0000   .000   .00
L  MS  .0000   .0000   .000   .000
L  CS  .0000   .0000   .000   .00
L  VCS .0000   .0000  .0000    .0000
N 170   0    .067   0    .95         .011   .025   .21    .31
N     25    .08
N 330   0    .067   0    .95         .011   .025   .21    .31
N     .25    .08
N 490   0    .067   0    .95         .011   .025   .21    .31
N     .25    .08
N 650   0    .067   0    .95         .011   .025   .21    .31
N     .25    .08
N 810   0    .067   0    .95         .011   .025   .21    .31
0N    .25    .08
SHYD
*   B  RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   2
R   98.5
T   65
W   .54
SSEND
```

T1 SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2 MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3 BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
P	0.050000	0.000000	1.000000	1.000000		1		

ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
		1.000000	1.000000				

SEC NO. 170.000

SEC NO. 330.000

SEC NO. 490.000

SEC NO. 650.000

SEC NO. 810.000

NO. OF CROSS SECTIONS READ IN = 5

NO. OF INPUT DATA MESSAGES= 0

END OF GEOMETRIC DATA
*1 SEDIMENT MODEL INCLUDES, SILT, AND SAND. TOTAL SAND LOAD IS DIVIDED
*2 INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3 BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4 TRANSPORT CAPACITY= USER SPECIFIED
*5 MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***

MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @	ELEVATIONS		
SEC NO.	SHAPE FACTOR	BED WIDTH @	LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
2500000.000 8000000.000
N 330 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 490 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 650 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 810 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

* B RUN 1, THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER DISCHARGE= 2.00
ELEVATION= 98.50
TEMPERATURE= 65.00
FLOW DURATION(DAYS) 0.13
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE ** 2.00 1.11 1.105171

ACCUMULATED AC-FT BY ENTRY	*	SILT			*	SAND			*		
DAYS	POINT	*	INFLOW	OUTFLOW	TRAP EFF	*	INFLOW	OUTFLOW	TRAP EFF	*	INFLOW	OUTFLOW
0.13	810.000	*	0.00			*	0.00			*		
TOTAL=	170.000	*	0.00	0.00	0.10	*	0.00	0.00	-0.18	*		

SECTION ID NO	BED CHANGE FEET	WS ELEV FEET	THALWEG EL FEET	Q CFS		SEDIMENT LOAD IN TONS/DAY SILT	SAND
810.000	0.00	100.73	100.50	2.	1.	4.	
650.000	0.00	100.37	100.00	2.	1.	4.	
490.000	0.00	99.77	99.50	2.	1.	5.	
330.000	0.00	99.35	99.00	2.	1.	5.	
170.000	0.00	98.73	98.50	2.	1.	7.	

END OF JOB

APPENDIX C-5

HEC-6 SEDIMENT TRANSPORT MODEL
DISCHARGE = 3.0 CFS @ .13 DAYS

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC   0     0   .0130
X1  170     3   0.0    40
GR 99.5   0.0  98.5    20  99.5    40
H   170  98.4  20.0    20
X1  330     3   0.0    40   160   160   160
GR 100      0    99    20   100    40
H   330  98.9  20.0    20
X1  490     3   0.0    40   160   160   160
GR 100.5    0  99.5    20 100.5    40
H   490  99.4  20.0    20
X1  650     3   0.0    40   160   160   160
GR 101      0   100    20   101    40
H   650  99.9  20.0    20
X1  810     3   0.0    40   160   160   160
GR 101.5    0 100.5    20 101.5    40
H   810 100.4  20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1        50     0     1
I3              1     1   1.80
I4         1     1     5   2.65
L  Q   .000   .10    1.0    100                    120
L SILT .0000   .0000   .000   .000
L  VFS .0000   .0000   .0000   .00
L  FS  .0000   .0000   .000   .00
L  MS  .0000   .0000   .000   .000
L  CS  .0000   .0000   .000   .00
L  VCS .0000  .0000  .0000    .0000
N 170   0    .067   0    .95         .011   .025   .21    .31
N     25    .08
N 330   0    .067   0    .95         .011   .025   .21    .31
N     .25   .08
N 490   0    .067   0    .95         .011   .025   .21    .31
N     .25   .08
N 650   0    .067   0    .95         .011   .025   .21    .31
N     .25   .08
N 810   0    .067   0    .95         .011   .025   .21    .31
0N    .25   .08
$HYD
*  B  RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   3
R   98.5
T   65
W   .13
$SEND
```

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS


   ALER     ASEL      CE       CC       LFA      NR     TAN      CRL
P 0.050000 0.000000 1.000000 1.000000       1


   ALER     ASEL      CE       CC       LFA      NR     TAN      CRL
                   1.000000 1.000000


SEC NO.   170.000


SEC NO.   330.000


SEC NO.   490.000


SEC NO.   650.000


SEC NO.   810.000

NO. OF CROSS SECTIONS READ IN =    5

NO. OF INPUT DATA MESSAGES=    0

END OF GEOMETRIC DATA
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***


MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
```

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @	ELEVATIONS		
SEC NO.	SHAPE FACTOR	BED WIDTH	@ LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
2500000.000 8000000.000
N 330 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 490 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 650 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 810 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

```
*  B RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER   DISCHARGE=     3.00
      ELEVATION=     98.50
    TEMPERATURE=     65.00
FLOW DURATION(DAYS)     0.13
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE **        3.00        1.11        1.105171
                 *                    *                    *
ACCUMULATED AC-FT BY ENTRY *          SILT          *          SAND          *
  DAYS          POINT *  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW
                 *                    *                    *
  0.13         810.000*    0.00              *     0.00              *
    TOTAL=     170.000*    0.00     0.00     0.00*    0.00     0.00    -0.46*
                 *                    *                    *


 SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD IN TONS/DAY
 ID NO       FEET        FEET     EL FEET      CFS      SILT      SAND
 810.000      0.00      100.82     100.50       3.       1.        3.
 650.000     -0.01      100.30      99.99       3.       1.       14.
 490.000      0.01       99.77      99.51       3.       1.        7.
 330.000      0.00       99.41      99.00       3.       1.        7.
 170.000      0.00       98.78      98.50       3.       1.        8.

END OF JOB
```

APPENDIX A-6

HEC-1 INPUT/OUTPUT SUBBASIN 2 AND 3
100-YEAR STORM

```
T1    SEDIMENT TRANSPORT FOR A 25-YR STORM ***HEC-2 FORMAT***
T2    MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF. HEC,DEC1971
T3    BASIN WAS SUBDIVIDED INTO 5 DISTICT ZONES FOR RUNOFF ESTIMATIONS
NC  0     0   .0130
X1  170     3   0.0    40
GR  99.5    0.0   98.5    20   99.5    40
H   170   98.4   20.0    20
X1  330     3   0.0    40   160   160   160
GR 100      0    99    20   100    40
H   330   98.9   20.0    20
X1  490     3   0.0    40   160   160   160
GR 100.5    0   99.5    20  100.5    40
H   490   99.4   20.0    20
X1  650     3   0.0    40   160   160   160
GR 101      0   100    20   101    40
H   650   99.9   20.0    20
X1  810     3   0.0    40   160   160   160
GR 101.5    0   100.5    20  101.5    40
H   810  100.4   20.0    20
EJ
*1    SEDIMENT MODEL INCLUDES, SILT, AND SAND.  TOTAL SAND LOAD IS DIVIDED
*2    INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3    BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4    TRANSPORT CAPACITY= USER SPECIFIED
*5    MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM
I1          50     0     1
I3                 1     1   1.80
I4          1      1     5   2.65
L  Q   .000   .10     1.0     100                      120
L SILT .0000   .0000    .000    .000
L  VFS .0000   .0000    .0000   .00
L  FS  .0000   .0000    .000    .00
L  MS  .0000   .0000    .000    .000
L  CS  .0000   .0000    .000    .00
L  VCS .0000   .0000  .0000     .0000
N 170   0     .067    0     .95          .011   .025   .21    .31
N      25    .08
N 330   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 490   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 650   0     .067    0     .95          .011   .025   .21    .31
N      .25   .08
N 810   0     .067    0     .95          .011   .025   .21    .31
0N     .25   .08
$HYD
*   B RUN 1,  THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT
Q   6
R   98.5
T   65
W   .13
$$END
```

T1 SEDIMENT TRANSPORT FOR A 25-YR AND 100 YEAR STORM
T2 MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF.
T3 BASIN WAS SUBDIVIDED INTO 5 DISTINCT ZONES FOR TRANSPORT ESTIMATIONS

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
P	0.050000	0.000000	1.000000	1.000000		1		

	ALER	ASEL	CE	CC	LFA	NR	TAN	CRL
			1.000000	1.000000				

SEC NO. 170.000

SEC NO. 330.000

SEC NO. 490.000

SEC NO. 650.000

SEC NO. 810.000

NO. OF CROSS SECTIONS READ IN = 5

NO. OF INPUT DATA MESSAGES= 0

END OF GEOMETRIC DATA

*1 SEDIMENT MODEL INCLUDES, SILT, AND SAND. TOTAL SAND LOAD IS DIVIDED
*2 INTO 5 CLASSES-VERY FINE,FINE,MEDIUM,AND COARSE AND VERY COARSE.
*3 BED MATERIAL GRADATION WAS DETERMINED FROM PERCENT FINER CURVE
*4 TRANSPORT CAPACITY= USER SPECIFIED
*5 MODEL VERIFIED FOR Q=9 CFS REPRESENTING MAX AT 100 YEAR STORM

BASIC BACKWATER TAPE
SEDIMENT TRANSPORT FOR A 25-YR AND 100 YEAR STORM

MARE ISLAND 900 AREA SUBBASIN 1 ASPHALT RUNOFF.
BASIN WAS SUBDIVIDED INTO 5 DISTINCT ZONES FOR TRANSPORT ESTIMATIONS

SEDIMENT PARAMETER DATA

	SPI	IBG	MNQ	SPGF	ACGR
I1	50.	0	1	1.000	32.174

	MTCL	IASL	LASL	SGSL	DTSL	STSD	PUSD	UWSD	CCSD
I3	1	1	1	1.800	0.020	0.020	82.000	65.000	5.700

	MTC	IASA	LASA	SPGS	GSF	BSAE	PSI	UWD
I4	1	1	5	2.650	0.667	0.500	30.000	93.000

FOLLOWING GRAIN SIZES UTILIZED

SILT SIZES= 0.000026

SAND SIZES UP= 0.000288 0.000580 0.001160 0.002319 0.004639

Q-QS RATING TABLE

L Q
L SILT
L VFS
L FS
L MS
L CS
L VCS

VOLUME VS DEPTH OF DEPOSITS

	VOLUME	MOVEABLE @	ELEVATIONS		
SEC NO.	SHAPE FACTOR	BED WIDTH @	LEFT SIDE	RIGHT SIDE	THALWEG
170.00	20.0	98.50	98.50	98.50	
330.00	20.0	99.00	99.00	99.00	
490.00	20.0	99.50	99.50	99.50	
650.00	20.0	100.00	100.00	100.00	
810.00	20.0	100.50	100.50	100.50	

INACTIVE BED, GRAIN SIZE DISTRIBUTION BY SIZE FRACTION,(N-CARDS)

N 170 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
2500000.000 8000000.000
N 330 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 490 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 650 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080
N 810 0.000 0.067 0.000 0.950 0.000 0.011 0.025 0.210 0.310
0.250 0.080

ACTIVE DEPOSITS, VOL. IN TONS

NONE SPECIFIED, ASSUMED ZERO

*MAKE SUM OF FRACTIONS ON N-CARD(********)LESS THAN XPI (N-5) (0.95000)*
SECTION NO= 170.000
SUBROUTINE STMOD2
*INPUT DATA*DIAGNOSTIC**

NO. OF INPUT DATA MESSAGES= 1

END OF SEDIMENT DATA

```
*  B RUN 1, THE FOLLOWING HYDROLOGIC DATA ILLUSTRATES CHANNEL SEDIMENT

DOWNSTREAM BOUNDARY DATA
WATER   DISCHARGE=     6.00
      ELEVATION=    98.50
    TEMPERATURE=    65.00
FLOW DURATION(DAYS)    0.13
SEDIMENT ROUTING, Q VS QS RATING TABLE

** SUBROUTINE INLOAD ** Q ABOVE TABLE **
**WATER DISCHARGE,WATER - SEDIMENT RATING TABLE **       6.00       1.11     1.105171
                 *                 *                 *
ACCUMULATED AC-FT BY ENTRY *        SILT        *       SAND        *
  DAYS        POINT *  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW  TRAP EFF*  INFLOW  OUTFLOW
                 *                 *                 *
  0.13        810.000*    0.00            *    0.00            *
    TOTAL=    170.000*    0.00    0.00    0.00*    0.00    0.00   -1.76*
                 *                 *                 *


 SECTION   BED CHANGE   WS ELEV   THALWEG      Q     SEDIMENT LOAD IN TONS/DAY
 ID NO       FEET        FEET     EL FEET      CFS     SILT     SAND
 810.000     0.00      100.89     100.50        6.      1.       7.
 650.000    -0.01      100.50      99.99        6.      1.      14.
 490.000     0.00       99.89      99.50        6.      1.      12.
 330.000     0.00       99.53      99.00        6.      1.      13.
 170.000    -0.01       98.87      98.49        6.      1.      15.

END OF JOB
```

VITA

Paul Dean Kuhlmeier was born on January 7, 1956 in Sioux Falls, South Dakota. He received B.S. and M.S. degrees in Civil Engineering in 1978 and 1981, respectively, from the South Dakota School of Mines and Technology, Rapid City, South Dakota. Mr. Kuhlmeier has also studied business administration at Rutgers University and Central Michigan University, computer science at Augustana College (South Dakota) and economics at South Dakota State University.

Mr. Kuhlmeier began his career with the U.S. Soil Conservation Service as a survey technician in 1976. Over the past 13 years he has held environmental engineering and management positions in government, industry, and private consulting. Presently, he is project director at International Technology Corporation in Knoxville, Tennessee where he focuses on hazardous waste problems. Mr. Kuhlmeier is a registered professional engineer, land surveyor, and geologist in several states. He is also a certified wastewater treatment plant operator.

Mr. Kuhlmeier maintains active membership in numerous professional societies including American Water Works Association, Water Pollution Control Federation, American Society of Civil Engineers, American Geophysical Union, American Chemical Society, and the National Water Well Association.