geographic features that affect runoff quantity and quality, and so on. Considering this situation, a measure of the magnitude of the urban runoff pollution level and methods for characterizing its variability were needed. The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary measure of the pollutant load. The rationale for adopting the EMC for characterizing urban runoff is discussed in the receiving water effects section of this chapter as well as in subsequent chapters. Event mean concentrations were calculated for each event at each site in the accessible data base. If a flow-weighted composite sample was taken, its concentration was used to represent the event mean concentration. Where sequential discrete samples were taken over the hydrograph, the event mean concentration was determined by calculating the area under the loadograph (the curve of concentration times discharge rate over time) and dividing it by the area under the hydrograph (the curve of runoff volume over time). Details of the calculation procedure have been described in the Data Management Procedures Manual. For the purpose of determining event mean concentrations, rainfall events were defined to be separate precipitation events when there was an intervening time period of at least six hours without rain.

A statistical approach was adopted for characterizing the properties of EMCs for standard pollutants. Standard statistical procedures were used to define the probability distribution, central tendency (a mean or median) and spread (standard deviation or coefficient of variation) of EMC data. EMC data for each pollutant from all storms and monitoring sites were complied in a central data base management system at the National Computer Center. The SAS computer statistical routines and other standard statistical methods were used to explore and characterize the data. The statistical methods used are, for the most part, not explained in this report since these are readily available in the literature. Nor are the operations of the SAS routines, which are available at most computer centers.

The underlying probability distribution of the EMC data was examined and tested by both visual and statistical methods. With relatively few isolated exceptions, the probability distribution of EMCs at individual sites can be characterized by lognormal distributions. Given this, concise characterization of the variable urban runoff characteristics at each of the sites is defined by only two values, the mean or median and the coefficient of variation (standard deviation divided by mean). Because the underlying distributions are lognormal, the appropriate statistic to employ for comparisons between individual sites or groups of sites is the median value, because it is less influenced by the small number of large values typical of lognormal distributions and, hence, is a more robust measure of central tendency. However, for comparisons with other published data which usually report average values and for certain computations and analyses (e.g., annual mass loads), the mean value is more appropriate.

Relationships among a number of statistical properties of interest are easily determined when distributions are lognormal. Figure 5-1 illustrates some relationships for lognormal distributions. In (a) the frequency distributions of two variable data sets which are log-normal and have the same median are shown. The log transforms of the data result in normal bell

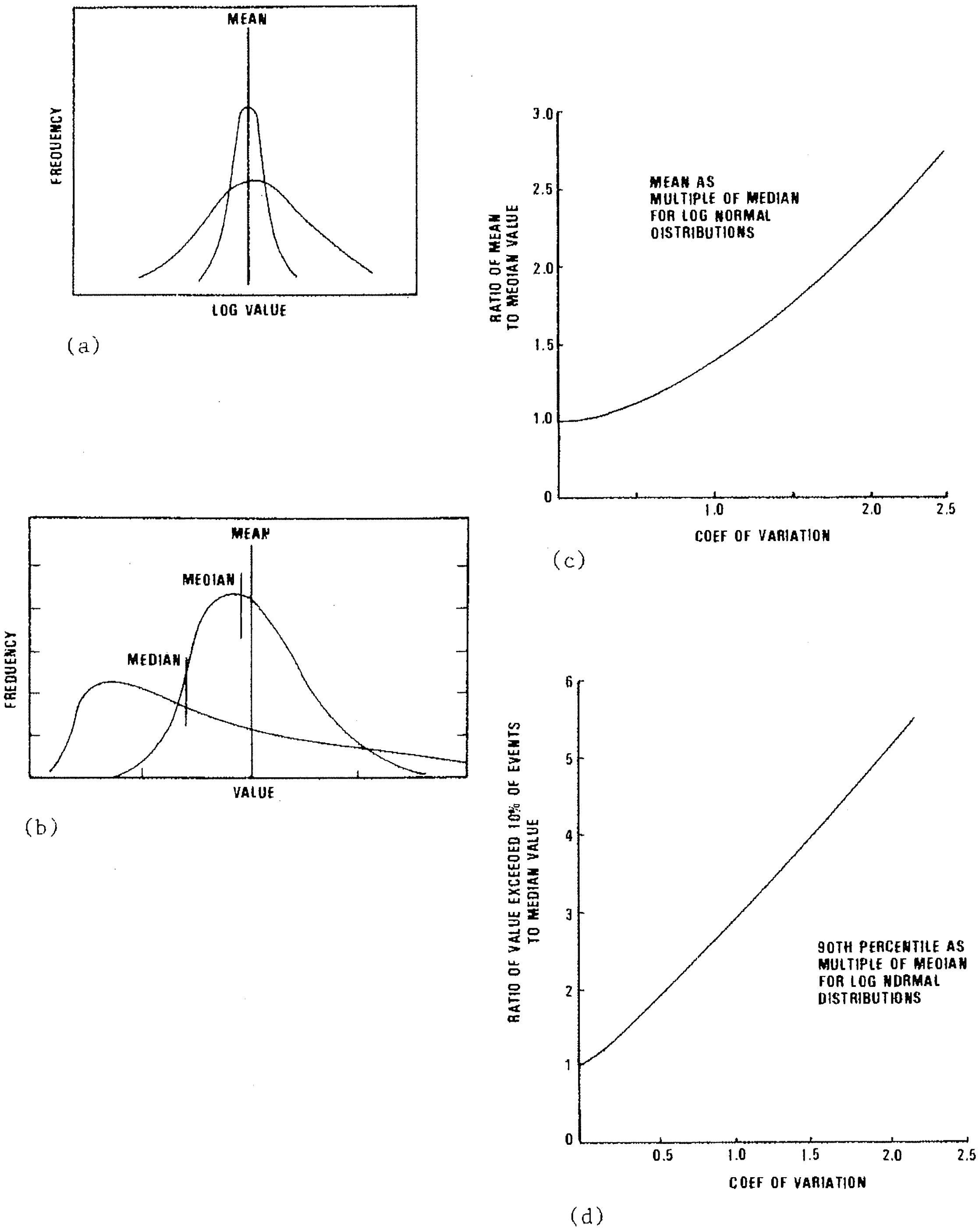


Figure 5-1. Lognormal Distribution Relationships

shaped distributions; more variable data (higher coefficient of variation) result in a greater spread. Frequency histograms prepared using untransformed data values produce skewed distributions, as shown by (b) which illustrates two data sets which have the same arithmetic mean. The effect of coefficient of variation is shown as well as the relation between mean and median for lognormal distributions. An established relationship exists between median and mean, as shown by (c) and described by:

$$\frac{\text{Mean}}{\text{Median}} = \sqrt{1 + (\text{Coef Var})^2}$$

When a distribution is known to be lognormal the best estimate of the population mean is that derived from the lognormal relationships. For small samples it can be expected to be different than the result of a straight arithmetic averaging of sample data; the two estimates of the mean will give similar values when the number of samples is very large.

In addition, the expected value at any probability or frequency of occurrence (X_α) can be determined by:

$$X_\alpha = \exp\ (\mu_{\ln x} + Z_\alpha\ \sigma_{\ln x})$$

where:

Z_α = the standard normal probability

$\mu_{\ln x}$ = mean of log-transformed data

$\sigma_{\ln x}$ = standard deviation of log-transformed data

X_α can be expressed as a ratio to the median value by the following equation which defines the ratio in terms of the coefficient of variation

$$\frac{X_\alpha}{\text{Median}} = \exp\ (Z_\alpha \sqrt{\ln\ (1 + (\text{Coef Var})^2)}).$$

This relationship is shown by (d) for 90th percentile values (10 percent exceedance, $Z_\alpha = 1.2817$).

The establishment of the fundamental distribution as lognormal, and the availability of a sufficiently large sample population of EMCs to provide reliable derived statistics, has a number of benefits:

- Concise summaries of highly variable data can be developed.
- Comparisons of results from different sites, events, etc., are convenient and are more easily understood.

- Statements can be made concerning frequency of occurrence. One can express how often values will exceed various magnitudes of interest.

- A more useful method of reporting data than the use of ranges is provided; one which is less subject to misinterpretation.

- A framework is provided for examining "transferability" of data in a quantitative manner.

Priority Pollutants

In cooperation with EPA's Monitoring and Data Support Division (MDSD), a special study element was built into two-thirds of the NURP projects (20 of 28) to identify which of the compounds on EPA's list of "Priority Pollutants" are found in urban runoff, and the concentrations at which they occur. The base effort collected 121 samples of urban runoff which were analyzed for priority pollutants. A supplementary special metals study secured 147 samples. Methods utilized in this study element are described in the following report which covers this activity:

> "NURP Priority Pollutant Monitoring Project: Summary of Findings", December 1983; EPA Monitoring and Data Support Division, Office of Water Regulations and Standards, Washington, D.C.

In addition to the above special study, as previously mentioned, most NURP projects monitored selected heavy metals (principally total copper, total lead, and total zinc) in their routine monitoring programs. Summaries of these data are presented in Chapter 6.

Hydrometeorological Statistics

Consistent with the adoption of a storm "event" as the fundamental time scale used in the analysis of data and the interpretation of effects, rainfall data were analyzed to define "event" statistics for a significant number of locations throughout the country. The SYNOP program was employed for developing the statistical parameters of rainfall intensity, duration, volume, and interval between storm events. This program has been detailed in the NURP "Data Management Procedures Manual."

In addition to rainfall, rainfall-runoff relationships were characterized for monitored storm events. The runoff coefficient, defined as the ratio of runoff volume to rainfall volume, was computed, and effects of such catchment characteristics as land use and imperviousness were investigated. Long-term streamflow records for numerous stations across the country were also analyzed to characterize regional trends.

RECEIVING WATER QUALITY EFFECTS

General

A number of individual NURP projects examined the site-specific impacts of urban runoff on water quality for a variety of beneficial uses and receiving water types. These results provide important information on the extent to which urban runoff constitutes a "problem" as well as "ground truth" measurements against which more generalized techniques can be compared. Methodologies employed in these local studies vary and are described in the individual project reports. Relevant site-specific project results are cited in Chapter 9.

Receiving water impact analyses cannot be readily generalized because there is a high degree of site-specificity to the important factors. The type of beneficial use dictates the pollutants which are of principal concern; the type of water body (e.g., stream, lake, estuary) determines how receiving water quality responds to loads; and physical characteristics (e.g., size, geometry, flows) have a major influence on the magnitude of response to a particular load.

Despite the inherent limitations of a set of generalized receiving water impact analyses, a screening level analysis was considered a necessary element for a nationwide assessment of the general significance of urban runoff in terms of water quality problems, especially adverse effects on beneficial uses. Accordingly, a set of analysis methodologies were adopted and utilized as screening techniques for characterizing water quality effects of urban runoff loads on receiving water bodies. A key requirement was to delineate the severity of water quality problems by quantifying the magnitude, and in the case of intermittent loads, the frequency of occurrence of water quality impacts of significance. These procedures are identified and described briefly below. Significant technical aspects are detailed further in the supplementary NURP report which addresses the receiving water impact analysis methodology.

It was not possible to perform a "National Assessment" in the usual sense of the term. NURP has determined that it is not realistic (if the basis is effect on beneficial use of a water body) to estimate the total number of water quality problem situations in the nation which result from urban stormwater runoff or the cost of control which would ultimately result. The available analysis methods do permit an assessment of a different kind. NURP applied the analysis procedures as a screening type analysis to define the conditions under which problems of different types are likely or unlikely to occur. From the results of these screening analyses, NURP has drawn inferences and made general statements (Chapters 7 and 9) on the significance of urban runoff. Where it has been possible or practical to do so, these general screening analyses were applied to local situations which exist within certain of the individual NURP projects. Comparisons were made between specific water quality effects or broader conclusions relative to problems derived from both local analysis and general screening methods.

Time Scales of Water Quality Impacts

There are three types of water quality impacts associated with urban runoff. The first type is characterized by rapid, short-term changes in water quality during and shortly after storm events. Examples of this water quality impact include periodic dissolved oxygen depressions due to oxidation of contaminants, or short-term increases in the receiving water concentrations of one or more toxic contaminants. These short-term effects are believed to be an important concern and were the prime focus of the NURP analysis.

Long-term water quality impacts, on the other hand, may be caused by contaminants associated with suspended solids that settle in receiving waters and by nutrients which enter receiving water systems with long retention times. In both instances, long-term water quality impacts are caused by increased residence times of pollutants in receiving waters. Other examples of the long-term water quality impacts include depressed dissolved oxygen caused by the oxidation of organics in bottom sediments, biological accumulation of toxics as a result of up-take by organisms in the food chain, and increased lake entrophication as a result of the recycling of nutrients contributed by urban runoff discharges. The long-term water quality impacts of urban runoff are manifested during critical periods normally considered in point source pollution studies, such as summer, low stream flow conditions, and/or during sensitive life cycle stages of organisms. Since long-term water quality impacts occur during normal critical periods, it is necessary to distinguish between the relative contribution of urban runoff and the contribution from other sources, such as treatment plant discharges and other nonpoint sources. A site-specific analysis is required to determine the impact of various types of pollutants during critical periods, and this aspect of urban runoff effects was not addressed in detail in NURP.

A third type of receiving water impact is related to the quantity or physical aspects of flow and includes short-term water quality effects caused by scour and resuspension of pollutants previously deposited in the sediments. This category of impact was not addressed by NURP, in general, although one project provides some information.

As indicated previously, the first type of change in water quality associated with discharges from urban runoff is characterized by short-term degradation during and shortly after storm events. The rainfall process is highly variable in both time and space. The intensity of rainfall at a location can vary from minute to minute and from location to location. Phenomena which are driven by rainfall such as urban runoff and associated pollutant loadings are at least as variable. Short term measurements, on a time scale of minutes, to define rainfall, the runoff flow hydrograph, and concentrations of contaminants (pollutographs) feasibly can be taken at only a rather limited number of locations. These measurements have usually been employed in an attempt to refine or calibrate calculation procedures for estimating runoff flows and loads. Most urban areas contain a network of drainage systems which collect and discharge urban runoff into one or more receiving water bodies. Since the rainfall, runoff, and pollutant loads vary in both time and space, it is impossible to determine by calculation or measurement the very short time scale (minute-to-minute) changes in water quality of a receiving water and assign the changes to specific sources of runoff. Although very short duration exposures (on the order of minutes) to very high concentrations of toxics can produce environmental damage (mortality or sublethal effects) to aquatic organisms, it is likely that exposures on the order of hours have the highest possibility of causing adverse environmental impacts. This results, in part, from the smoothing obtained by mixing numerous sources which have high frequency (short-term) variability.

In view of the above discussion, the time scale used by NURP for analysis of short-term receiving water impacts is the rainfall event time scale which is on the order of hours. To represent the average concentration of pollutants in urban runoff produced during such an event, NURP used the event mean concentration.

Criteria/Standards and Beneficial Use Effects

As discussed in previous chapters, three definitions have been adopted to assess receiving water problems associated with urban runoff; (1) impairment or denial of beneficial use, (2) violation of numerical criteria/standards, and (3) local perception of a problem. The procedures and methods employed in the NURP assessment focus on the first two problem definitions. A framework for identifying target receiving water concentrations associated with the criteria standards and beneficial use problems are provided below. The third problem type, local perception of a problem and degree of concern cannot be addressed by these quantitative procedures.

The analysis methods employed make it possible to project water quality effects caused by intermittent, short-term urban runoff discharges. Where appropriate, these effects are expressed in terms of the frequency at which a pollutant concentration in the water body is equalled or exceeded. However, if the basis for determining the significance of such water quality impacts (and hence the need for control) is taken to be the effect such receiving water concentrations have on the impairment or denial of a specific beneficial use, then it is necessary to go one step further. A basis is required for judging the degree to which a particular water quality impact constitutes an impairment of a beneficial use. With intermittent pollutant discharges, effects are variable and are best expressed in terms of a probability distribution from which estimates can be made of the frequency with which effects of various magnitude occur.

There is a rather broad consensus that existing water quality criteria, and water uses based on such criteria, are most relevant when considered in terms of continuous exposures (ambient conditions). Even where continuous discharges are involved, there has been discussion and debate as to whether a particular criterion should be interpreted as some appropriate "average" condition or a "never-to-exceed" limit. The basic issue is whether the more liberal interpretation will provide acceptable protection to the beneficial use for which the criterion in question has been developed. The only reason such distinctions become an issue is because the practical feasibility or relative economics, or both, are sufficiently different that one is encouraged to question whether the more restrictive interpretation is overly (or even excessively) conservative in terms of providing protection for the associated beneficial use.

The issue (i.e., whether traditional ambient criteria are excessively conservative measures of conditions which provide reasonable assurances of protection for a beneficial use when exceeded only intermittently) is particularly appropriate in the case of urban storm runoff. Analysis of rainfall records for a wide distribution of locations in the nation indicates that, even in the wetter parts of the country, urban runoff events occur only about 10 percent of the time. There are regional and seasonal differenc but typical values for annual average storm characteristics in the east half of the United States are:

	Average (Hours)	Median (Hours)	90th Percentile (Hours)
Storm Duration	6	4.5	15
Interval Between Storm Mid-Points	80	60	200

These estimates are based on results from an analysis of long-term rainf records for 40 cities throughout the country. Median and 90th percenti values are derived from data mean and variance based on a gamma distributi which has been shown to characterize the underlying distribution of st event parameters quite well.

In the semi-arid regions of the western half of the country, average st durations tend to be comparable to the above, but average intervals betwe successive storms increase substantially (two to four fold) and are high seasonal. With urban storm runoff, therefore, one is dealing with polluta discharges which occur over a period of a few hours every several days more or after long dry periods. In advective rivers and streams, the wat mass influenced by urban runoff tends to move downstream in relatively di crete pulses. Because of the variability in the magnitude of the pollut loads from different storm events, only a small percentage of these puls have high pollutant concentrations.

There are currently no formal "wet weather" criteria and, thus, no general accepted way intermittent exposures having time scale characteristics typic of urban runoff can be related to use impairment. In the belief that would be inappropriate to ignore such considerations in a general evaluati of urban runoff, NURP has developed estimates for concentration levels whi result in adverse impacts on beneficial use when exposures occur intermi tently at intervals/durations typical of urban runoff. These "effec levels" were used to interpret the significance of the variable, intermitt water quality impacts of urban runoff. It should be understood that th effects levels do not represent any formal position taken by EPA, but simply the most reasonable yardsticks available to meet the immediate nee of the evaluation of urban runoff. As used in the screening analysis proc dures, alternative values for "effects levels" may be readily substitut when either more accurate estimates can be made, or more (or less) conser tive approaches are indicated in view of the importance of a particular wat body or beneficial use.

Table 5-1 summarizes information on water quality criteria for a number contaminants routinely found in urban storm runoff. The data present include:

- Water quality criteria for substances on EPA's priority pollutant list (45 FR No. 79318, 11/28/80). These criteria provide

TABLE 5-1. SUMMARY OF RECEIVING WATER TARGET CONCENTRATIONS USED IN SCREENING ANALYSIS - TOXIC SUBSTANCES (ALL CONCENTRATIONS IN MICROGRAMS/LITER, µg/ℓ)

Contaminant	Water Hardness mg/l (as Ca CO_3)	Freshwater Aquatic Life		Saltwater Aquatic Life		Human Ingestion	Estimated Effect Level For Intermittent Exposure	
		24 Hour	Max	24 Hour	Max	(1)	Thresh-hold	Significant Mortality
Copper	50	5.6	12	4.0	23	NP	20	50 - 90
	100	5.6	22	4.0	23		35	90 - 150
	200	5.6	42	4.0	23		80	120 - 350
	300	5.6	62	4.0	23		115	265 - 500
Zinc	50	47	180	58	170	NP	380	870 - 3,200
	100	47	321	58	170		680	1,550 - 4,500
	200	47	520	58	170		1,200	2,750 - 8,000
	300	47	800	58	170		1,700	3,850 - 11,000
Lead	50	0.75	74				150	350 - 3,200
	100	3.8	172	(25)	(670)	50.0	360	820 - 7,500
	200	12.5	400				850	1,950 - 17,850
	300	50.0	660	(C)	(A)		1,400	3,100 - 29,000
Chrome (+3)	50		2,200					
	100	(44)	4,700	N.P.	(10,300)	170.00	8,650	
	300	(C)	15,000		(A)			
Chrome (+6)	-	0.29	21.0	18	1260	50.0		
Cadmium	50	0.01	1.5				3	7 - 160
	100	0.02	3.0	4.5	59.0	10	6.6	15 - 350
	300	0.08	9.6				20	45 - 1,070
Nickel	50	56	1,090					
	100	96	1,800	7.1	140.0	13.4		
	300	220	4,250					

<u>NOTES:</u>

- NF = No criteria proposed.
- Some toxic criteria are related to Total Hardness of receiving water. Where this applies, several values are shown. Other values may be calculated from equations presented in EPA's Criteria Document (Federal Register, 45,231, November 28, 1980). Where a single value is shown, water hardness does not influence toxic criteria.
- Concentration values shown within parentheses ( ) are not formal criteria values. They reflect either chronic (C) or acute (A) toxicity concentrations which the EPA toxic criteria document indicated have been observed. Values of this type were reported where the data base was insufficient (according to the formally adopted guidelines which were used in developing the criteria) for EPA to develop 24 hour and Max values.
- Note (1): The "Human Ingestion" criteria developed by the EPA Toxic Criteria documents are indicated to relate to ambient receiving water quality. The Drinking Water Criteria relate to finished water quality at the point of delivery for consumption.
- Estimated Effects levels reflect estimates of the concentration levels which would impair beneficial uses under the kind of exposure conditions which would be produced by Urban Runoff. They are an estimate of the relationship between continuous exposure and intermittent, short duration exposures (several hours once every several days). Threshold concentrations are those estimated to cause mortality of the most sensitive individual of the most sensitive species.

  Significant Mortality concentrations are shown as a range which reflects 50 percent of the most sensitive species and mortality of the most sensitive individual of the 25th percentile species sensitivity.

an extensive set of numerical values derived from bioassay studies.

- Estimates of "effects levels" which are suggested by NURP analysis to be relevant for the intermittent exposures characteristic of urban runoff.

By incorporating the numerical values for EPA's ambient water quality criteria and the concentration levels suggested by NURP for intermittent effects in the same table (or on the same graph in Chapter 7), a convenient, concise comparison is provided of the practical implications of applying one or the other as the yardstick for judging the protection or impairment of water use. The two sets of numerical values thus provide measures for two of the three options for defining a problem: violation of criteria or actual impairment of a beneficial use.

Comparison of the pollutant concentrations in urban runoff showing the frequency and magnitude of exceedance of ambient criteria and intermittent effects levels provides a qualitative sense of the control requirements (and implications regarding costs) attendant on the adoption of either problem definition as the operative one.

Rivers and Streams

The approach adopted to quantify the water quality effects of urban runoff for rivers and streams focuses on the inherent variability of the runoff process. What occurs during an individual storm event is considered secondary to the overall effect of a continuous spectrum of storms from very small to very large. Of basic concern is the probability of occurrence of water quality effects of some relevant magnitude.

To consider the intermittent and variable nature of urban runoff, a stochastic approach was adopted. The method involves a direct calculation of receiving water quality statistics using the statistical properties of the urban runoff quality and other relevant variables. The approach uses a relatively simple model of the physical behavior of the stream or river (as compared to many of the deterministic simulation models). The results are therefore an approximation, but appropriate as a screening tool.

The theoretical basis of the technique is quite powerful as it permits the stochastic nature of runoff process to be explicitly considered. Application is relatively straightforward, and the procedure is relevant to a wide variety of cases. These attributes are particularly advantageous given the national scope of the NURP assessment. The details of the stochastic method are summarized and presented below.

Figure 5-2 contains an idealized representation of urban runoff discharges entering a stream. The discharges usually enter the stream at several locations but are considered here to be adequately represented by an equivalent discharge flow which enters the system at a single point.

Receiving water concentration (CO) is the resulting concentration after complete mixing of the runoff and stream flows and is interpreted as the mean

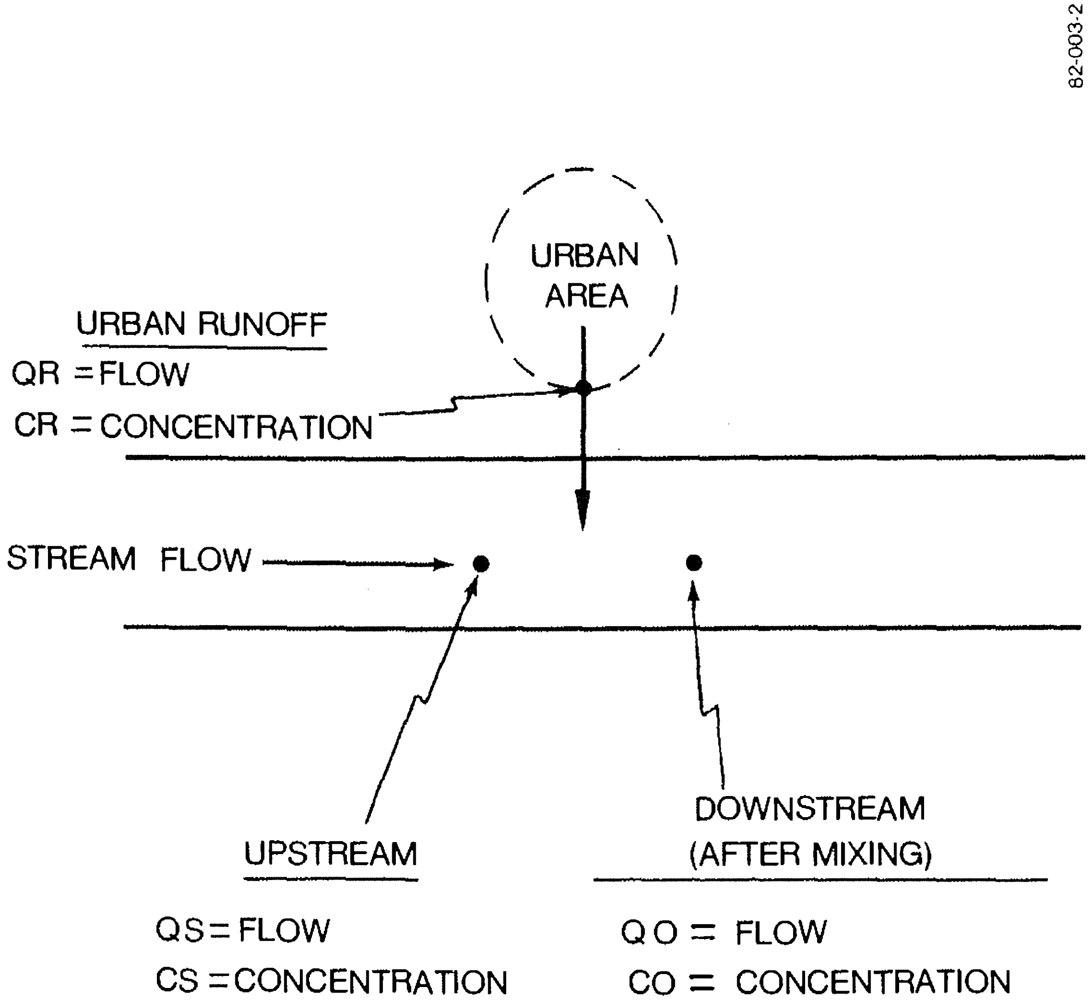


Figure 5-2. Idealized Representation of Urban Runoff Discharges Entering a Stream

stream concentration just downstream of all of the discharges as shown in Figure 5-2. The four input variables considered are:

- Urban runoff flow (QR)
- Urban runoff concentration (CR)
- Stream flow (QS)
- Stream concentration (CS)

Each is considered to be a stochastic random variable, which together combine to determine downstream flow and concentration. In addition, all variables are assumed to be independent, except urban runoff flow and streamflow where correlation effects can be incorporated as warranted.

An essential condition of the current computational structure is that each of the four variables which contribute to downstream receiving water quality can be adequately represented by a lognormal probability distribution; from analysis of data or other estimating procedures, the statistical properties of each of the input parameter distributions are defined. Examination of a reasonably broad cross-section of data indicates that lognormal probability distributions can adequately represent discharges from the rainfall/runoff process, the concentration of contaminants in the discharge, and the daily flow record of many rivers and streams, particularly for a national scale screening approach. It should be noted, however, that modifications of the computation techniques could be made to accommodate the use of other distributions (e.g., gamma, exponential) for some or all of the parameters.

The analysis procedure is described in more detail in the supplementary NURP report cited earlier. It essentially operates as follows:

- Downstream Concentrations. Stream concentrations of a pollutant are considered to result from the combination of upstream flow at background concentration and runoff flow at its concentration. Variations in stream concentrations below the urban runoff discharge result from variations in each of these inputs; the most significant source of variation being whether or not an event is occurring (i.e., whether runoff flows and loads are present). Stream flows must be considered because of the major effect of dilution on the resulting concentrations. Upstream concentrations can, however, be set at zero for the calculations; in which case, the result obtained is the exclusive effect of urban runoff discharges, and not the overall expected stream concentration. Effects of urban runoff can be evaluated by considering only the periods during which runoff occurs.

- Parameter Estimates. Estimates for runoff flows and concentrations are developed from information derived from the NURP monitoring programs. Information on stream flow can be obtained from analysis of local stream gage records. Upstream concentrations tend to be very site-specific; for this reason, the screening analysis calculated only the effect of urban runoff discharges.

- Statistical Calculations. From the statistical properties (specifically, the means and standard deviations) of the flows and concentrations, properties of the dilution ratio can be defined, and the statistical properties of the resulting instream concentrations are calculated directly. The frequency with which any particular target concentration is exceeded during wet weather can be calculated from the statistical properties of stream concentration, using formulas or scaled directly from a standard plot of cumulative (lognormal) probability distributions.

  The frequency with which the target concentration is exceeded during all periods -- wet and dry -- is simply the product of the wet weather frequency and the probability (frequency) that it is raining. The probability that it is raining at any time is defined by the ratio of mean storm duration to mean interstorm period, derived from the rainfall statistics.

$$\frac{D = \text{mean duration of storms}}{\Delta = \text{mean interval between storm midpoints}} = \text{fraction of time it is wet}$$

- Mean Recurrence Interval. In the presentation of results in Chapter 7, the probability distribution of event mean stream concentrations of an urban runoff pollutant during runoff periods is converted to a Mean Recurrence Interval (MRI) as a device to assist in the interpretation of results. The recurrence interval is defined as the reciprocal of probability. Because the basic calculation is based on storm events, this definition yields the overall average number of storms between specific event occurrences. Event recurrence is converted to what is believed to be a more meaningful time recurrence by dividing by the average number of storms per year, which is developed from analysis of rainfall records and defined as

  $$\frac{\text{Hours/year} = 8760}{\text{Average interval between storm midpoints}} = \text{average \# storms per year}$$

  As an example of the MRI calculations consider a stream concentration which has an exceedance probability of 1.0 percent (Pr = 0.01)

  $$\text{Recurrence Interval} = 1/\text{Pr} = 1/0.01 = 100$$

  The analysis is in terms of storm events, not time. Therefore this result is interpreted as one storm in every 100 events on average, will produce concentrations greater than the selected value. For an area where rainfall patterns produce an average of 100 storms per year, the average recurrence interval expressed in time units rather than events, is:

  $$\begin{array}{l}\text{Recurrence} \\ \text{Interval} \\ \text{(time)}\end{array} = \frac{\text{event recurrence}}{\text{\# events/year}} = \frac{100 \text{ events}}{100 \text{ events/year}} = 1 \text{ year}$$

Currently, the primary use of the above procedure is as a screening tool in which approximate results and relative values are of interest. In this regard, NURP believes the Mean Recurrence Interval is a very useful definition. It should be interpreted as the long-term average interval between occurrences.

When results of this nature are interpreted, the following factors should be noted. The recurrence intervals of most interest relate to very low probabilities of occurrence. The tails of distributions may have appreciable uncertainty, and in the natural water systems, distributions may be lognormal over the bulk of the range but may deviate from the assigned distribution at the extremes. Computed stream concentrations at long recurrence intervals are likely to be conservative, that is, overstated because there are likely to be practical upper limits for runoff concentrations and lower limits to stream flow.

It also should be noted that serial correlations of streamflows or the tendency of wet and dry years to occur in clusters, though not a general behavior, may be significant in some cases. This situation would cause the average one year condition, for example, not to repeat itself every year but rather to occur several times per year, at intervals greater than one year.

Other Receiving Waters

Other receiving waters of general interest in assessing urban runoff effects include lakes, estuaries, embayments, and coastal zones. The methods adopted for lakes are briefly described below. The other receiving waters generally require site-specific and often complex analysis techniques (numerical methods, multi-dimensional modeling, etc.). Given this, a generalized screening-level assessment was not believed to be appropriate for this report. A number of the individual NURP projects consider these coastal water bodies and report on the specific methods adopted and results obtained.

For lake eutrophication problems, the time scale for analysis is considerably longer than the short (event scale) periods necessary for estuaries and rivers. For this case, annual average loads were used in a steady-state analysis performed using the type of empirical model advanced by Vollenweider and others. The EMC data developed from NURP monitoring programs can be readily converted to annual loads directly from annual flows or indirectly based on annual rainfall.

For total phosphorus, typically the limiting nutrient of concern, average concentrations are calculated using the following formula:

$$P = \frac{W'}{H/\tau \cdot \upsilon_s} \cdot 1000$$

The input values include pollutant mass loading (W'), lake physical characteristics of depth (H) and residence time (τ) and reaction rate coefficients (υ_s). The relative contribution of all load sources to lake total P concentrations can be defined by solving this equation for each of the sources. By comparing results in terms of lake concentrations for initial conditions (no control), and then modifying loads to reflect various levels of control, alternative control operations can be compared directly to effect on lake water quality.

Some judgement is involved in defining acceptable lake water quality concentrations, which depend in part on water use and on regional norms and expectations.

EVALUATION OF CONTROLS

General

The evaluation of controls has two elements: (a) characterizing the controls' performance capabilities and (b) defining costs. For this report, only the characterization of performance is emphasized; cost relationships are addressed to a more limited extent. EPA's Economic Analyses Staff, Office of Analysis and Evaluation, has prepared the following report under contract:

> "Collection of Economic Data from Nationwide Urban Runoff Program Projects," EPA Office of Water Regulations and Standards, April 7, 1982.

This report, issued at an early stage in the NURP program, assembled and analyzed cost information on potential control measures. Useful cost information for detention basins was developed by the Washington, D.C. area NURP project and is discussed further in Chapter 8.

Detention Basins

There are a number of procedures which can be adopted for evaluation of detention basin control devices. Procedures adopted by individual NURP projects are described in project reports. The procedure adopted by NURP to generalize the analysis of detention basins, and provide a planning level basis for estimating capabilities and requirements, is detailed in a detention basin handbook being issued by NURP as a supplementary report.

Results presented in Chapter 8 provide a summary of observed performance characteristics of the detention devices monitored under the NURP program and a projection of long-term performance expected on the basis of basin size and regional rainfall characteristics. The latter result is based on the probabalistic analysis methodology described in the supplementary report. Planning level cost estimates for control of urban runoff using this technique are also presented.

Street Sweeping

A number of the individual NURP projects adopted street sweeping as a principal subject of investigation. Procedures and results are described in individual project reports and are consolidated and summarized in Chapter 8. The adopted procedure and detailed results are presented in the supplementary NURP report, which was cited earlier.

Recharge Devices

Recharge devices include impoundments or other structures such as pits, trenches, retention basins, percolating catch basins, in-line percolation chambers or perforated pipes, which function by intercepting some portion of storm runoff and allowing it to percolate into the ground.

One of the basic questions which arises when controls of this type are considered is whether the percolation encouraged will produce undesirable degradation of groundwater quality. This aspect was examined by two NURP projects, and is discussed in Chapter 7 of this report.

Evaluation of percolating basins of any size is readily accomplished using the standard storage/treatment routines of stormwater models such as STORM or SWMM. In such cases the local soil permeability (the percolation rate) is applied as the treatment rate. In addition, statistical analysis procedures described in "A Statistical Method for the Assessment of Urban Stormwater" (EPA 440/3-79-023, May 1979) have been developed. A probabalistic analysis methodology adapted from the latter approach has been used by NURP to provide estimates of performance capabilities of recharge devices, which are presented in Chapter 8. A detailed discussion of the methodology is provided in the supplementary NURP report on detention/recharge devices cited earlier.

CHAPTER 6
CHARACTERISTICS OF URBAN RUNOFF

INTRODUCTION

This chapter presents a condensed summary of data developed by the individual NURP projects together with analysis results and interpretations based on the aggregated data from all projects.

Both the format for the summaries and the evaluations performed were selected to best serve the NURP objective of developing a national perspective. The results presented do not exhaust the useful information and insights which can be derived from the extensive data base that has been assembled. Individual project reports and a substantial number of articles published in a variety of technical journals independently examine specific aspects of urban runoff, often from the perspective of local issues.

Comprehensive tabulations of NURP data have been assembled and will be made available to interested parties for use in local planning or continuing research or engineering activities. As noted below, only a portion of the entire data base generated by the 28 NURP projects has been made generally accessible at this time. Under an ongoing effort, the entire data base is being subjected to final quality assurance checks and placed into a separate file, copies of which will be made available to interested parties upon request. In addition, a summary of the event averaged data, used for the analyses presented in this chapter, is reproduced in a Data Appendix issued with this report.

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations and mass loadings. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provide a basis for identifying patterns of similarities or differences and testing for their significance. To meet the objective of maximizing the degree of transferability of urban runoff data, the NURP approach involved covering a spectrum of regional and land use characteristics, requiring consistent quality assurance programs among all projects, and encouraging each of the projects to obtain data for a statistically significant number of storm events at a site.

The portion of the NURP data base used in the characterization of urban runoff presented in this section excludes monitoring sites which are downstream of devices which modify runoff (e.g., detention basins). The data base of acceptable "loading sites" consists of 81 sites in 22 different cities, and includes more than 2300 separate storm events. The actual number of events for specific pollutants varies, and is somewhat smaller than the total number of storms monitored because all pollutants were not measured for all storms at all sites.

Data summaries and analyses were performed using storm event average values; within-event fluctuations are not considered. An event mean concentration (EMC) for pollutants of interest has been determined for each monitored storm. Preliminary results presented in an earlier NURP report were based on analysis of "pooled" EMCs which were available at the time regardless of site. This provided a useful start, a reference for individual NURP project activities, and established the order of magnitude of concentrations of various pollutants in urban runoff. With the substantially larger data set now available, a more useful approach is possible. For the analyses and comparisons presented in this chapter, the storm event average data were aggregated by site to describe site characteristics. Site mean values were then aggregated or compared.

Summaries, comparisons, and evaluations were restricted to concentrations and runoff-rainfall ratios. Although loading data (Kg/Ha) are also available for all monitored storms, they have not been used in comparisons for the following reason. Mass load is very strongly influenced by the size (volume) of the monitored storm event. Monitored events usually represent a very small sample of all storms for an area, are generally biased toward larger events, and are different from site to site. Therefore comparisons between sites or locations using loading data derived from monitored storms are quite likely to present a distorted picture.

Event mean concentrations, on the other hand, have been determined to be essentially uncorrelated with runoff volume, as discussed further later in this chapter. Site comparisons can be made with high confidence levels using concentration data, and the most meaningful load comparisons would be those developed by using concentrations, area rainfall volumes, and runoff-rainfall relationships.

Separate summaries of results are provided below for standard pollutants, coliform bacteria, pollutant loads, and priority pollutants.

LOGNORMALITY

As was pointed out in Chapter 5, the key to the mathematical tractability of the NURP methodologies is that the data can be well represented by a known probability density function (pdf). There are actually two issues involved; (1) the adequacy of the assumed pdf in terms of representing the essential characteristics of the data set in question, and (2) the estimation of the parameters of the population pdf that the observed data set is presumed to represent. These will be discussed in turn.

Adequacy of Representation

One can fit a polynomial of order (n-1) exactly to any data set of n numerical items, but its utility in predicting the probability of realizing a given value on a subsequent trial (either within or outside the original data set, i.e., the interpolation or extrapolation problem) is likely to be very limited. The number of parameters involved and the need to investigate its properties on an individual basis are further deterrents to such a practice. There is no dearth of pdf's that have been the subject of intensive investigation. However, the selection of a pdf is an objective choice that is best made based on professional knowledge of the processes deemed important to the desired probability model and the use to be made of it. For example, if the data are known to result from the product of many small effects, their logs will be the sum of the logs of these effects. By appeal to the central limit theorem, it is known that this sum is asymptotically normal and, therefore, that the data will be lognormally distributed. Based upon such natural expectations and prior experience (of a growing body of other workers in the field as well), the lognormal pdf was chosen. The fact that the variables of interest can assume only positive values with a finite mean and a finite non-zero lower bound (even in a standardized form) leads to the rejection of any pdf defined over the entire real domain, such as the normal distribution for instance.

There are a number of statistical procedures for evaluating the normality of a complete sample; at least nine can be found in the current literature. Some are origin and scale invariant (e.g., the Shapiro-Wilk, standard third moment, standard fourth moment, and studentized range) and thus are appropriate for testing the composite hypothesis of normality. Others require the complete specification of the null distribution (e.g., Kolmogorov-Smirnoff, Cramer-Von Mises, weighted Cramer-Von Mises, modified Kolmogorov-Smirnoff-D, and chi-squared), and typically, the mean and variance of the specified normal hypothesis are taken to be the known mean and variance of the complete sample. Some procedures (e.g., chi-squared) utilize the specified theoretical pdf, while others (e.g., the modified Kolmogorov-Smirnoff D-test) utilize the cumulative frequency distribution.

In testing for normality (in the logorithmic domain in our case), one specifies the level of significance (α), i.e., the probability of rejecting the null hypothesis when it is in fact true (Type I error). The choice of α requires tempered judgement, however. The power of a test (β) is the probability of rejecting the null hypothesis when it is in fact false. The probability of accepting the null hypothesis when it is in fact false (Type II error) is $1-\beta$. For a given sample size and test, fixing a value for α also determines a value for β (i.e., they are not independent). The smaller the α level, the less powerful the test. Thus one is forced to make a trade-off between the consequences of a Type I or II error when selecting an α value.

The median EMC values for each constituent at each site were calculated, and these sample sets were examined for lognormality using the Kolmogorov-Smirnoff D test. The α levels for TSS, Total P, TKN, Total Pb, and Total Zn were all greater than 0.15, indicating a high power level. In other words, these sample sets are extremely well represented by a lognormal distribution. For COD and nitrate + nitrite the α levels were 0.059 and 0.057 respectively, indicating a lower power level but suggesting that even for these constituents the lognormal distribution quite well describes the data. Because BOD, Soluble P, and Total Cu were measured at fewer than half of the project sites, the D-test could not meaningfully be used (i.e., n is too small). Stated another way, at the $\alpha = 0.05$ level, the hypothesis that the samples were drawn from a population with a lognormal distribution cannot be rejected for any of the constituents examined.

Turning to the individual sites, there were very few instances where n was large enough to support the meaningful use of the D-test, and so a different approach for examining the appropriateness of the lognormal distribution was used. Essentially it consisted of examining the cumulative frequency distributions (in log space) and third and fourth moment based statistics for adequacy of representation. Taking into account detection limit phenomenon, uncertainties associated with sampling and analytical determination errors (especially at low concentration levels), and an occasional outlier, well over 90 percent of the constituent distribution at all NURP sites were quite well represented by the lognormal distribution. For the few remaining data sets, the lognormal distribution, although not perfect, was adequate for our purposes.

Estimation of Parameters

As noted in Chapter 5, the lognormal distribution is completely specified by two parameters, the mean and the coefficient of variation. The values of these two parameters as calculated from the sample data set are the best estimates of the parameters of the underlying population in the maximum likelihood sense. For this reason, they were used in the NURP analysis. However, due to the existence of detection limit problems and sampling/analytical determination errors, the reasonableness of this decision was examined in general for all constituents and in great detail for Total Cu, the results of which will be described below.

For each of the 49 NURP sites where at least five Total Cu determinations were made, data were plotted (in logarithmic form) on probability paper. A line of best fit was drawn in, using professional judgement where detection limit or outlier problems existed, and the values of the median and standard deviation were read from the plot and converted into arithmetic space. These were then compared with those values calculated from the data themselves. One example is given in Figure 6-1 (the 116th and Claude Street site in Denver). Here the median and coefficient of variation from the plot (20 μg/l and 0.75) compare very well with those calculated directly from the data (22 μg/l and 0.74).

An example of an outlier plot is given in Figure 6-2 (the strip commercial site in Knoxville, TN). The one very low value (1 μg/l) is one-twentieth the typical detection limit (20 μg/l) and clearly does not belong to the same distribution that the other values do. Ignoring it, a very good fit exists and the parameters of the plot are 30 μg/l and 0.37 for the median and coefficient of variation as compared with the 25 μg/l and 1.35 values calculated from the data. The difference in medians is not too great, but the difference in coefficients of variation is quite large (over a factor of 3.5). This means that the upper end of the tail of the pdf is quite overestimated by the parameters estimated from the data and, consequently, that

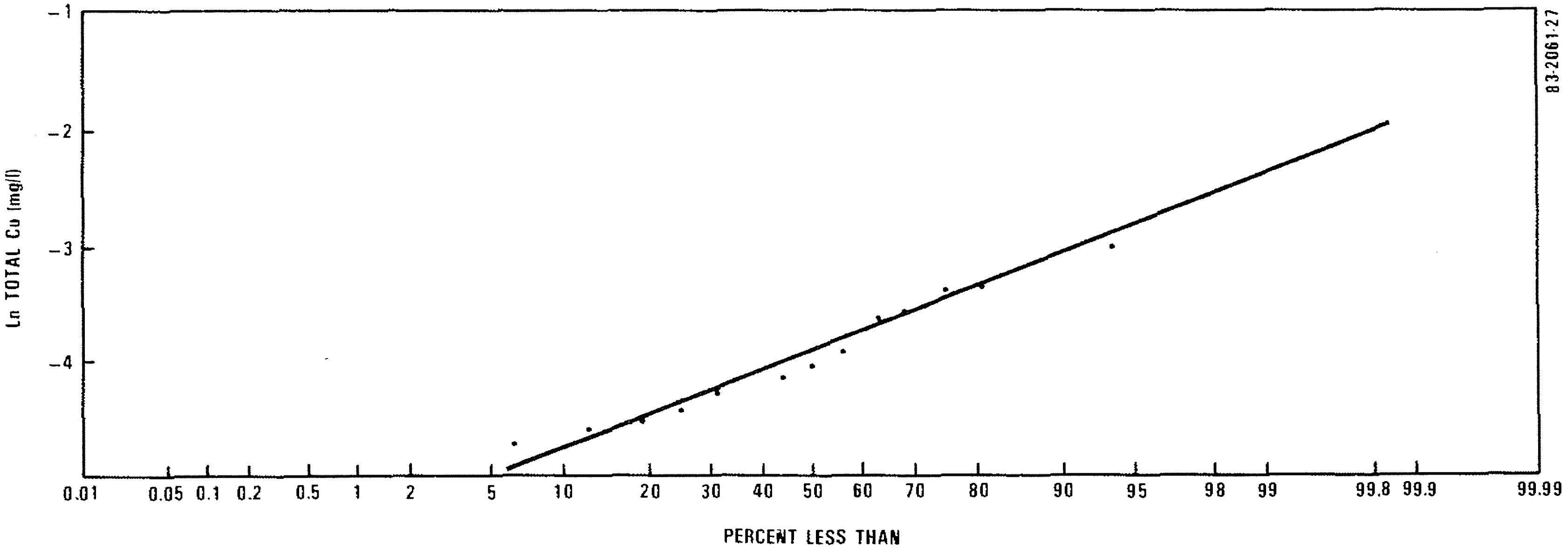


Figure 6-1. Cumulative Probability Distribution of Total Cu at C01 116 and Claude Site

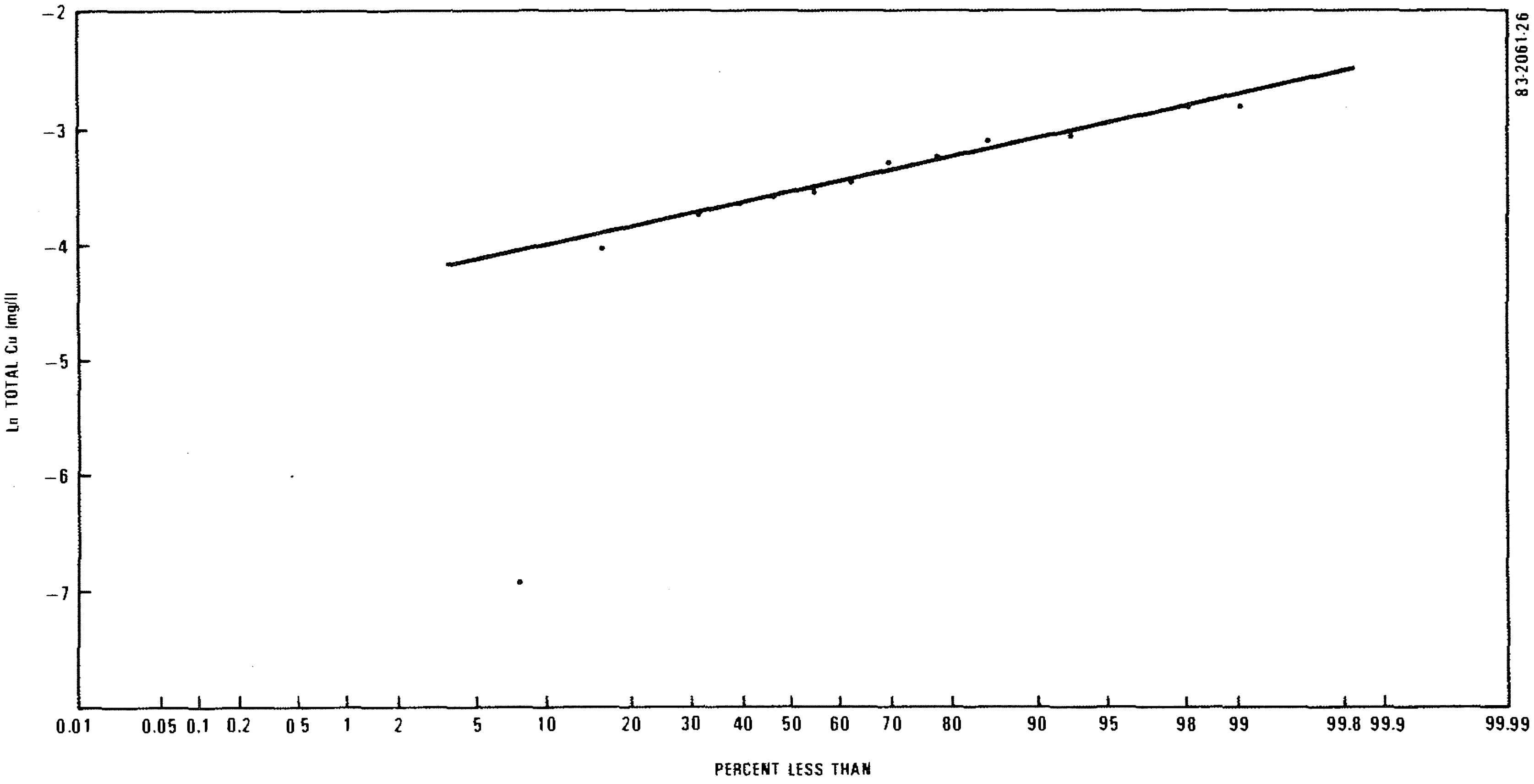


Figure 6-2. Cumulative Probability Distribution of Total Cu at TN1 SC Site

subsequent analyses will be extremely conservative, i.e., higher values of copper concentrations will occur less often than predicted. In general, the effect of an outlier is to increase or decrease the estimate of the median, depending upon whether the outlier is high or low, and to increase the estimate of the coefficient of variation as compared to those obtained from the remainder of the data.

An example of a detection limit problem is given in Figure 6-3, the plot of copper data of the Durham, NH parking lot site. Although only four points appear on the plot, actually n = 31, meaning that 27 points are represented by the first plotting position (90.6 percent). These values (all reported at 100 μg/l) are presumably the detection limit of the analytical laboratory. Of course in reality not all 27 values are 100 μg/l; they are simply equal to or less than this value. Fitting a line to the remaining four data points merely assigns appropriate plotting positions to these "less than" values. The estimates of the median and coefficient of variation from the plot are 63 μg/l and 0.36 respectively, as compared to the estimates from the data of 103 μg/l and 0.13. In this case, the latter significantly overestimates the median and significantly underestimates the coefficient of variation, and this is the general effect when a detection limit problem is present. In terms of the effect on prediction of rare occurrences of high copper levels (the upper tail of the pdf) these effects are somewhat counterbalancing. To the extent that the increase in the coefficient of variation dominates, the results of subsequent analyses will not be conservative, since larger concentrations will occur somewhat more frequently than would be predicted.

When the results of this exercise are compared for all 49 sites, the median as estimated from the plot was found to be higher than that estimated from all the data at only six sites, was equal at five sites, and was less at 38 sites. However, at only three sites was the change greater than 10 μg/l. Considering the population of all copper sites, the average median is 47 μg/l and the coefficient of variation is 0.84 when the estimates are based on all the data. If the estimates are based upon the plots, the respective values are 42 μg/l and 0.24 respectively. The significant reduction in the coefficient of variation in this latter case deserves comment, because it suggests that much of the apparent variability from site to site is due to data artifacts such as detection limit phenomena, outliers, and/or sampling/analytical errors. Similar comparisons of the coefficients of variation for each site showed increases at 21 sites, 6 unchanged, and decreases at 22 sites. Considering all sites, the average coefficient of variation is essentially unchanged (0.61 vs 0.63) as is its variability (0.47 vs 0.49).

Based on the results of the analyses which have been performed, the NURP findings are as follows:

- Lognormal distributions adequately represent both the storm-to-storm variations in pollutant EMC's at an urban site, and site-to-site variations in the median EMC's which characterize individual sites.

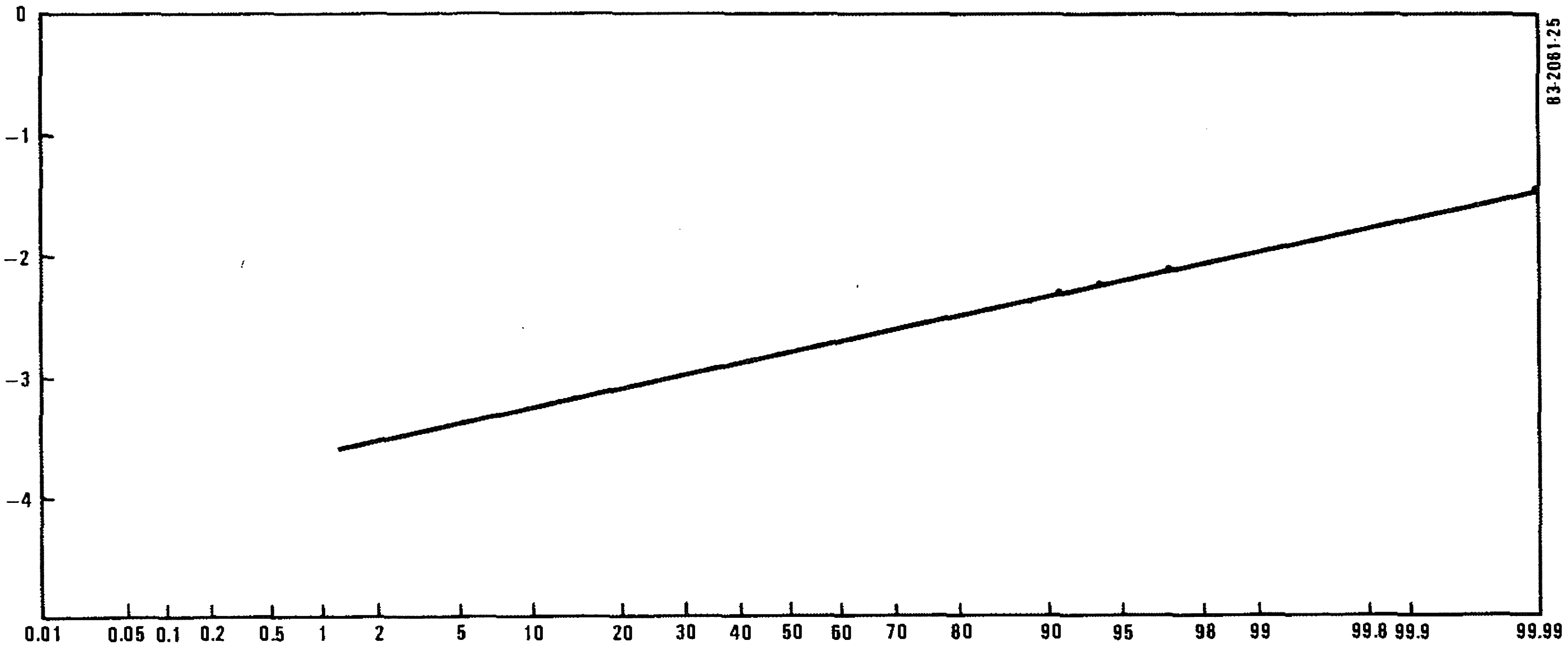


Figure 6-3. Cumulative Probability Distribution
of Total Cu at NH1 Pkg. Site

- More detailed analysis to compensate for sampling errors (e.g., outliers and detection limit problems) would result in some adjustments in the statistical parameters tabulated later on in this chapter. The data summaries presented are based on statistics computed directly from the log transforms of the data.

- Such adjustments would not have any significant effect on overall results nor on the general conclusions reached. However, at a small percentage of sites, the parameter estimates for some pollutants would change significantly.

- In general, estimates of the site median EMC would be least affected; estimates of variability more so. It is likely that the very high or very low values for coefficient of variation (storm-to-storm variability) would be adjusted to more central values.

STANDARD POLLUTANTS

This grouping includes the following pollutants:

TSS - Total Suspended Solids
BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TP - Total Phosphorus (as P)
SP - Soluble Phosphorus (as P)
TKN - Total Kjeldahl Nitrogen (as N)
NO_{2+3}-N - Nitrite + Nitrate (as N)
Cu - Total Copper
Pb - Total Lead
Zn - Total Zinc

It includes pollutants of general interest which are usually examined in other studies (both point and nonpoint sources) and includes representatives of important categories of pollutants, namely solids, oxygen consuming constituents, nutrients, and heavy metals.

Condensed Data Summary

Tables 6-1 through 6-10 summarize the NURP results for these pollutants. Monitoring sites are grouped in each of the tables according to dominant land use. Broad categories have been used; residential, commercial, industrial, urban open/nonurban (other), and mixed, this latter category being used for sites which had no predominant land use. It should be noted that the industrial category does not include heavy industry sites, but more typically reflects an industrial park type of use. As a result, most of these sites are more closely related to a commercial use than to the typical image called up by the term industrial site. For subsequent comparisons, the data shown in Tables 6-1 through 6-10 for the commercial and industrial sites, are combined and designated as commercial land use.

TABLE 6-1. SITE MEAN TSS EMCs (mg/ℓ)

Residential

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	11	17	41	14	343	1.64	265	182-385
2	CO1 Cherry	100	57	24	18	14	160	.98	129	87-190
3	CO1 116 & Clayton	100	167	14	29	16	365	1.17	232	154-349
4	DC1 Dufief	100	17	-	-	8	56	1.02	39	21-74
5	DC1 Carriage	100	68	21	37	49	175	1.47	98	76-127
6	DC1 Stratton	100	8	-	-	31	54	1.01	38	30-49
7	IL1 Joan N	100	54	18	19	51	215	1.36	127	96-155
8	KS1 Overton	100	58	8	38	15	2216	1.42	1243	766-2017
9	MA2 Hemlock	100	50	5	18	5	78	2.49	29	8-111
10	MD1 Dalton Hill	100	14	10	51	19	74	1.32	45	30-68
11	MD1 Homeland	100	23	9	29	13	50	1.05	26	15-46
12	MD1 Mt Wash	100	17	12	29	20	95	1.17	62	44-89
13	MD1 Res Hill	100	10	35	76	13	123	1.05	85	57-125
14	NY1 Carll's R.	100	71	15	20	23	42	.65	32	25-42
15	NH1 [illegible]	100	-	-	-	9	65	.53	57	41-81
16	NC3 Franklin	100	160	5	22	30	114	1.15	98	57-150
17	NY3 E. Roch.	100	346	18	18	7	294	1.12	196	101-380
18	TX1 Rollingwood	100	60	3	21	9	227	1.12	150	85-261
19	WA1 Surrey	100	95	9	29	117	111	.51	101	94-108
20	WI1 Burbank	100	61	15	50	45	266	.44	247	219-278
21	WI1 Hastings	100	13	37	51	35	170	.62	141	117-169
22	FL1 Kryne Apts	100	9	-	6	12	51	1.23	34	21-56
23	TX1 Hart	99	378	9	40	35	155	1.51	82	49-137
24	WI1 Lincoln	97	36	18	57	23	251	.59	206	165-258
25	TN1 R7	96	29	4	13	31	61	1.13	42	25-68
26	DC1 Westleigh	93	41	2	21	41	75	1.45	43	33-57
27	CO1 SC - 92nd	92	63	-	37	11	156	.94	119	83-171
28	IL1 John S.	93	59	19	18	49	248	1.50	176	106-278
29	TN1 F1	91	109	21	33	11	631	.72	492	345-704
30	WA1 Lake Hills	91	102	12	37	126	127	.80	100	90-110
31	IL1 Maple S.	90	28	22	13	59	111	1.08	211	174-256
32	FL1 Charter Hlg	99	42	-	16	12	33	1.76	10	9-10
33	DC1 Fairidge	88	19	-	14	47	25	1.55	14	10-18
34	CO1 Asbury	88	127	9	22	9	493	.92	380	244-593
35	IL2 Comb Inlets	86	528	8	17	27	250	.75	200	161-249
36	MA1 Locust	95	154	31	16	6	257	1.75	128	48-339
37	NC1 #1033	84	374	6	27	66	291	1.92	135	104-174
38	MA1 Jordan	79	110	10	21	9	79	1.74	39	19-81
39	DC1 Stedwick	78	23	15	34	47	54	1.02	38	31-47

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	COV	Median	90% Confidence Limits
1	CA1 Seaview	100	632	-	-	11	738	.63	551	485-628
2	CO1 Rooney Gulch	100	405	0	3	7	481	.63	341	223-521
3	NY2 Zourwell	100	28,416	-	4	11	154	.92	91	74-113
4	NY2 English Br	98	5,748	-	1	29	17	2.45	6	4-10
5	NY2 West Br	97	6,339	-	3	28	64	2.77	22	14-35
6	NY3 Thomas Cr	91	17,728	3	11	9	63	.74	51	34-77
7	NY3 Traver Cr	96	2,103	-	6	5	33	.37	26	14-50
8	NY2 Sheriff Dock	80	552	-	7	32	178	2.35	149	99-224

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	COV	Median	90% Confidence Limits
1	KS1 Noland	-	30	3	69	16	290	.91	209	145-301
2	MD1 Hampden	-	17	[illegible]	72	20	52	1.62	31	24-41
3	IL1 [illegible] N	-	12	2	58	58	283	1.61	179	145-229
4	MI1 Waverly	-	10	11	68	15	85	1.28	52	39-69
5	TN1 SC	-	187	3	43	12	71	1.07	45	31-64
6	WI1 Wood Ctr	-	45	12	51	37	363	.74	297	255-351
7	MA1 Rt 9	-	378	7	25	7	151	2.05	154	[illegible]
8	MA1 Convent	-	180	1	33	6	59	1.53	30	13-63
9	MI3 Grand P Gt	-	453	5	36	21	159	1.76	99	85-114
10	MI2 Pitt AA-S	-	2001	2	21	6	46	.77	[illegible]	[illegible]
11	MI2 Cedar	-	76	-	5	27	293	1.92	139	99-202
12	MA1 Anna	-	601	9	12	6	150	2.45	[illegible]	13-156
13	MI1 Pitt AA-N	-	2871	7	26	6	68	.47	61	42-88
14	MI1 Grace N	-	164	5	25	24	172	.95	131	101-171
15	MI3 Swift Run	-	1207	3	4	5	56	.53	59	26-124
16	SD1 Meade	-	2030	-	-	15	3091	1.39	1804	1126-2890
17	CA1 Knox	-	1542	12	-	16	283	1.12	171	115-255
18	FL1 N. [illegible]	-	30	-	13	15	82	1.99	21	11-39
19	FL1 Wilder	-	194	-	97	10	43	.71	27	20-37
20	CO1 North Ave	-	69	9	50	32	402	.96	334	247-451

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	266	1.89	122	81-183
1	NC1 1013 (CBD)	100	23	0	69	60	163	1.15	87	68-111
3	MI3 Southgate	100	179	2	21	12	141	.76	112	79-159
4	WI1 Post Office	100	12	0	100	58	212	.90	161	131-197
5	NH1 Pkg Lot	100	1	0	91	12	24	1.68	16	[illegible]
6	TN1 CBD	100	26	0	99	15	171	.73	99	74-132
7	WI1 Rustler	100	12	0	100	42	202	.68	167	142-196
8	KS1 SC Metcalf	96	58	-	97	12	80	2.12	35	21-55
9	FL1 Norma Pk	91	47	-	85	17	22	1.13	14	9-22
10	WI1 State Fair	74	29	10	77	29	412	.97	296	242-362

Industrial

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TSS Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	15	0	69	5	48	.81	18	14-23
2	MI1 Indus Drain	100	63	0	64	18	92	.87	71	53-95
1	KS1 Lenexa	56	72	-	34	18	102	1.31	63	40-97
4	MI1 Grace S.	52	15	5	19	20	188	.94	137	101-186

TABLE 6-2. SITE MEAN BOD EMCs (mg/ℓ)

Residential

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	CO1 Big Dry Cr	100	71	19	41	0	-	-	-	-
2	CO1 Cherry	100	57	24	38	0	-	-	-	-
3	CO1 116/Claude	100	167	14	24	0	-	-	-	-
4	DC1 Dufief	100	12	-	-	0	-	-	-	-
5	DC1 Lakeridge	100	68	21	33	0	-	-	-	-
6	DC1 Stratton	100	8	-	-	4	-	-	-	-
7	IL1 John N	100	54	16	19	0	-	-	-	-
8	KS1 Overton	100	58	8	38	5	12	.59	11	6-18
9	MA2 Hemlock	100	50	5	16	0	-	-	-	-
10	MD1 Bolton Hill	100	14	30	53	0	-	-	-	-
11	MD1 Mooeland	100	23	9	29	0	-	-	-	-
12	MD1 Mt Wash	100	17	12	29	0	-	-	-	-
13	MD1 Res Hill	100	10	55	76	0	-	-	-	-
14	NH1 Cap'l't P.	100	31	13	20	0	-	-	-	-
15	NH1 Linqua	100	-	-	-	0	-	-	-	-
16	NY3 Cranston	100	106	5	22	0	-	-	-	-
17	NH1 C. Port.	100	144	18	38	0	-	-	-	-
18	TN1 Rollingwood	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	0	-	-	-	-
20	WI1 Burbank	100	61	15	50	28	1	.64	6	5-1
21	WI1 Hastings	100	35	17	51	20	9	.62	8	6-10
22	IL1 Young Acts	100	9	-	6	12	16	1.10	11	1-12
23	TX1 Hart	99	578	0	40	4	-	-	-	-
24	WI1 Lincoln	[illegible]	16	15	57	11	18	1.21	17	7-20
25	TN1 R2	96	95	4	13	10	9	.66	7	5-10
26	DC1 Westleigh	93	41	1	21	3	-	-	-	-
27	KS1 IC - 92nd	92	63	-	17	5	29	.66	23	13-41
28	IL1 John S.	92	39	18	18	0	-	-	-	-
29	TN1 R1	91	69	13	33	9	14	.87	11	7-18
30	WA1 Lake Hills	91	102	12	37	0	-	-	-	-
31	IL1 Hollis S.	90	19	33	53	0	-	-	-	-
32	IL1 Charter Hou	89	42	-	15	12	11	1.28	6	5-13
33	DC1 Fairidge	88	19	-	34	5	5	.64	4	2-7
34	CO1 Asbury	86	171	9	22	0	-	-	-	-
35	IL2 Comb Inlets	85	524	8	17	0	-	-	-	-
36	MA1 Locust	85	154	11	16	0	-	-	-	-
37	KS1 JCP3	84	314	6	27	7	11	.43	10	6-15
38	MD1 Jordan	79	110	10	23	0	-	-	-	-
39	DC1 Stedwick	78	77	15	34	0	-	-	-	-

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	KS1 Nyland	-	36	1	68	5	-	-	-	-
2	MD1 Hampden	-	11	40	32	0	-	-	-	-
3	IL1 Hartlin N	-	17	3	58	0	-	-	-	-
4	MI1 Waverly	-	10	31	68	21	9	.64	7	6-9
5	TN1 SC	-	387	3	43	12	14	.87	11	7-16
6	WI1 Wood Ctr	-	45	32	51	31	14	.54	11	11-16
7	MA1 Rt 9	-	138	1	21	0	-	-	-	-
8	MA1 Convent	-	100	3	33	0	-	-	-	-
9	MI1 Grand R Ot	-	453	5	38	13	8	.61	7	5-9
10	MI3 Pitt AA-S	-	2401	2	21	6	5	.49	5	3-7
11	NY2 Cedar	-	76	-	5	0	-	-	-	-
12	MA1 Anna	-	601	9	17	0	-	-	-	-
13	MI3 Pitt AA-N	-	2827	1	26	6	6	.76	5	3-9
14	MI1 Grace N	-	364	5	39	11	9	.38	7	5-17
15	MI3 Swift Run	-	1207	2	4	5	3	.41	3	3-4
16	SO1 Meade	-	2030	-	-	14	19	.75	15	15-21
17	CA1 Knox	-	1542	13	-	0	-	-	-	-
18	FL1 M. Jesult	-	30	-	13	15	16	.95	17	9-17
19	FL1 Wilder	-	194	-	97	15	15	1.19	10	7-14
20	CO1 North Ave	-	69	9	50	12	-	-	-	-

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	CO1 Villa Italia	100	74	0	93	9	-	-	-	-
2	MD1 1011 (CBD)	100	21	0	69	23	18	.86	13	10-2?
3	NY1 Southgate	100	179	2	21	0	-	-	-	-
4	WI1 Post Office	100	12	0	100	35	9	.50	8	7-?
5	NH1 Pkg Lot	100	1	0	40	11	17	.86	13	10-16
6	TN1 CBD	100	26	0	99	11	21	.46	13	10-15
7	WI1 Austler	100	12	4	-	27	13	.79	10	8-13
8	KS1 IC Metcalf	96	58	-	92	13	9	.48	7	6-9
9	FL1 Norma St	91	47	-	45	12	13	.88	9	6-13
10	WI1 State Fair	74	29	10	71	15	19	.71	15	11-26

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	LA1 Seaview	100	634	-	-	0	-	-	-	-
2	CO1 Rooney Gulch	100	405	0	1	0	-	-	-	-
3	NY1 Ingersoll	100	58,414	-	4	3	-	-	-	-
4	NY1 English Br	98	5,249	-	1	0	-	-	-	-
5	NY1 West Br	97	6,328	-	1	0	-	-	-	-
6	NY3 Thomas Cr	91	17,719	1	11	0	-	-	-	-
7	NY3 Beaver Cr	90	7,301	-	6	5	3	.41	2	-
8	NY2 Thornell Rock	89	552	-	7	0	-	-	-	-

Industrial

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	BOD Mean	BOD COV	BOD Median	BOD 90% Confidence Limits
1	MA1 Addison	100	18	6	65	0	-	-	-	-
2	MI1 Lucas Drain	100	63	0	64	9	10	.58	9	6-13
3	KS1 Lenexa	56	13	-	44	8	14	.77	11	7-17
4	MI1 Grace S.	53	35	5	39	9	5	.34	5	4-6

	Site	Land Use %	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	COD Mean	COV	Median	90% Confidence Limits
1	TP1 Pic Dep Tr	100	33	19	43	16	129	.72	105	19-139
2	CO1 Cherry	100	57	14	38	18	122	.60	102	71-136
3	TA1 Ct. Claude	100	163	14	24	15	137	.14	103	16-139
4	MI1 Miller	100	32	-	-	7	64	.20	62	51-74
5	OC1 Lakeridge	100	62	31	11	44	60	.56	50	43-58
6	HC1 Stratton	100	8	-	-	31	51	.55	45	39-53
7	TI1 16th N	100	54	18	14	31	126	.80	94	79-122
8	KS1 Overlook	100	58	8	18	14	162	.67	135	101-180
9	MA2 Hemlock	100	50	5	10	11	-	-	-	-
10	MI1 [illegible] Hill	100	14	30	51	15	219	1.36	128	85-193
11	MC1 Maryland	100	33	9	29	13	177	.13	139	101-192
12	MC1 Mt. Wash	100	17	12	29	10	166	.65	136	96-170
13	MI. Res Hill	100	14	55	76	13	171	.85	115	94-194
14	NI1 Carll's R.	100	73	33	20	0	-	-	-	-
15	NI1 Iliaqua	100	-	-	-	0	-	-	-	-
16	NI3 Pralstein	100	166	5	22	8	33	.43	31	24-41
17	NY3 E. Moch	100	346	18	35	7	96	.11	87	86-102
18	TX1 Fallingwood	100	50	3	31	9	70	.35	64	54-84
19	WE1 Shirley	100	95	9	39	118	46	.54	42	39-46
20	WI1 Eastland	100	53	15	50	27	39	.79	30	24-38
21	WI1 Westlrns	100	33	17	51	71	41	.55	36	30-44
22	SI1 Lubbg Acls	100	9	-	0	12	73	.96	52	34-79
23	TI1 Marl	99	338	9	40	11	83	.83	63	49-94
24	WI1 Llewald	98	36	15	57	15	91	.95	66	46-94
25	TH1 PC	96	93	4	13	11	45	.39	42	34-53
26	DC1 Westlemall	93	41	3	21	39	51	.41	46	41-52
27	TS1 [illegible] - 92nd	92	51	-	37	11	176	.98	126	80-147
28	IL1 John S.	91	39	16	19	29	111	.80	87	69-108
29	TH1 91	91	69	11	33	11	120	.96	87	66-135
30	WA1 Lawl Hills	91	107	17	37	127	44	.54	38	16-41
31	IL1 Mailts S.	90	28	27	37	10	180	.72	140	119-178
32	TX3 Charter Hde	89	42	-	16	12	55	.64	47	35-64
33	OC1 Fairbgr	88	19	-	14	48	53	.46	47	42-52
34	CO1 Asbury	86	127	9	33	9	234	1.12	155	49-273
35	IL3 Comb Intels	85	524	8	17	24	108	.90	102	78-134
36	MA1 Lesuit	85	154	11	16	6	104	.45	95	67-135
37	ML3 11023	84	324	4	37	34	90	.57	64	51-82
38	MA1 Jordan	79	110	10	21	9	79	.53	70	51-95
39	OC2 Gledwild	28	27	15	34	49	45	.60	19	34-45

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	COD Mean	COV	Median	90% Confidence Limits
1	CO1 Shaview	100	633	-	-	14	111	.42	102	90-123
2	CO1 Poncry Gulch	100	405	0	1	3	73	.33	69	54-87
3	NY1 Cornell	100	25,416	-	4	8	25	.10	31	18-74
4	NY2 Fdglisn Rd	98	5,248	-	1	11	-	-	-	-
5	NY2 West Br	97	5,338	-	1	0	-	-	-	-
6	NY3 Thomas Cr	91	17,728	1	11	6	26	.26	25	21-32
7	NI3 Ulster Cr	90	2,303	-	6	5	25	.15	15	21-36
8	NY2 Sheltif Dorl	80	557	-	7	0	-	-	-	-

	Site	Land Use %	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	COD Mean	COV	Median	90% Confidence Limits
1	KS1 Holland	-	16	3	66	12	106	.56	89	55-132
2	MD1 Hampden	-	12	40	72	30	111	.33	99	80-115
3	TI1 Mattis N	-	12	3	55	35	195	.56	154	130-195
4	MI1 Waverly	-	30	11	68	27	64	.30	58	40-61
5	TH1 SC	-	147	1	41	13	40	.70	49	16-67
6	WI1 Wood Ctr	-	45	12	81	39	92	.57	90	19-41
7	MA1 Rt 9	-	318	7	71	6	107	.62	68	51-142
8	MA1 Concert	-	100	3	73	8	77	.22	61	40-89
9	MI1 Oraliff & Ot	-	453	5	38	16	71	.47	65	55-14
10	MI3 Pitt AA-S	-	2001	7	21	4	-	-	-	-
11	NY2 Cedar	-	76	-	5	0	-	-	-	-
12	MA1 Anna	-	601	9	12	4	89	.51	76	53-116
13	MI3 Pitt AA-N	-	2841	7	26	3	-	-	-	-
14	MI3 Grace N	-	154	5	25	17	72	.43	68	55-79
15	MI3 Twelf Run	-	1307	7	4	5	35	.10	39	25-33
16	SD1 Meade	-	2030	-	-	14	179	.39	167	140-206
17	CA3 Knox	-	1543	17	-	21	93	.60	80	85-99
18	FL1 N. Jerusl	-	31	-	13	15	51	1.18	33	22-51
19	FL2 Wilder	-	194	-	97	11	51	.38	48	41-57
20	TN1 North Ave	-	50	9	50	32	289	.74	275	186-275

Commercial

	Site	Land Use Coml	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	COD Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	14	0	91	27	184	.67	139	109-178
2	MC1 Mall [illegible]	100	21	0	69	40	120	.76	84	58-117
3	NI3 Southgate	100	179	2	21	9	41	.34	35	31-41
4	MI1 Post Office	100	12	0	100	42	52	.12	48	41-55
5	SH1 Pkg Lot	100	3	0	90	33	95	.79	19	65-95
6	TH2 FPO	100	26	0	90	15	71	.52	55	53-91
7	WI1 Whistler	100	10	0	-	26	59	.76	47	37-64
8	LS1 1C Metcalf	96	59	-	97	26	35	.86	41	13-55
9	FL1 Norma Ct	91	47	-	45	12	41	.43	17	29-47
10	WI3 State Fair	74	79	10	77	21	113	.48	94	84-117

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (P/A)	% IMP.	No. of OBS	COD Mean	COV	Median	90% Confidence Limits
1	MA2 Addition	100	18	0	69	0	-	-	-	-
2	MI1 Indus Drain	100	53	0	64	17	61	.45	53	4[illegible]
3	KS1 Lenexa	56	32	-	44	16	58	.60	50	39-64
4	MI1 Grace S.	57	75	5	39	11	60	.79	47	35-64

TABLE 6-4. SITE MEAN TOTAL P EMCs (μg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (1/A)	% IMP.	No. of OBS	Total P Mean	Total P COV	Total P Median	Total P 90% Confidence Limits
1	CO1 Big Dry Cr	100	31	19	41	16	693	.94	508	356-716
2	CO1 Cherry	100	57	24	18	14	479	.54	342	291-479
3	CO1 Ste Claude	100	107	14	24	15	630	.65	513	392-672
4	DC1 Dufief	100	12	-	-	5	499	.12	435	353-640
5	DE1 Lakeridge	100	68	21	13	45	321	.18	256	212-302
6	DC1 Stratton	100	8	-	-	28	340	.54	300	255-351
7	IL1 John N	100	54	19	19	13	750	.62	616	518-753
8	KS1 Overton	100	58	8	38	8	1636	.91	1207	737-2031
9	MA2 Hemlock	100	50	5	16	5	314	1.05	236	95-493
10	MD1 Bolton Hill	100	34	30	53	19	912	1.15	613	425-883
11	MD1 Homeland	100	23	9	29	13	421	.70	345	253-471
12	MD1 Mt Wash	100	11	32	29	20	556	.83	428	324-566
13	MD1 Res Hill	100	10	55	76	13	4090	1.05	2825	1845-4326
14	NY1 Laurel's R.	100	73	13	20	24	221	.54	195	163-233
15	NY1 Unqua	100	-	-	-	8	229	.61	196	114-285
16	NY3 Kingston	100	166	5	22	13	301	.54	265	206-340
17	NY3 E. Pech.	100	346	18	18	8	448	.47	405	300-546
18	TX1 Rollingwood	100	60	3	21	9	268	.56	231	169-322
19	WA1 Surrey	100	95	9	29	119	239	.83	184	164-205
20	WI1 Burbank	100	63	15	30	45	229	.45	209	188-231
21	WI1 Hastings	100	31	17	51	35	258	.51	230	203-264
22	IL1 Young Apts	100	9	-	5	12	333	.65	279	205-380
23	TX1 Hail	99	178	9	40	14	333	.80	260	189-349
24	WI1 Lincoln	97	36	18	57	23	453	.59	373	298-466
25	TN1 RE	98	81	4	11	11	246	.41	222	183-287
26	IL1 Westleigh	93	41	3	21	41	397	.35	319	268-380
27	KS1 1C - 52nd	92	53	-	37	10	1791	1.11	782	441-1405
28	IL1 John S.	91	33	18	38	32	712	.65	604	502-727
29	TN1 P1	93	69	11	33	11	705	.15	665	552-805
30	WA1 Lake Hills	91	102	32	37	127	264	.81	204	184-227
31	IL1 Maltss S.	90	28	22	37	32	587	.69	483	401-582
32	FL1 Charter Oak	89	42	-	16	36	395	1.61	208	116-314
33	DC1 Fairidge	98	19	-	34	37	151	.13	254	242-334
34	CO1 Asbury	66	127	9	23	9	1025	.71	834	561-1239
35	IL2 Comb Inlet	86	524	8	17	26	506	.19	291	314-511
36	MD1 Locust	85	154	31	16	6	3228	.39	961	545-1711
37	NC1 11073	84	124	6	27	67	529	.99	125	117-444
38	MA1 Jordan	79	110	10	21	8	448	.95	324	190-555
39	CO1 Stedwick	76	21	15	34	44	388	.65	326	281-379

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (1/A)	% IMP.	No. of OBS	Total P Mean	Total P COV	Total P Median	Total P 90% Confidence Limits
1	RC1 Seneca	100	633	-	-	13	590	.82	455	319-549
2	NC1 Grumpi Gulch	100	405	0	1	7	420	.41	388	224-528
3	NY1 Thorwell	100	25,416	-	4	33	191	.46	175	141-217
4	NY2 English Br	95	5,248	-	1	30	27	1.30	17	[illegible]
5	NY2 Wait Br	97	5,138	-	1	31	52	1.27	32	24-41
6	NY3 Thomas Cr	91	17,224	1	11	17	195	.42	177	140-221
7	NY1 Traver Cr	90	7,393	-	6	5	91	.36	85	50-171
8	NY2 Sheriff Cool	80	551	-	7	12	264	1.01	186	145-238

Mixed

	Site	Land Use %	Area (A)	Pop. Den (1/A)	% IMP.	No. of OBS	Total P Mean	Total P COV	Total P Median	Total P 90% Confidence Limits
1	LS1 Noland	-	16	3	55	7	565	.34	528	413-671
2	MD1 Hampden	-	17	40	72	20	750	1.41	436	[illegible]
3	IL1 Maltss N	-	12	3	56	35	498	.56	431	[illegible]
4	MI1 Waverly	-	30	11	68	35	196	.44	167	[illegible]
5	TN3 SC	-	187	3	43	13	352	.64	296	[illegible]
6	WI1 Wood Ctr	-	45	12	81	97	280	.50	240	[illegible]
7	MA1 R1	-	339	7	23	5	1176	.65	995	[illegible]
8	MA1 Convent	-	109	1	31	8	459	1.99	205	[illegible]
9	MI1 Grand R St	-	453	5	38	22	459	.55	184	[illegible]
10	MI3 Pitt AA-S	-	2001	2	21	6	103	.50	91	[illegible]
11	NI2 Cedar	-	76	-	5	12	163	1.30	231	[illegible]
12	MA1 Roma	-	601	9	13	8	434	.60	405	[illegible]
13	MI3 Pitt AA-N	-	2971	7	26	6	768	.47	243	[illegible]
14	MI1 Grace N	-	164	5	28	23	394	.54	311	225-410
15	MI3 Swill Run	-	1207	2	4	5	134	.56	117	71-193
16	SD3 Meadp	-	2020	-	-	15	1685	1.29	1153	743-1621
17	CP1 Knox	-	3542	12	-	19	418	.50	374	311-451
18	FL1 N. Detroit	-	30	-	13	15	196	.71	151	120-214
19	FL1 Wilder	-	194	-	97	15	229	.52	204	163-255
20	CO1 North Ave	-	89	9	50	38	764	.69	673	570-795

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (1/A)	% IMP.	No. of OBS	Total P Mean	Total P COV	Total P Median	Total P 90% Confidence Limits
1	CO1 Villa Italia	100	24	0	91	27	704	1.25	438	316-601
2	NC1 1013 (CBD)	100	73	0	69	51	395	.56	342	304-323
3	NY5 Southgate	100	173	3	21	12	216	.26	209	193-239
4	WI1 Post Office	100	12	0	100	30	118	.56	94	84-106
5	NH1 Pag Lot	100	1	0	46	27	173	1.21	114	[illegible]
6	TN1 C66	100	26	0	99	15	212	.43	195	[illegible]
7	WI1 Rustler	100	12	0	-	44	105	.79	86	69-98
8	KS1 U. Metcalf	96	68	-	97	20	245	.92	130	[illegible]
9	FL1 Norma Fk	91	47	-	45	12	151	.50	135	[illegible]
10	WI1 State Fair	79	64	10	[illegible]	19	313	1.19	330	245-443

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (1/A)	% IMP.	No. of OBS	Total P Mean	Total P COV	Total P Median	Total P 90% Confidence Limits
1	MA2 Addison	100	12	3	69	5	114	.80	85	41-176
2	IL1 Index Drain	100	63	0	64	18	541	.58	472	375-589
3	KS1 Lenexa	58	72	-	44	16	591	.87	452	315-616
4	NC1 Grove S.	52	75	5	19	37	438	.11	365	271-455

Residential										
	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P			
							Mean	COV	Median	90% Confidence limits
1	CO1 Big Dry Cr	100	33	19	41	15	193	.64	163	125-213
2	CO1 Cherry	100	57	24	38	14	212	.47	192	155-237
3	CO1 116/Claude	100	167	14	24	16	196	.35	179	154-208
4	DC1 Dufief	100	12	-	-	6	448	.55	392	757-598
5	DC1 Lakeridge	100	68	21	33	47	69	.62	59	51-68
6	DC1 Stratton	100	8	-	-	27	251	.65	210	173-256
7	IL1 John N	100	54	18	19	0	-	-	-	-
8	KS1 Overton	100	58	8	38	8	313	.41	290	223-378
9	MA2 Nemioct	100	50	5	16	5	165	.89	120	58-249
10	MD1 Bolton Hill	100	14	30	51	0	-	-	-	-
11	MD1 Homeland	100	23	9	29	0	-	-	-	-
12	MD1 Mt Wash	100	17	12	29	0	-	-	-	-
13	MD1 Pes Hill	100	10	55	76	0	-	-	-	-
14	NY1 Carll's R.	100	73	13	20	0	-	-	-	-
15	NY1 Unqua	100	-	-	-	0	-	-	-	-
16	NY3 Cranston	100	166	5	22	0	-	-	-	-
17	NY1 E. Roch.	100	346	18	38	0	-	-	-	-
18	TX1 Rollingwood	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	0	-	-	-	-
20	WI1 Burbank	100	63	15	50	0	-	-	-	-
21	WI1 Hastings	100	33	17	51	0	-	-	-	-
22	FL1 Young Apts	100	9	-	6	0	-	-	-	-
23	TX1 Hart	99	178	9	40	0	-	-	-	-
24	WI1 Lincoln	97	36	18	57	0	-	-	-	-
25	TN1 P2	96	89	4	13	11	132	.63	112	82-154
26	DC1 Westleigh	93	41	3	21	41	223	.71	182	154-215
27	KS1 IC - 92nd	92	63	-	37	10	241	.62	205	147-285
28	IL1 John S.	91	19	18	18	0	-	-	-	-
29	TN1 R1	91	69	11	33	11	136	.94	99	64-153
30	WA1 Lake Hills	91	102	12	37	0	-	-	-	-
31	IL1 Mattis S.	90	28	22	37	0	-	-	-	-
32	FL1 Charler Ndg	89	42	-	16	0	-	-	-	-
33	DC1 Fairidge	88	19	-	34	46	297	.87	224	186-270
34	CO1 Asbury	86	127	9	22	9	212	.22	207	181-232
35	IL2 Comb Inlets	85	524	8	17	24	98	1.21	63	95-88
36	NH1 Locust	85	154	11	16	6	184	.42	169	171-235
37	NY1 #1823	84	374	6	22	0	-	-	-	-
38	MA1 Jordan	79	110	10	21	7	202	1.11	136	70-262
39	DC1 Stedwick	78	22	15	34	41	251	.70	206	174-243

Mixed										
	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P			
							Mean	COV	Median	90% Confidence limits
1	KS1 Holand	-	36	3	68	8	165	.52	146	105-203
2	MD1 Hampden	-	17	40	72	0	-	-	-	-
3	IL1 Mattis N	-	17	3	58	0	-	-	-	-
4	MI1 Waverly	-	30	11	68	32	43	.76	34	28-47
5	TN1 SC	-	187	3	43	13	192	1.17	128	81-203
6	WI1 Wood Ctr	-	45	12	81	0	-	-	-	-
7	MA1 Rt 9	-	338	7	23	5	160	.38	150	106-213
8	MA1 Convent	-	100	1	33	6	106	1.83	51	19-138
9	MI1 Grand R Ot	-	453	5	38	20	68	.68	56	44-71
10	MI3 Pitt AA-S	-	2001	2	21	6	13	.37	13	10-17
11	NY2 Cedar	-	76	-	5	26	49	1.16	32	23-44
12	MA1 Anna	-	601	9	12	4	-	-	-	-
13	MI3 Pitt AA-N	-	2871	7	26	6	59	.88	44	74-82
14	MI1 Grace N	-	164	5	28	21	47	.47	42	35-50
15	MI3 Swift Run	-	1207	2	4	5	39	.46	35	73-53
16	SD1 Meade	-	2030	-	-	14	87	.61	74	57-97
17	CA1 Knox	-	1542	12	-	18	169	.99	120	85-168
18	FL1 N. Jesuit	-	30	-	13	0	-	-	-	-
19	FL1 Wilder	-	194	-	97	0	-	-	-	-
20	CO1 North Ave	-	69	9	50	30	228	.95	165	179-212

Commercial										
	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P			
							Mean	COV	Median	90% Confidence limits
1	CO1 Villa Italia	100	24	0	91	26	293	1.09	198	147-266
2	NC1 1013 (CBD)	100	23	0	69	0	-	-	-	-
3	NY3 Southgate	100	179	2	21	0	-	-	-	-
4	WI1 Post Office	100	12	0	100	0	-	-	-	-
5	NH1 Pkg Lot	100	1	0	90	0	-	-	-	-
6	TN1 CBD	100	26	0	99	15	46	.32	17	78-50
7	WI1 Rustler	100	12	0	-	0	-	-	-	-
8	KS1 IC Metcalf	96	58	-	97	21	116	1.06	80	58-111
9	FL1 Norma Pt	91	47	-	45	0	-	-	-	-
10	WI1 State Fair	74	29	10	77	0	-	-	-	-

Urban Open and Nonurban										
	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P			
							Mean	COV	Median	90% Confidence Limits
1	CA1 Sraviow	100	633	-	-	12	145	1.20	93	55-150
2	CO1 Rooney Gulch	100	405	0	1	7	137	.46	124	90-171
3	NY3 Thornell	100	28,416	-	4	0	-	-	-	-
4	NY2 English Br	98	5,748	-	1	18	5	.35	5	4-6
5	NY2 West Br	93	5,138	-	1	26	8	.56	7	6-8
6	NY1 Thomas Cr	91	17,728	1	11	0	-	-	-	-
7	MI3 Traver Cr	90	2,301	-	6	5	31	.55	29	18-47
8	NY2 Sheriff Duck	80	552	-	7	12	39	1.11	25	20-14

Industrial										
	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	SOL P			
							Mean	COV	Median	90% Confidence limits
1	MA2 Addison	100	18	0	69	5	75	.92	55	26-116
2	MI2 Indus Drain	100	63	0	64	14	127	.72	103	76-140
3	KS1 Lenexa	56	72	-	44	16	346	1.66	179	108-296
4	MI1 Grace S.	52	75	5	39	16	59	1.74	37	74-56

TABLE 6-6. SITE MEAN TKN EMCs (μg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	31	19	41	16	2,169	.58	2043	1617-2584
2	CO1 Cherry	100	57	24	38	14	2,609	.39	2430	2014-2904
3	CO1 116/Claude	100	167	14	74	15	2,891	.51	2501	2010-1112
4	DC1 Dufief	100	17	-	-	6	2,066	.11	2048	1841-2278
5	DC1 Lakeridge	100	68	21	33	48	1,774	.64	1450	1259-1670
6	DC1 Stratton	100	8	-	-	28	1,811	.34	1686	1494-1904
7	IL1 John N	100	54	18	19	13	1,994	.81	1107	7520-3811
8	TS1 Overton	100	58	8	38	5	-	-	-	-
9	MA2 Hemlock	100	50	5	16	5	1,679	.55	1217	1971-5252
10	MD1 Bolton Hill	100	14	39	51	18	6,067	.17	4815	1640-6170
11	MD1 Homeland	100	21	9	79	13	6,505	.40	6044	4996-7112
12	MD1 Mt Wash	100	17	12	29	70	6,915	.41	6408	5502-7461
13	MD1 Res Hill	100	10	55	76	13	10,803	.41	9915	9089-12154
14	NY1 Carll's R.	100	71	11	20	24	1,487	.71	1201	955-1509
15	NY1 Unqua	100	-	-	-	8	1,408	.26	1161	1148-1618
16	RI1 Cranston	100	166	5	77	11	1,492	.45	1358	1098-1679
17	NY3 E. Roch.	100	346	18	18	7	3,246	.90	2411	1369-4245
18	IL1 Rollingwood	100	60	1	21	9	5,004	2.37	1942	828-4554
19	WA1 Surrey	100	95	9	29	118	1,007	.62	857	785-915
20	WI1 Burbank	100	61	15	50		1,260	.50	1125	908-1195
21	WI1 Hastings	100	13	17	51	15	1,102	.54	969	801-1173
22	FL1 Young Apts	100	9	-	6	12	1,139	.70	1097	791-1522
23	TX1 Hart	99	178	9	40	11	1,016	.25	2412	1674-3474
24	WI1 Lincoln	97	16	18	57	1	-	-	-	-
25	TN1 P2	96	84	4	11	11	476	.11	452	379-519
26	DC1 Westleigh	93	41	3	21	41	1,901	.56	1660	1447-1904
27	KS1 JC - 47nd	92	61	-	12	8	4,187	.94	3051	1790-5200
28	IL1 John S.	91	19	18	18	12	1,527	1.04	2441	1886-1155
29	TN1 Ri	91	69	11	11	11	1,131	.14	1071	894-1281
30	WA1 Lake Hills	91	102	12	37	127	1,056	.71	852	774-938
31	IL1 Mattis S.	90	28	77	37	37	1,440	.69	2825	2343-3406
32	FL1 Charter Hdg	89	42	-	16	12	1,704	.83	1309	899-1905
33	DC1 Fairidge	88	19	-	34	46	2,712	.51	1958	1711-2215
34	CO1 Asbury	86	122	9	22	1	3,735	.56	3761	7774-4788
35	IL2 Comb Inlets	85	524	6	17	0	-	-	-	-
36	MD1 Locust	85	154	11	16	6	2,695	.38	2522	1864-3412
37	NC1 #1021	84	324	6	23	67	1,488	.94	1086	921-1277
38	WA1 Jordan	79	110	10	21	9	1,191	.60	1194	845-1682
39	DC1 Stedwick	78	27	15	34	43	1,895	.57	1543	1435-1881

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	COV	Median	90% Confidence Limits
1	CA1 Seaview	100	613	-	-	13	3674	.59	1159	2411-4139
2	CO1 Rooney Gulch	100	405	0	1	7	2954	.57	2615	1813-3768
3	NY1 Hornell	100	28,416	-	4	11	1099	.50	482	778-1240
4	NY2 English Br	98	5,248	-	1	15	340	.50	305	246-328
5	NY2 West Br	97	5,338	-	1	24	392	.57	147	292-412
6	NY1 Thomas Cr	91	17,728	1	11	10	1111	.16	1045	854-1279
7	MI3 Fraser Cr	90	2,101	-	6	5	889	.11	883	796-981
8	NY2 Sheriff Dock	80	552	-	7	13	963	.76	765	628-937

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	COV	Median	90% Confidence Limits
1	KS1 Noland	-	36	3	68	0	-	-	-	-
2	MD1 Hampden	-	37	40	72	19	6994	.55	6140	5004-7531
3	IL1 Mattis N	-	17	3	58	15	2872	.64	2172	7006-7805
4	WI1 Waverly	-	10	11	68	15	1490	.51	1116	1142-1516
5	TN1 SC	-	187	1	41	11	623	.50	558	442-705
6	WI1 Wood Ctr	-	45	12	81	16	1452	.35	1369	1180-1589
7	MA1 Rt 9	-	338	7	23	5	2446	.50	2188	1194-1412
8	MA1 Convent	-	100	1	33	8	1080	.64	910	615-1147
9	WI1 Grand R Ot	-	451	5	18	21	1631	.47	1506	1104-1780
10	MI1 Pitt AA-S	-	7001	2	21	6	845	.79	811	647-1025
11	NY2 Cedar	-	76	-	5	21	1237	.81	951	724-1749
12	MA1 Anna	-	601	9	12	6	1888	.70	1547	920-7601
13	MI3 Pitt AA-N	-	2821	7	76	6	1056	.22	1011	867-1213
14	WI1 Grace N	-	164	5	28	21	1988	.87	1807	1536-2135
15	MI3 Swift Run	-	1707	2	4	5	1116	.15	1104	958-1273
16	SD1 Meade	-	2010	-	-	11	4741	.50	1807	3010-4802
17	CA1 Knox	-	1542	17	-	70	2270	.75	1775	1171-2298
18	FL1 N. Jesuit	-	30	-	31	15	1388	.49	1244	1011-1542
19	FL1 Wilder	-	194	-	47	15	1107	.11	1056	970-1212
20	CO1 North Ave	-	69	4	50	21	4196	.65	1522	2847-4156

Commercial

	Site	Land Use % Com'l	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	22	1657	.85	2785	2185-3548
2	NC1 1011 (CBD)	100	21	0	64	61	1611	.10	1118	1152-1409
3	NY1 Southgate	100	174	2	21	13	1256	.45	1144	975-1414
4	WI1 Post Office	100	12	0	100	27	1021	.44	916	915-1035
5	NH1 Pkg Lot	100	1	0	42	18	2110	.66	1761	1116-2754
6	TN1 CBD	100	26	0	99	15	646	.41	597	499-714
7	WI1 Rustler	100	12	0	-	25	1073	.61	916	755-1110
8	KS1 JC Metcalf	96	58	-	47	37	1175	.71	949	720-1252
9	FL1 Norma Pk	91	47	-	45	12	876	.84	633	437-925
10	WI1 State Fair	74	29	10	27	8	1656	.65	1189	913-2068

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	TKN Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	18	0	69	5	2042	.49	1879	1227-2974
2	WI1 Indus Drain	100	63	0	64	18	1274	.57	1107	891-1376
3	KS1 Lenexa	56	72	-	44	17	1385	.21	1117	796-1568
4	WI1 Grace S.	52	75	5	39	18	1731	.56	1491	1205-1850

TABLE 6-7. SITE MEAN NITRITE PLUS NITRATE EMCs (μg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N			
							Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	33	19	41	15	527	.34	499	429-580
2	CO2 Cherry	100	57	24	38	14	709	.40	657	542-288
3	CO1 116/Claude	100	167	14	24	16	670	.51	529	469-715
4	DC3 Dufief	100	12	-	-	8	420	.35	445	354-558
5	DC1 Lakeridge	100	68	21	33	49	246	.62	633	552-725
6	DC1 Stratton	100	8	-	-	33	418	.86	312	254-395
7	IL1 John K	100	54	18	14	-	-	-	-	-
8	KS1 Overton	100	58	8	38	-	-	-	-	-
9	MA2 Hemlock	100	50	5	16	4	-	-	-	-
10	MD1 Bolton Hill	100	14	10	52	19	9535	1.59	5073	3246-7930
11	MD1 Homeland	100	23	9	29	13	6343	4.56	1358	570-3234
12	MD1 Mt Wash	100	17	12	29	20	7822	1.56	4229	2253-6492
13	MD1 Res Hill	100	10	55	26	13	6938	1.08	4207	1048-2269
14	NY1 Carll's R.	100	73	13	20	24	230	1.38	442	318-627
15	NY1 Unqua	100	-	-	-	8	1593	-	-	1020-1872
16	NY3 Cranston	100	166	5	22	0	-	-	-	-
17	NY3 E. Roch.	100	346	18	38	0	-	-	-	-
18	TX1 Rollingwood	100	60	3	21	9	829	.51	283	581-1055
19	WA1 Surrey	100	95	9	79	0	-	-	-	-
20	WI1 Burbank	100	63	15	50	18	275	.48	699	580-843
21	WI1 Hastings	100	13	17	51	24	625	.39	582	510-664
22	FL1 Young Apts	100	9	-	6	12	311	.64	262	193-355
23	TN1 Hart	99	328	9	40	10	1625	.54	1430	1062-1912
24	WI1 Lincoln	97	36	18	57	3	-	-	-	-
25	IL1 R2	96	89	4	19	11	997	1.34	232	136-412
26	DC1 Westleigh	93	41	9	71	41	202	.59	606	525-700
27	KS1 IC - 92nd	92	63	-	37	0	-	-	-	-
28	IL1 John S.	91	39	18	18	0	-	-	-	-
29	IL1 R1	91	69	11	33	21	578	.72	458	315-665
30	WA1 Lake Hills	91	102	12	37	0	-	-	-	-
31	IL1 Mallis S.	90	28	22	37	0	-	-	-	-
32	FL1 Charter Mdg	89	42	-	16	12	610	.77	483	139-688
33	DC1 Fairidge	88	19	-	34	48	927	.66	772	667-893
34	CO1 Asbury	86	122	9	22	9	881	.21	862	258-980
35	IL2 Comb Inlets	85	524	6	32	21	296	.55	699	526-848
36	MA1 Locust	65	154	11	16	5	1705	.69	1406	726-2549
37	NC1 41023	84	324	6	27	67	716	.68	591	521-620
38	MA1 Jordan	79	110	10	21	9	1747	.55	1094	295-1505
39	SC1 Stedwick	78	27	15	34	47	837	.70	686	588-800

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N			
							Mean	COV	Median	90% Confidence Limits
1	CA1 Seaview	100	611	-	-	12	1542	.49	1381	1087-1759
2	CO1 Rooney Gulch	100	405	<1	1	7	581	1.03	405	717-756
3	NY3 Thornell	100	28,416	-	4	0	-	-	-	-
4	NY2 English Br	98	5,248	-	1	30	240	.60	206	173-245
5	NY2 West Br	97	5,338	-	1	11	862	.53	761	656-868
6	NY3 Thomas Cr	91	17,228	5	11	0	-	-	-	-
7	MI3 Trayer Cr	90	2,303	-	6	5	1108	.17	1092	930-1283
8	NY2 Sheriff Dock	86	552	-	7	33	383	1.82	268	209-143

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N			
							Mean	COV	Median	90% Confidence Limits
1	KS1 Noland	-	36	3	68	0	-	-	-	-
2	MD1 Hampden	-	17	40	72	20	11,529	4.00	2293	1457-5355
3	IL1 Mallis N	-	17	3	58	0	-	-	-	-
4	WI1 Waverly	-	30	11	68	35	725	.49	696	610-794
5	TN1 SC	-	187	3	43	13	582	1.49	327	192-558
6	WI1 Wood Ctr	-	45	12	81	17	252	.69	618	474-805
7	MA1 Rt 9	-	338	7	23	5	1,789	.48	1613	1045-2490
8	MA1 Convent	-	100	1	13	6	960	.39	894	656-1218
9	MI1 Grand R Ot	-	453	5	38	23	883	.44	807	694-938
10	MI3 Pitt AA-S	-	2001	2	21	6	284	.48	256	376-322
11	NY2 Cedar	-	26	-	5	32	248	.72	201	-
12	MA1 Anna	-	601	9	52	6	1,268	.60	1086	688-1218
13	MI3 Pitt AA-N	-	2821	7	26	5	469	.24	456	364-571
14	WI1 Grace N	-	164	5	28	21	825	.43	803	693-931
15	MI3 Swift Run	-	1202	7	4	5	1,033	.26	821	431-1563
16	SD1 Meade	-	2030	-	-	15	616	.40	521	429-680
17	CA1 Knox	-	1542	12	-	17	1,111	.36	1044	901-1210
18	FL1 N. Jasull	-	30	-	13	14	126	.54	392	261-422
19	FL1 Wilder	-	194	-	92	15	456	.42	412	336-505
20	CO1 North Ave	-	69	9	50	32	1,744	.92	1286	1012-1626

Commercial

	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N			
							Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	1180	.86	895	709-1143
2	NC1 1013 (CBD)	100	23	0	69	61	1518	.55	980	878-1094
3	NY3 Southgate	100	129	2	21	0	-	-	-	-
4	WS1 Post Office	100	12	0	100	28	708	.68	584	479-712
5	NH1 Pkg Lot	100	15	0	90	28	801	.84	615	486-778
6	TN1 T.B.G	100	26	0	99	15	662	.62	562	434-778
7	WI1 Rustler	100	12	0	-	25	781	.69	642	527-791
8	KS1 IC Metcalf	96	58	-	97	0	-	-	-	-
9	FL1 Norma Pk	91	42	-	45	12	356	.46	323	257-405
10	WI1 State Fair	74	29	10	72	12	781	.50	702	540-897

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	NO_{2+3}-N			
							Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	18	5	69	5	1355	.79	1301	997-1706
2	MI1 Indus Drain	100	63	0	64	18	686	.40	637	584-746
3	KS1 Lenexa	56	72	-	44	0	-	-	-	-
4	WI1 Grace S.	52	75	5	39	12	742	.52	657	534-808

TABLE 6-8. SITE MEAN TOTAL COPPER EMCs (μg/ℓ)

Residential										
						Total Copper				
	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	33	19	41	16	32	.82	25	18-34
2	CO1 Cherry	100	57	24	38	14	35	1.48	20	12-33
3	CO1 116/Claude	100	157	14	24	16	28	.74	22	16-29
4	DC1 Dufief	100	12	-	-	21	-	-	-	-
5	DC1 Lakeridge	100	68	21	33	14	18	.55	33	26-42
6	DC1 Stratton	100	8	-	-	10	28	.30	21	23-32
7	IL1 John N	100	54	18	19	36	83	.85	63	51-78
8	KS1 Overton	100	58	8	38	12	91	.50	81	83-101
9	MA1 Hemlock	100	60	5	16	0	-	-	-	-
10	MD1 Bolton Hill	100	14	10	51	19	107	.70	88	68-112
11	MD1 Homeland	100	23	9	79	13	312	.14	296	252-349
12	MD1 Mt Wash	100	32	12	29	20	26	.78	20	15-25
13	MI1 Lex Hill	100	10	65	36	13	42	.59	34	25-46
14	MI1 Collins R.	100	71	13	20	0	-	-	-	-
15	MI1 Knaus	100	-	-	-	0	-	-	-	-
16	NH1 Cranston	100	166	5	22	0	-	-	-	-
17	NH1 E. Point	100	246	38	38	0	-	-	-	-
18	TN1 Rollingwood	100	60	1	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	0	-	-	-	-
20	WI1 Burbank	100	61	35	50	0	-	-	-	-
21	WI1 Hastings	100	31	17	51	0	-	-	-	-
22	FL1 Young Apts	100	4	-	6	12	6	.36	6	5-7
23	WI1 Marl	99	328	9	40	0	-	-	-	-
24	WI1 Lincoln	97	16	18	53	0	-	-	-	-
25	TN1 P2	96	89	4	13	11	28	1.54	15	8-22
26	DC1 Westleigh	93	41	3	21	6	31	.43	34	24-48
27	KS1 [illegible] - 9Fnd	92	61	-	17	2	-	-	-	-
28	IL1 John S.	91	39	12	18	16	43	.84	33	26-40
29	TN1 P1	91	69	11	13	11	51	.60	52	34-70
30	WA1 Lake Hills	91	107	12	37	7	22	.34	21	15-29
31	IL1 Mailes S.	90	20	22	33	36	45	.76	36	30-44
32	FL1 Charter Rdg	89	42	-	16	12	10	.94	7	6-11
33	DC1 Fairidge	88	30	-	34	9	26	.39	26	17-31
34	CO1 Asbury	86	127	9	22	9	59	.64	45	29-71
35	IL1 Lamb Inlets	85	124	8	17	26	49	.53	43	36-51
36	MA1 Locust	85	154	11	16	6	107	.21	104	80-135
37	NC1 #1021	84	324	8	27	65	39	.80	33	29-3[illegible]
38	MA1 Jordan	79	110	10	31	8	74	.24	72	-
39	DC1 Stedwick	78	27	15	34	9	31	.15	25	23-35

Mixed										
						Total Copper				
	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	KS1 Noland	-	36	1	68	9	48	.38	45	16-57
2	MD1 Hampden	-	43	40	78	20	81	.96	51	45-92
3	IL1 Mattis N	-	17	3	58	17	48	.53	17	31-45
4	MI1 Waverly	-	30	13	69	16	15	.50	13	10-16
5	TN1 SC	-	181	3	41	13	42	1.35	25	14-41
6	WI1 Wood Ctr	-	45	12	81	11	-	-	-	-
7	MA1 Pt 9	-	119	7	23	7	112	.49	100	71-141
8	MA1 Tonerhill	-	100	1	31	7	105	.41	96	71-170
9	MI1 Grand R 01	-	453	5	38	33	31	.53	26	20-35
10	MI3 Pitt AA-S	-	2003	2	25	0	-	-	-	-
11	NY2 Cedar	-	76	-	5	0	-	-	-	-
12	MA1 Anna	-	601	9	12	5	54	.51	46	30-70
13	MI3 Pitt AA-N	-	2811	7	35	0	-	-	-	-
14	MI1 Grand N	-	164	5	38	9	14	.31	13	11-18
15	MI2 Swift Run	-	1203	2	4	0	-	-	-	-
16	SO1 Meade	-	2030	-	-	0	-	-	-	-
17	CA1 Knox	-	1542	12	-	17	95	1.14	65	44-94
18	FL1 N. Jesuit	-	30	-	13	15	7	.61	5	5-8
19	FL1 Wilder	-	394	-	[illegible]	15	5	.84	5	4-7
20	CO1 North Ave	-	69	9	51	12	71	.83	54	47-74

Commercial										
						Total Copper				
	Site	Land Use % Com	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	34	0	91	27	31	.87	25	20-32
2	NC1 1011 (CBD)	100	23	0	49	61	70	.54	61	52-68
3	NH1 Smilegate	100	179	0	21	0	-	-	-	-
4	WI1 Post Office	100	12	2	100	0	-	-	-	-
5	NH1 Pkg Lot	100	3	0	95	11	104	.13	101	-
6	TN1 CBD	100	26	0	99	15	42	.60	16	28-46
7	WI1 Rustler	100	12	0	-	0	-	-	-	-
8	KS1 11 Metcalf	96	58	-	97	6	31	.33	19	10-51
9	[illegible] Norma 2k	93	47	-	65	12	11	.37	10	8-13
10	WI1 State Fair	74	24	10	77	0	-	-	-	-

Urban Open and Nonurban										
						Total Copper				
	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	CA1 Seaview	100	633	-	-	12	59	.33	55	46-65
2	CO1 Rooney Gulch	100	405	0	1	7	37	1.09	25	11-48
3	NH1 Thornell	100	28,410	-	4	0	-	-	-	-
4	NY[illegible] English Cr	98	4,749	-	1	0	-	-	-	-
5	NY[illegible] West Br	97	5,328	-	1	0	-	-	-	-
6	NY[illegible] Thomas Cr	91	17,725	1	11	0	-	-	-	-
7	NH1 Teague Cr	90	7,303	-	8	0	-	-	-	-
8	NH1 Sherrill [illegible]	90	557	-	7	0	-	-	-	-

Industrial										
						Total Copper				
	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	MA[illegible] Addison	100	18	0	19	0	-	-	-	-
2	MI1 [illegible] Drain	100	53	0	64	6	30	.53	17	12-[illegible]
3	KS1 Lenexa	58	72	-	44	5	35	.24	35	28-41
4	MI1 Grace S.	58	15	8	3[illegible]	7	25	.35	21	14-[illegible]

TABLE 6-9. SITE MEAN TOTAL LEAD EMCs (μg/ℓ)

	Residential						Total lead			
	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	CO1 Big Dry Cr	100	13	19	41	16	183	.88	117	98-191
2	CO1 Cherry	100	51	24	18	14	194	.92	143	99-207
3	CO1 116thClarke	100	167	14	24	16	292	.87	210	151-292
4	DC1 Dufief	100	12	-	-	1	-	-	-	-
5	DC1 Lakeridge	100	68	21	33	19	227	.54	200	164-245
6	DC3 Stratton	100	8	-	-	0	-	-	-	-
7	IL1 John N	100	54	18	19	16	217	.71	191	158-211
8	KS1 Overton	100	58	8	16	11	118	.19	128	104-157
9	MA2 Hemlock	100	55	5	16	0	-	-	-	-
10	MD1 Dalling Sq1	100	14	30	51	19	2345	4.53	592	295-1188
11	MD1 Homeland	100	21	9	29	19	76	.48	69	56-86
12	MD1 Mt Wash	100	17	12	29	21	86	.48	77	65-92
13	MD1 Res Hill	100	10	55	76	17	461	1.86	218	119-399
14	NY1 Carll's P	100	71	13	20	0	-	-	-	-
15	NY1 Pequa	100	-	-	-	8	88	1.16	52	26-103
16	RI1 Cranston	100	166	5	22	31	34	.77	27	19-38
17	NY3 E. Roch.	100	146	18	38	8	191	.89	144	86-240
18	TX1 Rollingwood	100	60	3	21	0	-	-	-	-
19	WA1 Surrey	100	95	9	29	138	152	.51	136	126-146
20	WI1 Burbank	100	63	15	50	44	95	.72	77	65-91
21	WI1 Hastings	100	33	17	51	15	108	.67	90	75-107
22	IL1 Young Apts	100	9	-	6	12	75	1.03	51	14-82
23	TX1 Mark	99	178	9	40	0	-	-	-	-
24	WI1 Lincoln	91	16	18	57	22	303	1.39	200	141-280
25	TN1 42	96	59	4	13	11	111	.41	123	99-151
26	DC1 Westleigh	97	41	1	21	5	186	.17	184	157-236
27	KS1 IL - 52nd	92	61	-	37	1	-	-	-	-
28	IL1 John S.	91	39	18	18	13	217	.80	169	138-208
29	TN1 41	91	69	11	11	31	440	.61	376	277-511
30	WA1 Lake Hills	91	102	17	39	126	192	.67	159	140-174
31	IL1 Mallys S.	98	28	22	17	37	595	1.12	196	308-508
32	FL1 Charter Ridg	89	42	-	16	12	49	1.60	26	14-47
33	DC1 Fairidge	68	19	-	14	1	-	-	-	-
34	LI1 Asbury	86	127	9	32	9	431	.12	151	351-524
35	IL2 Lamb Inlets	85	524	6	17	74	132	1.01	277	169-304
36	MA1 Locust	85	154	11	16	6	213	.67	225	116-171
37	MI1 #1023	84	129	6	27	66	254	.98	182	151-215
38	MA1 Jordan	79	110	10	21	9	168	.17	160	112-194
39	DC1 Stedwick	78	27	75	34	11	141	.43	110	105-161

	Mixed						Total lead			
	Site	Land Use 1	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	KS1 Holland	-	36	1	68	9	164	.49	147	110-196
2	MD1 Hampden	-	17	40	72	20	227	.82	176	131-232
3	IL1 Mattis N	-	17	3	58	41	554	1.06	180	103-472
4	MI1 Waverly	-	30	11	68	24	311	1.09	75	55-101
5	TN1 SC	-	187	1	43	13	237	.31	227	195-264
6	WI1 Wood Ctr	-	95	12	81	45	582	.94	424	348-517
7	MA1 Rt 9	-	338	7	31	7	419	1.02	167	165-471
8	MA1 Convent	-	100	1	13	7	196	.94	143	80-257
9	MI1 Grand R Dt	-	451	5	38	18	122	.90	91	66-125
10	MI3 Pitt AA-S	-	2001	2	23	6	23	1.63	11	4-28
11	NY2 Cedar	-	76	-	5	28	75	1.25	41	34-69
12	MA1 Anna	-	601	9	12	4	-	-	-	-
13	MI3 Pitt AA-M	-	2871	7	26	5	61	.71	50	27-92
14	MI1 Grace A	-	164	5	28	18	170	1.79	99	65-151
15	MI3 Swift Run	-	1207	2	4	4	-	-	-	-
16	SD1 Meade	-	2030	-	-	24	381	1.13	254	165-390
17	CA1 Knox	-	1542	12	-	22	495	.99	351	259-475
18	FL1 N. Jesuit	-	10	-	13	15	56	1.22	35	23-54
19	FL1 Wilder	-	194	-	97	15	86	.85	55	46-91
20	CO1 North Ave	-	69	9	50	31	158	.51	278	226-343

	Commercial						Total lead			
	Site	Land Use % Coml	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	262	1.21	187	172-224
2	NC1 1011 (CBD)	100	27	0	69	61	382	.91	296	254-345
3	NY3 Southgate	100	179	0	21	13	47	.50	42	31-57
4	WI1 Post Office	100	12	2	100	59	191	.93	145	126-173
5	NH1 Pkg Lot	100	1	0	90	11	208	.93	152	121-197
6	TN1 CBD	100	26	5	99	15	158	.52	140	112-175
7	WI1 Rustler	100	12	0	-	44	123	.77	98	83-115
8	KS1 1C Mescall	96	58	-	97	7	-	-	-	-
9	FL1 Marina Pk	91	47	-	45	12	46	1.01	37	31-44
10	WI1 State Fair	74	39	10	37	27	409	.86	310	243-396

	Urban Open and Nonurban						Total lead			
	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	FN1 Sanview	100	631	-	-	7	214	.54	159	91-279
2	CO1 Rooney Gulch	100	405	1	1	7	52	.41	39	22-69
3	NY3 Thornell	100	25,416	-	4	10	12	.42	11	9-14
4	MI2 English Br	98	5,208	-	1	21	4	.60	9	6-10
5	MI2 West Br	97	1,278	-	1	25	38	1.40	22	15-31
6	NY3 Thomas Cr	91	17,128	1	11	32	35	1.65	18	10-31
7	MI3 Traver Cr	90	7,303	-	6	0	-	-	-	-
8	MI3 Sheriff Dust	90	557	-	7	17	132	1.05	91	73-113

	Industrial						Total lead			
	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	18	0	69	0	-	-	-	-
2	MI1 Indus Swain	100	63	0	64	13	116	.77	93	65-124
3	KS1 Lenexa	56	72	-	44	6	-	-	-	-
4	MI1 Grace S.	52	15	5	39	17	114	.76	93	66-118

TABLE 6-10. SITE MEAN TOTAL ZINC EMCs (μg/ℓ)

Residential

	Site	Land Use % Res	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	CO1 Fig Dry Cr	100	37	19	41	15	194	.80	151	170-208
2	CO1 Cherry	100	57	24	38	19	195	.61	165	170-211
3	CO1 116 Claude	100	167	14	24	13	195	.66	158	171-206
4	DE1 Dufief	100	22	-	-	8	156	.26	161	137-179
5	DC1 Lakeridge	100	58	27	31	46	129	.70	106	91-171
6	DC1 Stratton	100	5	-	-	22	84	.47	76	66-88
7	TC1 John N	100	54	15	19	0	-	-	-	-
8	KS1 Overland	100	52	8	36	33	831	.97	590	399-891
9	MA2 Hemlock	100	50	5	16	0	-	-	-	-
10	MD1 Gallion Hill	100	14	10	52	19	1768	2.21	573	117-971
11	MD1 Homeland	100	21	6	29	33	120	.15	113	96-114
12	MD1 Mt Wash	100	17	12	39	29	92	.54	91	67-98
13	MD1 Res Hill	100	10	55	76	11	523	1.20	140	211-542
14	NY1 Carll's C	100	71	11	20	0	-	-	-	-
15	NY1 Unqua	100	-	-	-	0	-	-	-	-
16	NH2 Cranston	100	160	5	22	9	435	.89	117	195-499
17	NY3 L. Roch	100	346	18	39	8	988	1.10	127	180-594
18	TX1 Rollingwood	100	60	1	21	0	-	-	-	-
19	WA1 Surrey	100	91	9	29	118	124	.42	114	107-121
20	WI1 Burbank	100	63	15	50	18	106	1.14	63	42-95
21	WI1 Hastings	100	33	17	51	21	106	1.20	69	49-97
22	IL1 Young Apts	100	9	-	6	17	60	.45	55	44-69
23	TX1 Hart	99	376	9	40	0	-	-	-	-
24	WI1 Lincoln	97	36	18	57	0	-	-	-	-
25	TN1 R2	96	89	4	37	11	91	.57	81	61-109
26	OR1 Wessleigh	93	41	1	21	14	67	.96	48	38-61
27	KS1 IC - 92nd	92	63	-	17	3	-	-	-	-
28	IL1 John S.	91	39	38	18	1	-	-	-	-
29	SD1 R1	91	69	11	11	11	412	.59	754	261-4[illegible]
30	WA1 Lake Hills	91	102	12	17	126	120	.51	107	99-115
31	IL1 Mallis S.	90	38	22	17	0	-	-	-	-
32	FL1 Charter Hng	85	47	-	16	12	54	1.02	78	35-59
33	OR1 Fairidge	88	19	-	14	44	86	.52	76	67-86
34	CO1 Asbury	86	127	9	22	9	149	.61	295	206-422
35	IL2 Cumb Inlets	85	524	8	17	27	210	.69	189	154-212
36	MA1 Locust	85	154	11	16	6	247	.11	216	184-301
37	NC1 #1023	64	374	6	27	66	178	.81	118	139-160
38	MA1 Jordan	79	110	10	21	9	218	.28	219	177-249
39	OC1 Stedwick	79	27	15	14	45	91	.70	75	64-86

Urban Open and Nonurban

	Site	Land Use % Open	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	CO1 Geezley	100	673	-	-	17	193	.69	160	125-205
2	CO1 Rooney Gulch	100	405	0	1	7	115	.56	91	61-136
3	NY3 Thornhill	100	15,415	-	4	4	292	2.39	306	110-720
4	NY2 English Pk	99	5,208	-	1	0	-	-	-	-
5	NY2 Res't Br	97	5,138	-	1	0	-	-	-	-
6	NY3 Thomas Cr	51	17,728	1	11	9	1063	3.14	347	124-639
7	NY3 Traver Cr	90	2,767	-	6	2	-	-	-	-
8	NY2 Sheriff Gael	88	552	-	7	0	-	-	-	-

Mixed

	Site	Land Use %	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	KS1 Holand	-	35	3	68	9	[illegible]	1.19	525	247-440
2	MD1 Hampden	-	11	40	72	17	319	.75	112	[illegible]
3	IL1 Mottis N	-	17	1	98	0	-	-	-	-
4	MI1 Waverly	-	30	11	56	17	121	.95	110	92-111
5	TN1 SC	-	197	7	43	13	144	.40	134	114-1[illegible]
6	WI1 Hoqg Clr	-	45	17	61	27	425	1.21	305	227-474
7	MA1 Ply	-	738	[illegible]	[illegible]	[illegible]	244	.37	226	165-304
8	MA1 Convent	-	130	1	33	[illegible]	[illegible]	.60	173	[illegible]
9	MI1 Grand R III	-	451	6	38	14	145	.71	60	[illegible]
10	WI1 Pit1 AA-S	-	2901	2	31	4	-	-	-	-
11	FL2 Cedar	-	76	-	6	0	-	-	-	-
12	MA1 Anon	-	601	9	33	5	176	1.50	99	[illegible]
13	MI3 Pelr 4A-N	-	2871	7	26	4	-	-	-	-
14	MI1 Grace N	-	154	5	78	9	149	.35	146	[illegible]
15	MI3 Swift Run	-	1207	2	4	7	-	-	-	-
16	SD1 Meade	-	2610	-	-	0	-	-	-	-
17	CA1 Knox	-	1542	17	-	21	202	[illegible]	31	[illegible]
19	FL1 N. Jesuit	-	30	-	11	15	94	.68	79	69-101
19	FL1 Wilder	-	194	-	97	15	51	.95	27	[illegible]
20	CO1 North Ave	-	69	9	50	13	541	.82	471	241-[illegible]

Commercial

	Site	Land Use % Comm	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	CO1 Villa Italia	100	74	0	91	27	128	.82	297	195-[illegible]
2	NC1 1011 (C90)	100	21	0	19	60	531	.51	478	428-576
3	MI1 Southgate	100	179	2	21	9	1436	1.56	517	314-1747
4	WI1 Post Office	100	12	0	100	32	145	1.16	44	71-124
5	NH1 Plg Lot	100	1	0	36	31	511	.65	410	361-517
6	TN1 CBD	100	26	0	99	15	115	.41	289	240-349
7	WI1 Rustler	100	12	0	-	19	156	.75	175	96-161
8	KS1 IC Metcalf	96	58	-	97	7	465	.79	168	372-611
9	FL1 Norma Pk	91	47	-	45	12	17	.88	29	19-41
10	WI1 State Fair	74	29	10	77	7	380	.65	234	150-163

Industrial

	Site	Land Use % Ind	Area (A)	Pop. Den (#/A)	% IMP.	No. of OBS	Total Zinc Mean	COV	Median	90% Confidence Limits
1	MA2 Addison	100	10	0	69	0	-	-	-	-
2	MI1 Indus Drain	100	62	0	64	7	244	.32	225	167-303
3	KS1 Lenexa	56	72	-	44	6	1721	3.79	701	217-2864
4	MI1 Grace S.	52	75	5	39	7	233	.54	196	175-264

* All observations below detection limit.

These tables (one for each pollutant) list each of the appropriate sites in the data base, grouped according to general land use category. Some pertinent site characteristics are identified: drainage area, population density, and the percentage of the total area covered by impervious surfaces. The number of monitored storms at each site is tabulated. Urban runoff quality is summarized by the mean and median EMC for all storms monitored at the site, the storm-to-storm variability of EMC's (defined by the coefficient of variation), and the 90 percent confidence limits for the site median EMC.

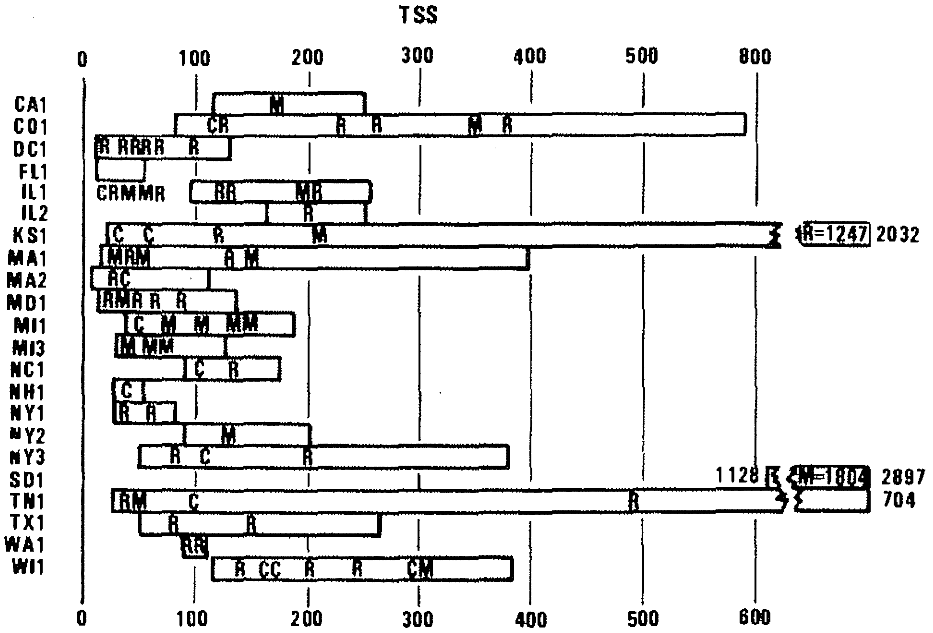
Transferability of Data

The urban runoff loading site EMC data were carefully examined in an effort to determine whether specific groupings of results would suggest the presence of consistent patterns of similarities and/or differences that could be used to support estimates of urban runoff characteristics at unmonitored locations and sites.

Variability of EMCs at a Site. Inspection and analysis of the individual site coefficient of variation entries in Tables 6-1 through 6-10 shows that with very few exceptions (usually associated with constituents that were monitored in fewer than 10 storm events) the coefficients of variation fall in the range of 0.5 to 1.0. This applies to all constituents except TSS, for which the range in coefficients of variation is more like 1 to 2.

The frequency of occurrence of any EMC of interest can be estimated readily from the coefficient of variation by using the procedures outlined in Chapter 5. Thus, for TSS, 90 percent of the individual storm events at a given site will have EMCs that do not exceed a value of roughly 3 to 5 times the median EMC value for that site. For the other constituents, 90 percent of the individual storm events at a site will have EMCs less than about 2 to 3 times the median EMC value for that site. More refined estimates and values for other exceedance probabilities can be readily computed using the relationships presented in Chapter 5.

Effect of Geographic Location. Figures 6-4 through 6-13 indicate the range of median EMC's at individual sites, grouped by project. The land use category of the site is indicated by the letter R for residential, M for mixed, and C for commercial/industrial, and the plotting position is the median value as given by the data in Tables 6-1 through 6-10. The ends of the bars for each project are the highest and lowest 90 percent confidence limits for site median EMCs at the project for the constituent in question. Inspection of Figures 6-4 through 6-13 indicates that, for any given constituent, each project can be put into one of three rather general categories: (1) low EMCs and tightly grouped; (2) average characteristics; and (3) wide range and high EMCs. Using the numbers 1, 2, and 3 as shorthand, project categories for each constituent are summarized in Table 6-11. Although no site is category consistent for all constituents, WASHCOG (DC1), Tampa (FL1), Lansing (MI1), and Ann Arbor (MI3) tend to have lower and more tightly grouped EMCs than the others while Kansas City (KS1), Lake Quinsigamond (MA1), and Baltimore (MD1) tend to have a wider range and higher EMCs than the others. Thus we can conclude that some projects represented in the database appear, from the monitoring sites selected, to tend towards somewhat higher or lower EMC median values and ranges than the bulk of the projects. However, there are no distinct geographical patterns revealed.



83-2061

Figure 6-4. Range of TSS EMC Medians (mg/l) by Project

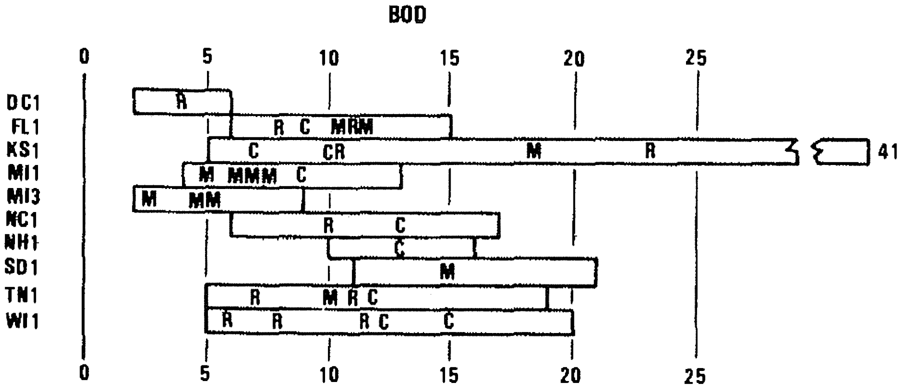


Figure 6-5. Range of BOD EMC Medians (mg/l) by Project

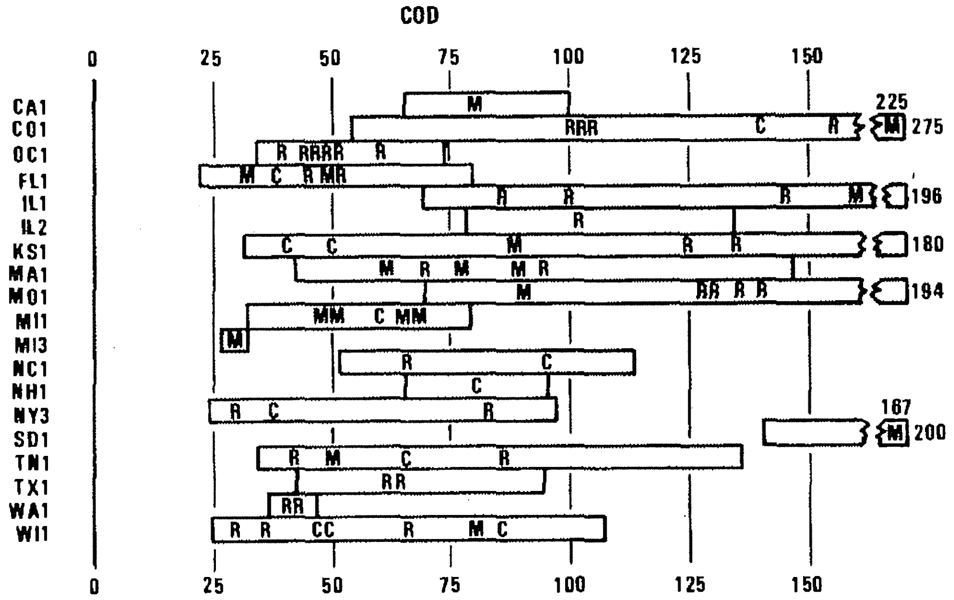


Figure 6-6. Range of COD EMC Medians (mg/l) by Project

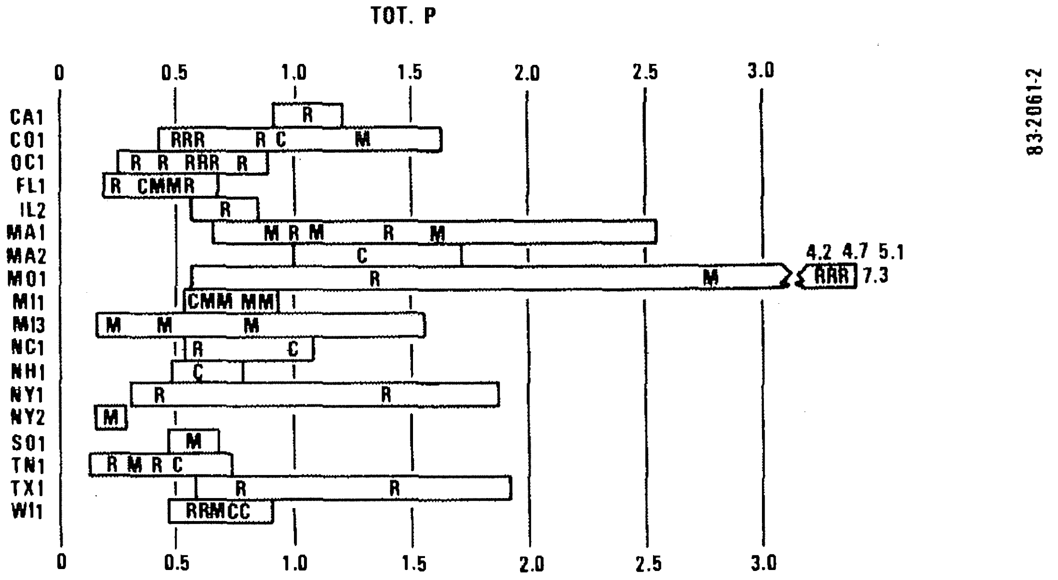


Figure 6-7. Range of Total P EMC Medians (mg/l) by Project

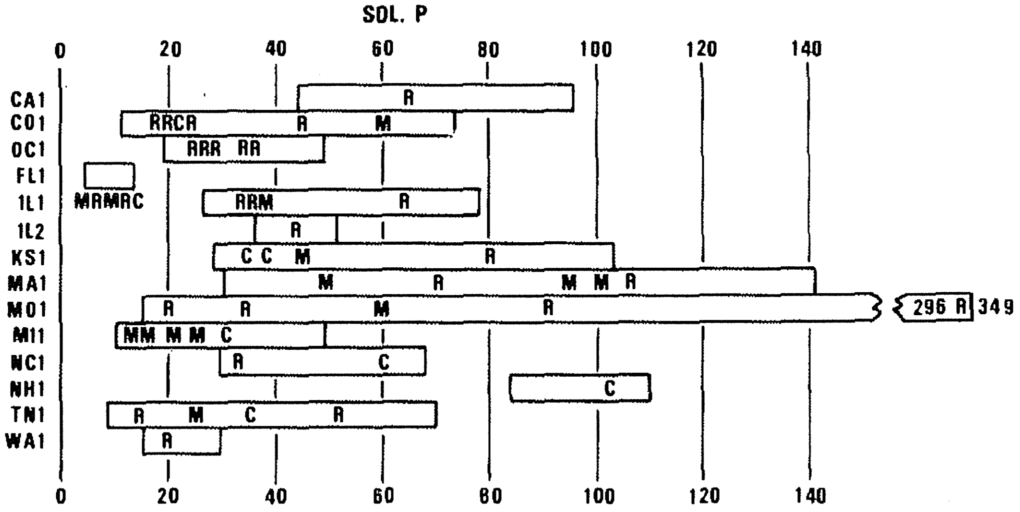


Figure 6-8. Range of Soluble P EMC Medians (mg/l) by Project

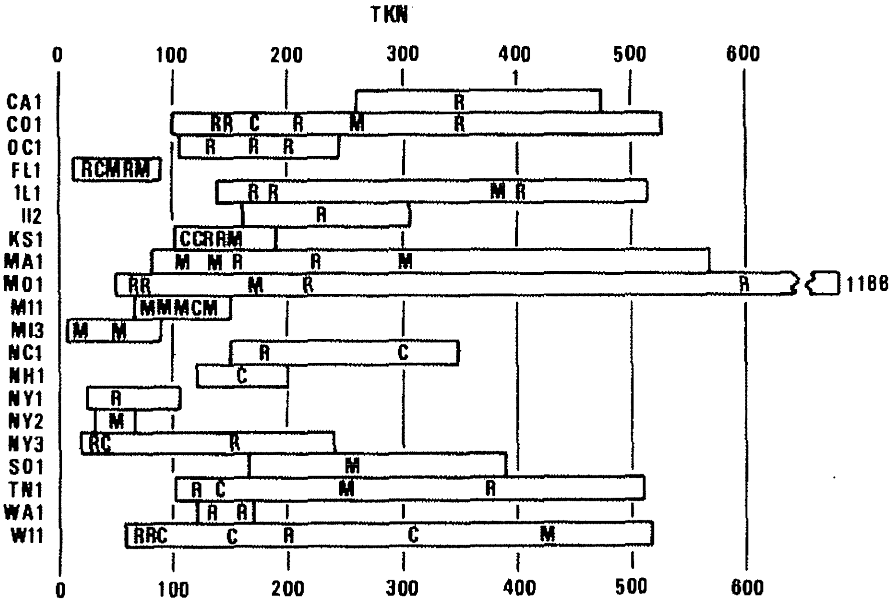


Figure 6-9. Range of TKN EMC Medians (mg/l) by Project

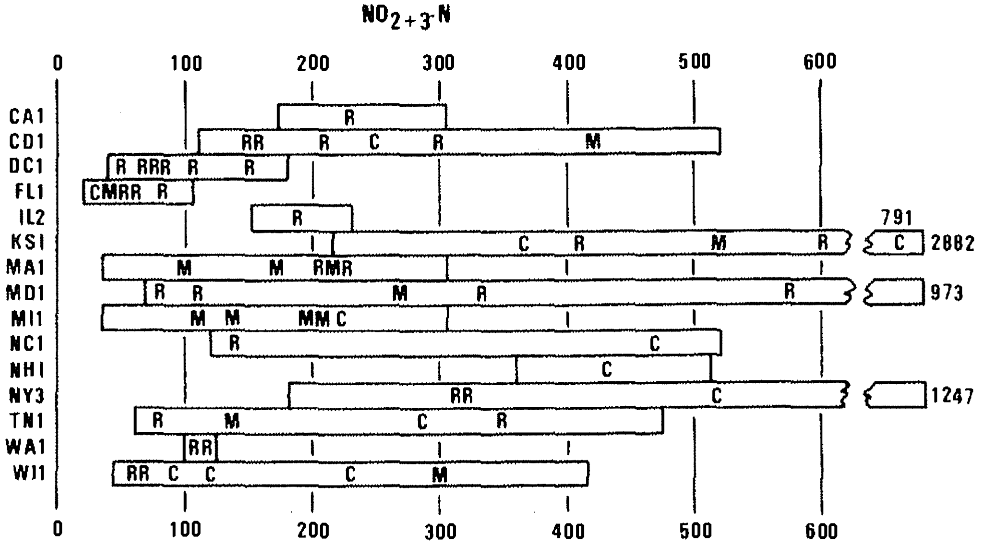


Figure 6-10. Range of NO_{2+3}-N EMC Medians (mg/l) by Project

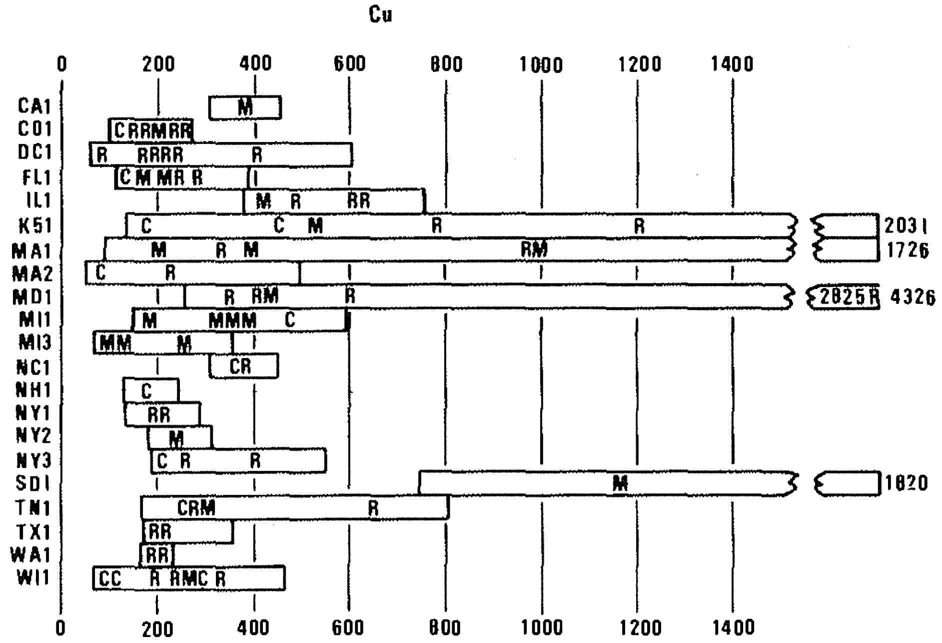


Figure 6-11. Range of Total Cu EMC Medians (µg/l) by Project

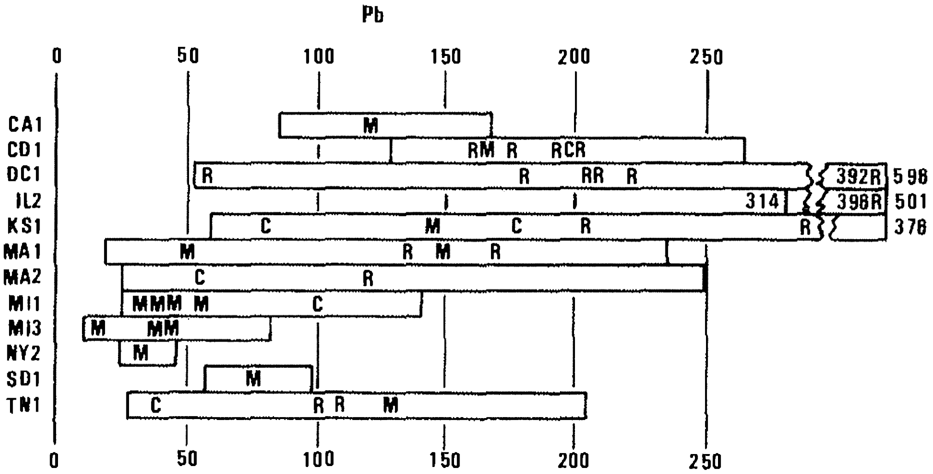


Figure 6-12. Range of Total Pb EMC Medians (µg/l) by Project

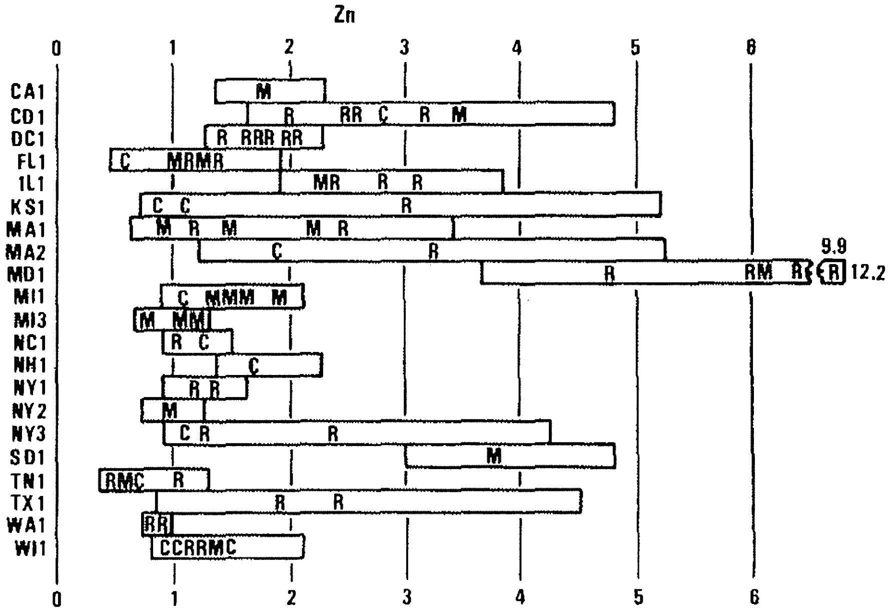


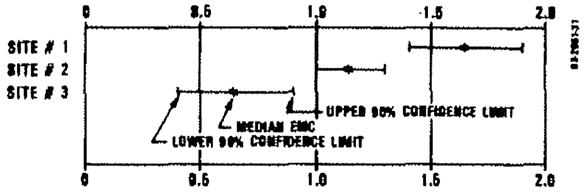
Figure 6-13. Range of Total Zn EMC Medians (µg/l) by Project

TABLE 6-11. PROJECT CATEGORY SUMMARIZED BY CONSTITUENT

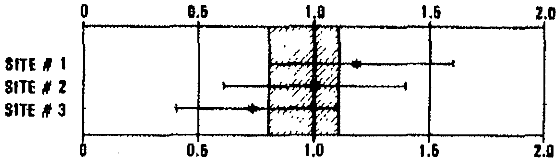
	CO1	DC1	FL1	IL1	KS1	MA1	MD1	MI1	MI3	NY3	TN1	WI1
TSS	3	1	1	2	3	3	1	1	1	2	3	2
BOD	-	-	2	-	3	-	-	2	1	-	2	2
COD	3	1	1	3	3	2	3	1	-	1	2	2
Tot. P.	1	2	1	2	3	3	3	2	1	2	2	2
Sol. P.	2	3	-	-	3	2	-	2	1	-	2	-
TKN	2	1	1	2	2	2	3	1	1	2	1	1
NO_{2+3}-N	2	1	1	-	-	3	3	1	2	-	1	1
Tot. Cu	2	1	1	2	2	3	3	1	-	-	2	-
Tot. b	2	1	1	2	1	2	3	1	-	1	2	2
Tot. Zn	2	1	1	-	3	2	3	2	-	3	2	2

It must also be realized that had any particular project monitored other local sites (or additional sites) its categorization could well change. This can be seen qualitatively by perusing Figures 6-4 through 6-13 and mentally dropping the highest or lowest site from each grouping. Although some locations, such as Tampa, will undoubtably and appropriately be influenced by the relatively low EMCs and tight groupings found there in estimating probable values for other urban sites in the area, there is little to warrant attributing similar characteristics to other locations in the same geographical region. For the other locations it would appear that individual site differences eclipse any possible geographic ones.

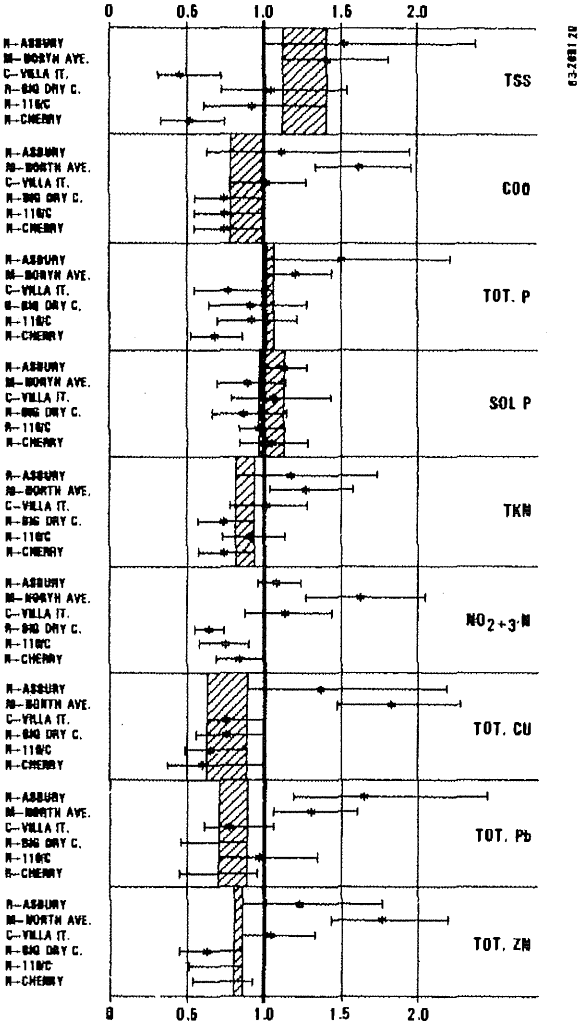
Effect of Land Use Category. The data in Tables 6-1 through 6-10 were presented by land use category; residential, mixed, commercial, industrial, and open/non-urban. The question to be addressed here is the extent to which such site categorization can be used to assist in predicting EMC parameters for unmonitored sites. Two approaches were used. In the first, the site data for each project with more than three sites were normalized by dividing the site median and its upper and lower 90 percent confidence limits by the average project median value for the constituent in question. This procedure simply allows all constituents to be viewed on a common scale that is centered at unity. An example of the result is given in Figure 6-14. A legend is provided in Figure 6-14(a) showing the lower 90 percent confidence limit, the upper 90 percent confidence limit, and the location of the point estimate of the median within this confidence interval for a hypothetical constituent. Sites that fall to the right of the unity line have higher EMCs than average for this location, while sites that fall to the left of the unity line have lower EMCs than average. Thus, the interpretation is that for this location, Site #1 is the "dirtiest" (has the highest EMC value), Site #3 is the "cleanest", and Site #2 is in between, being somewhat "dirtier" than average. Since the 90 percent confidence limits for these three sites no not overlap, we know that this difference is statistically significant.



(a) Significantly Different Sites



(b) Sites with No Significant Difference



(c) EMC Data from Denver (CO1)

Figure 6-14. Range of Normalized EMC Medians at Denver (CO1)

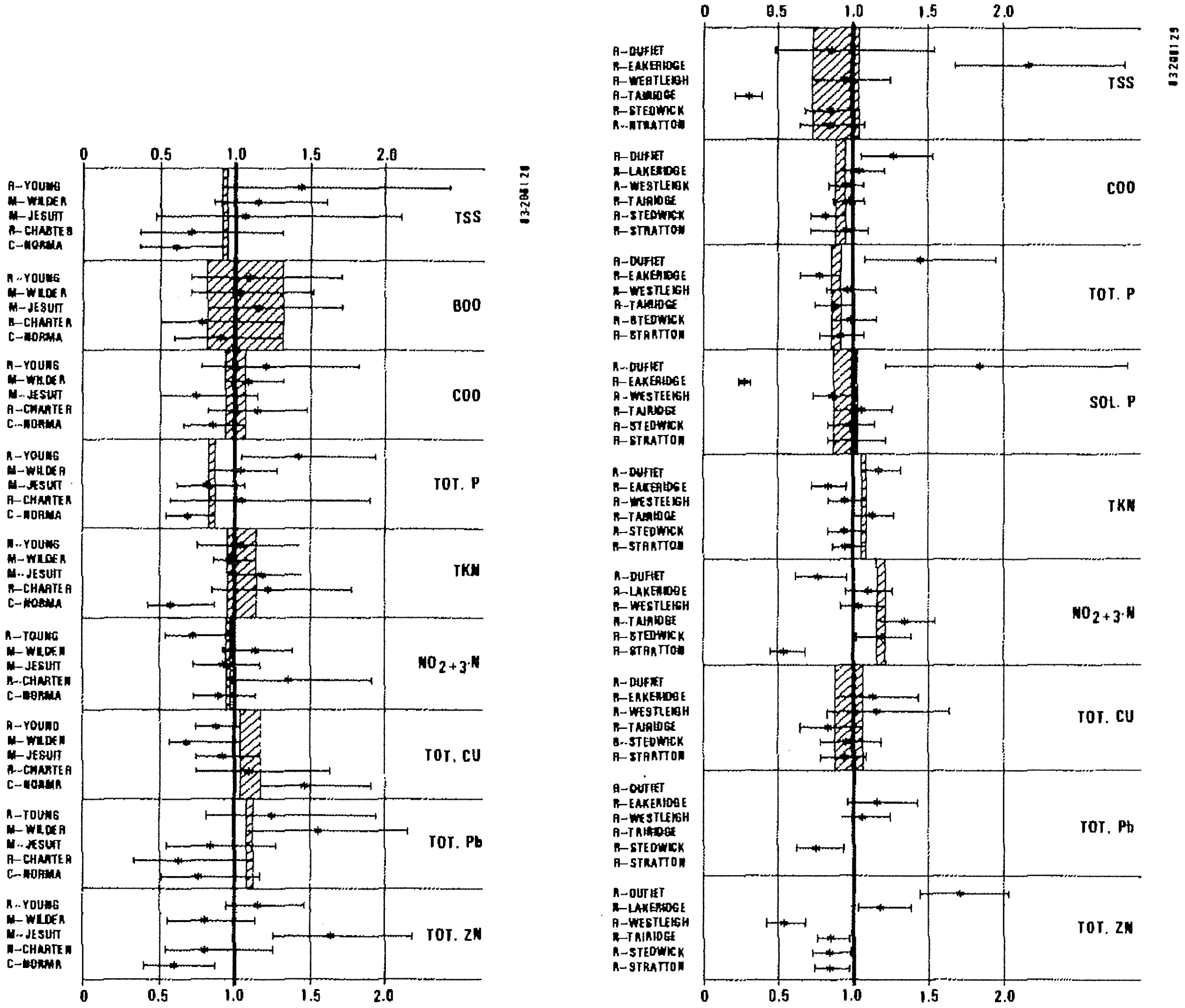
The actual data for the Denver (CO1) project are presented in Figure 6-14(c). With the exception of nitrate + nitrite, there is little to no statistically significant difference among the majority of the sites for each constituent examined. The lack of consistency among the sites over the various constituents is apparent. One can observe that the Cherry site (residential) tends to plot at the lowest position for all constituents, suggesting that it is the "cleanest," the Asbury site (also residential) tends to plot at the highest position, suggesting that it is the "dirtiest." The Big Dry Cottonwood site, which is also residential, tends to fall between these two. Careful examination of other site data does not provide any evidence to explain this difference in response for sites in the same land use category at the same location. Thus, based on the information presented in Figure 6-14(c), one is forced to conclude that land use category does not provide a useful basis for predicting differences in site EMC values, at least for this project.

When the foregoing type of analysis was applied to the other applicable NURP projects, the results were the same. As another example, the range of normalized EMC medians at Tampa (FL1) and WASHCOG (DC1) are shown in Figure 6-15. These are essentially similar to the Denver results just discussed.

The WASHCOG data presented in Figure 6-15(b) suggest that there is little consistent difference among residential land use sites at that project. The data from Champaign/Urbana (IL1) presented in Figure 6-16 suggest just the opposite. As a part of this project's experimental design, two site pairs were selected. The sites of each pair were expected to respond in a similar fashion. That they do and that the responses of the two pairs are different from each other for most constituents is apparent in Figure 6-16. However, there is no consistency in the pair responses. For example, the Mattis pair has significantly higher EMC values for TSS, COD, and Total Pb, while the John Pair is higher in Total P. The residential land use category for these sites provides no explanation of these differences in response.

Based upon the foregoing approach, we can conclude that, while there can be differences in the responses of different sites at a given location, significant differences do not appear to be widespread, and where they occur, the site land use category is virtually useless in trying to understand or predict them.

The second approach to examining the effect of land use category on the EMC parameters of a site makes use of the observation, discussed earlier, that geographic location has no discernible effect on site response. Since site to site variability was shown to be very well represented by the lognormal distribution, analysis procedures similar to those described previously for characterizing an individual site were applied. Table 6-12 lists the median EMCs for all sites within each land use category. The coefficient of variation quantifies the variability of site characteristics within the land use category. To the extent that the sites included in this database provide a "representative" sample of the land use classifications, then the information summarized by Table 6-12 indicates the effect of land use on urban storm runoff pollutant discharges.



(a) Tampa Sites

(b) WASHCOG Sites

Figure 6-15. Range of Normalized EMC Medians at FL1 and DC1

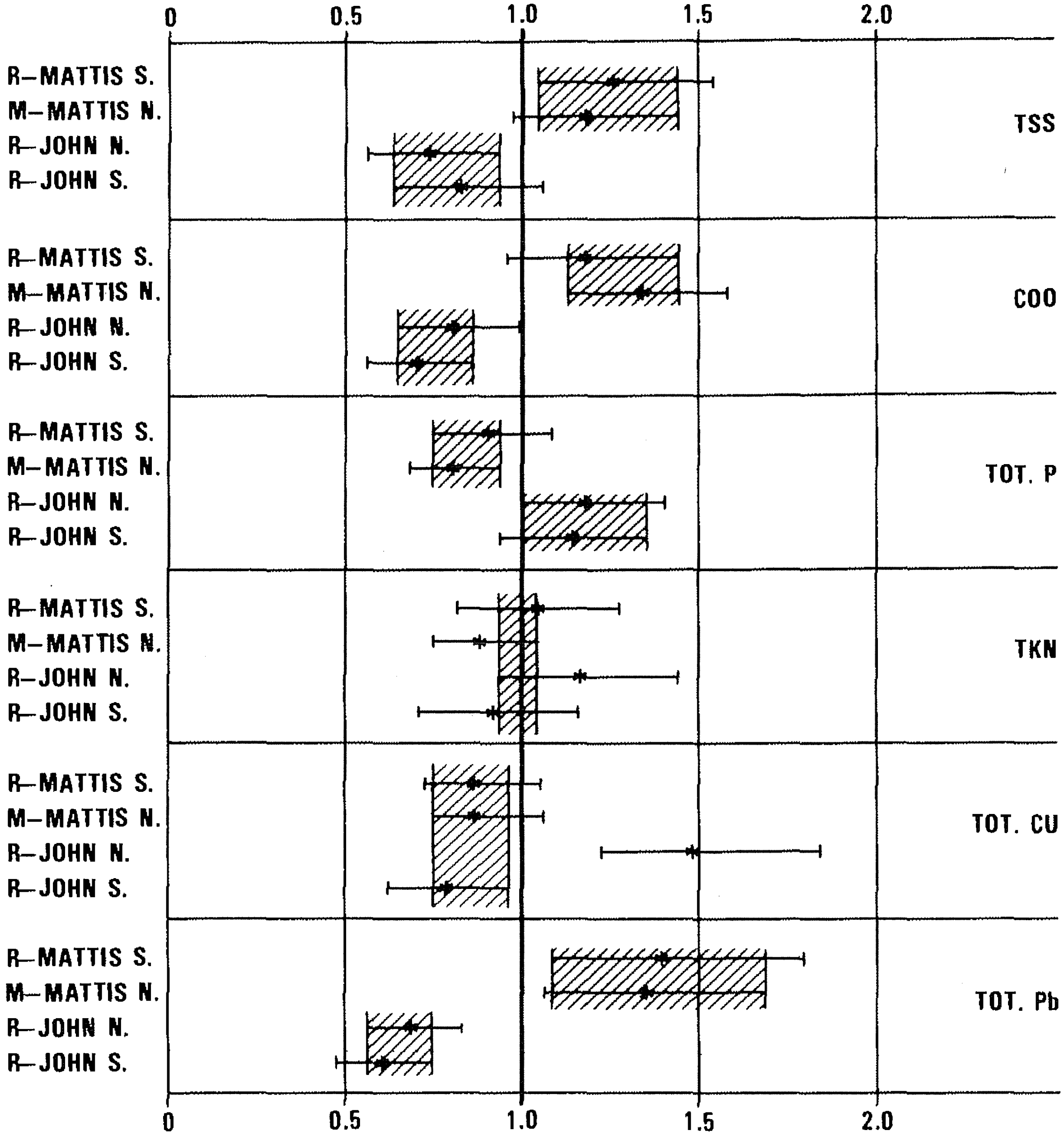


Figure 6-16. Range of Normalized EMC Medians at IL1

TABLE 6-12. MEDIAN EMCs FOR ALL SITES BY LAND USE CATEGORY

Pollutant		Residential		Mixed		Commercial		Open/Nonurban	
		Median	CV	Median	CV	Median	CV	Median	CV
BOD	mg/ℓ	10.0	0.41	7.8	0.52	9.3	0.31	-	-
COD		73	0.55	65	0.58	57	0.39	40	0.78
TSS		101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/ℓ	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper		33	0.99	27	1.32	29	0.81	-	-
Total Zinc		135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen		1900	0.73	1288	0.50	1179	0.43	965	1.00
NO_2 -N + NO_3 -N		736	0.83	558	0.67	572	0.48	543	0.91
Total P		383	0.69	263	0.75	201	0.67	121	1.66
Soluble P		143	0.46	56	0.75	80	0.71	26	2.11

Some caution in the interpretation of the information presented in Table 6-12 is in order since statistical confidence limits are not given. These are indicated in Figure 6-17 (a through k), which illustrates land use differences graphically, with additional statistical detail derived from the basic parameters listed in Table 6-11, to assist in interpretation and comparisons. The box plots which compare characteristics of all sites within a land use category identify the land use, median EMC, its 90 percent confidence limits, and the 10, 25, 75 and 90 percent quantities for the sites. Careful perusal of these box plots leads one to the conclusion that only the open/non-urban land use category appears to be significantly different overall. Responses of the other land use categories are varied and inconsistent among constituents. This may be seen in a somewhat different way by observing the plotting positions of the land use categories presented in Figures 6-4 through 6-13. Here also, there are no consistent tendencies. There are undeniably some trends. For example, in Figure 6-7 commercial sites occupy the lowest plotting position at each project for total phosphorus (MI1 and one WI1 site are exceptions), which certainly suggests that there might be a land use category difference for this constituent.

Review of Figure 6-17(j), however, suggests that while a trend to lower total phosphorus EMC values is apparent as one goes from residential, to mixed, to commercial land uses, the statistical significance may not be great. The actual site median total phosphorus EMC probability density functions for each land use are presented in Figure 6-18. Here it can be seen that although three different pdfs can be drawn for residential, mixed, and commercial land use categories, their degree of overlap is so great that there is little statistical significance to the apparent difference. Since this was the strongest tendency towards land use effect, we must conclude that using this approach there is again no truly discernible and consistent effect of land use on the quality of urban runoff.

The one exception is the open/non-urban category which, as its name suggests, includes atypical sites. The data in Table 6-12 and the box plots of Figure 6-12 suggest that the pdfs for this land use category are quite different from those of the other land use categories, and this is in fact the case. Figure 6-18 shows it dramatically for total phosphorus.

Thus, regardless of the analytical approach taken, we are forced to conclude that, if land use category effects are present, they are eclipsed by the storm to storm variabilities and that, therefore, land use category is of little general use to aid in predicting urban runoff quality at unmonitored sites or in explaining site to site differences where monitoring data exist.

Correlation Between EMCs and Runoff Volume. To examine the possible relationship between the event mean concentration of a particular constituent and the runoff volume, linear correlation coefficients (r) were calculated. The null hypothesis that the two variables are linearly unrelated was tested at both the 90 and 95 percent confidence levels. Since it is possible for correlation to be either positive or negative, the two-tailed test was used. Failure to reject the null hypothesis is interpreted as meaning that linear dependency between the two variables in the population has not been shown.

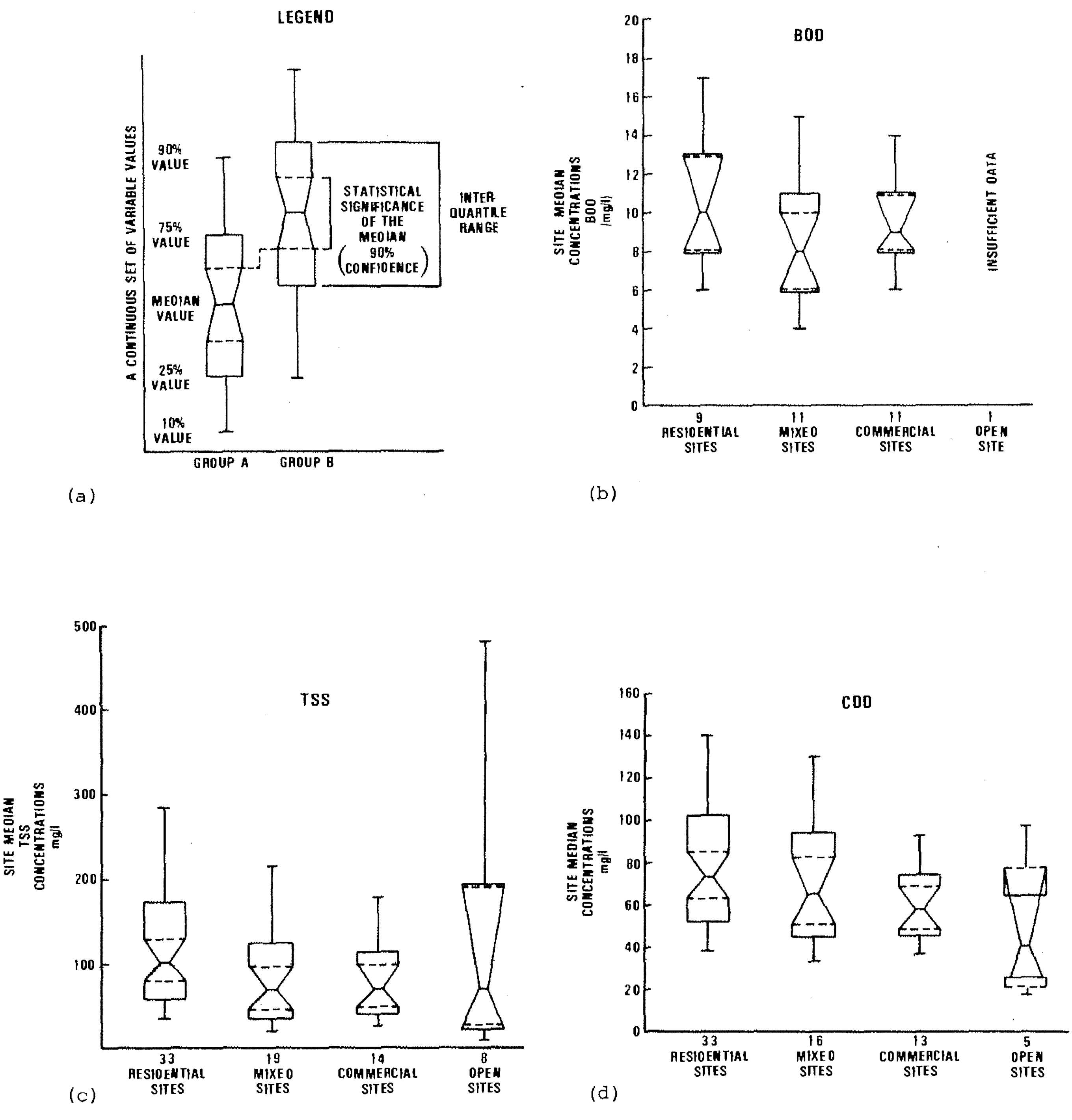
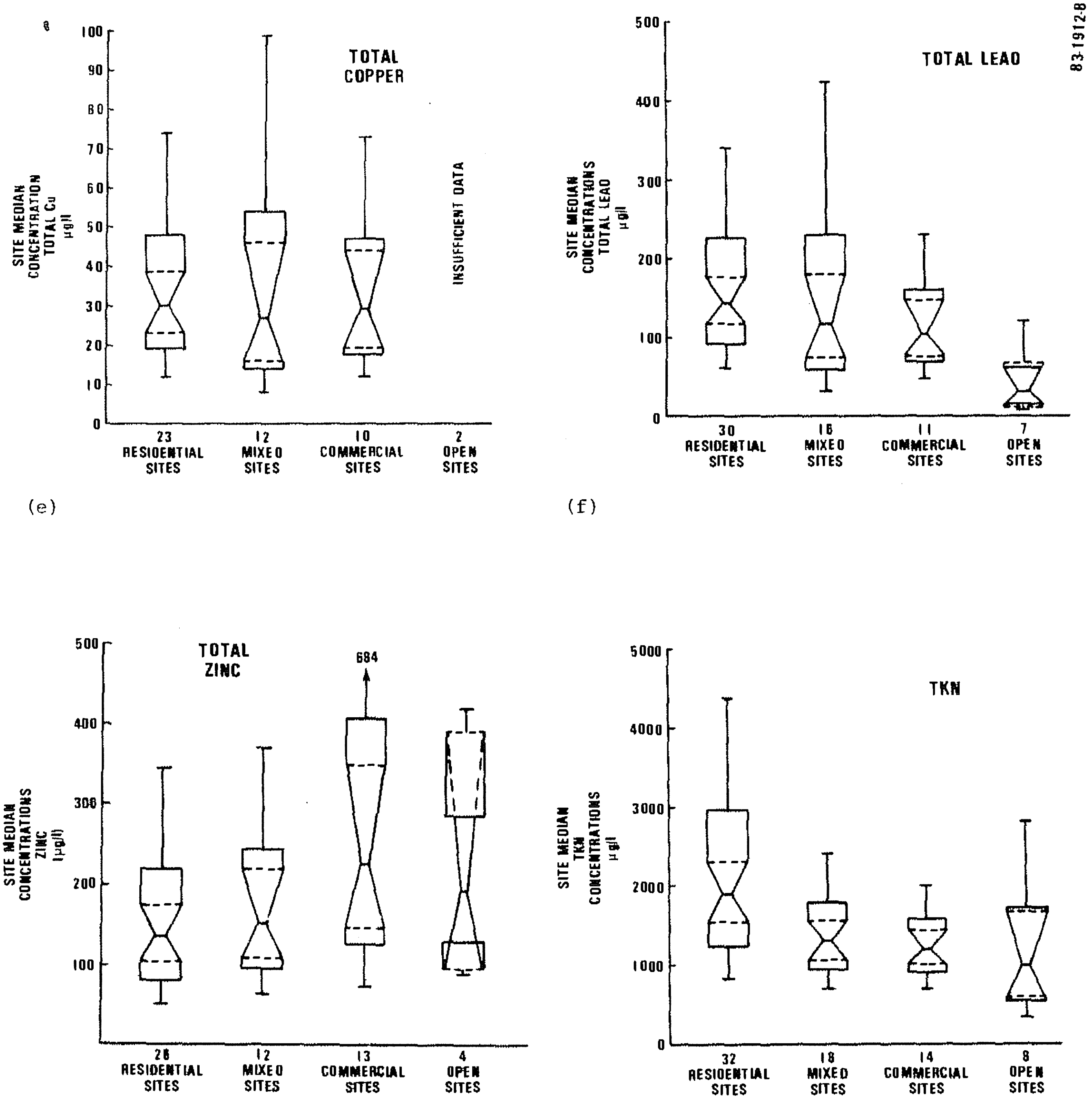


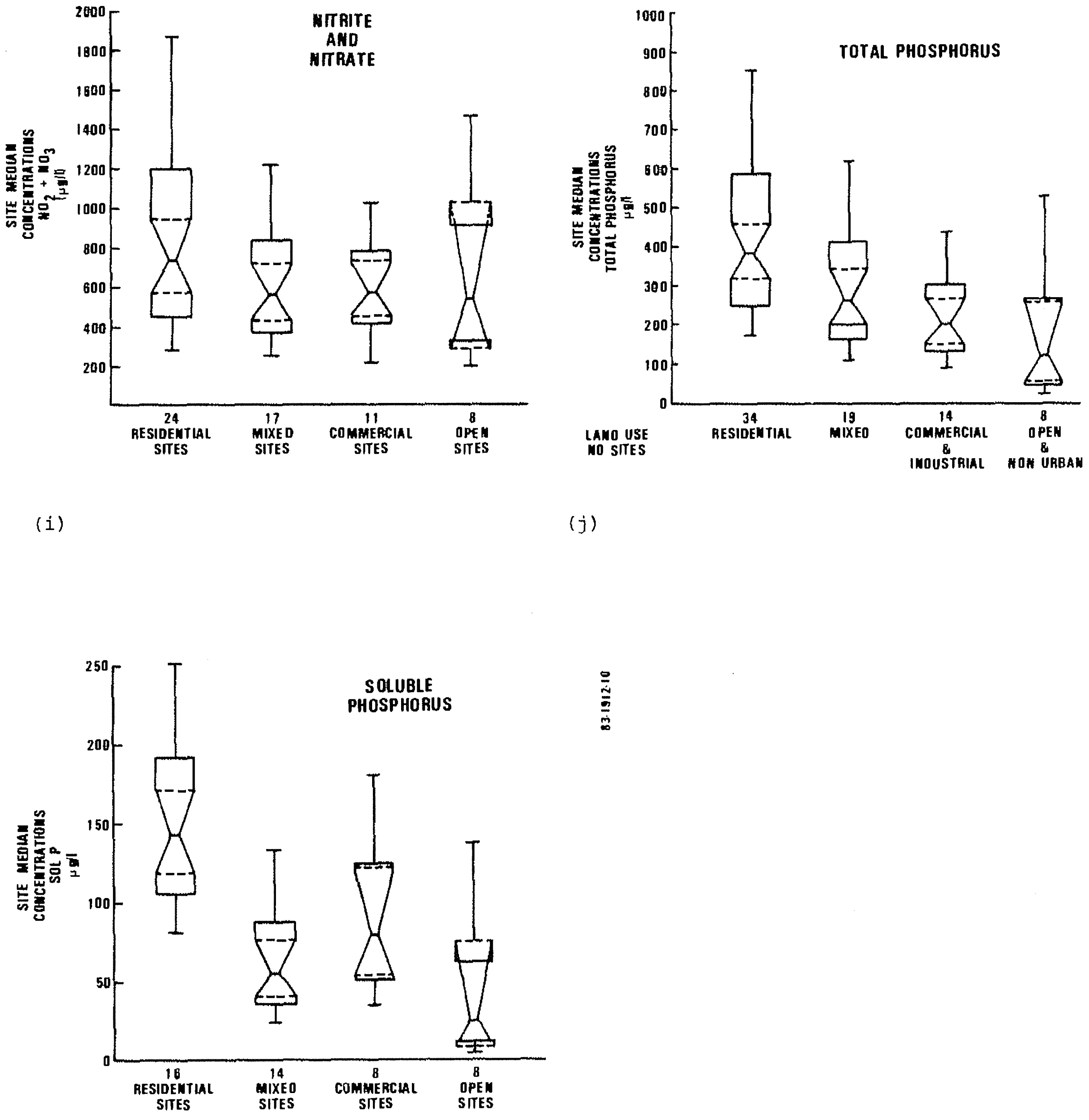
Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses



(e) (f)

(g) (h)

Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses (Cont'd)



(i)

(j)

(k)

Figure 6-17. Box Plots of Pollutant EMCs for Different Land Uses (Cont'd)

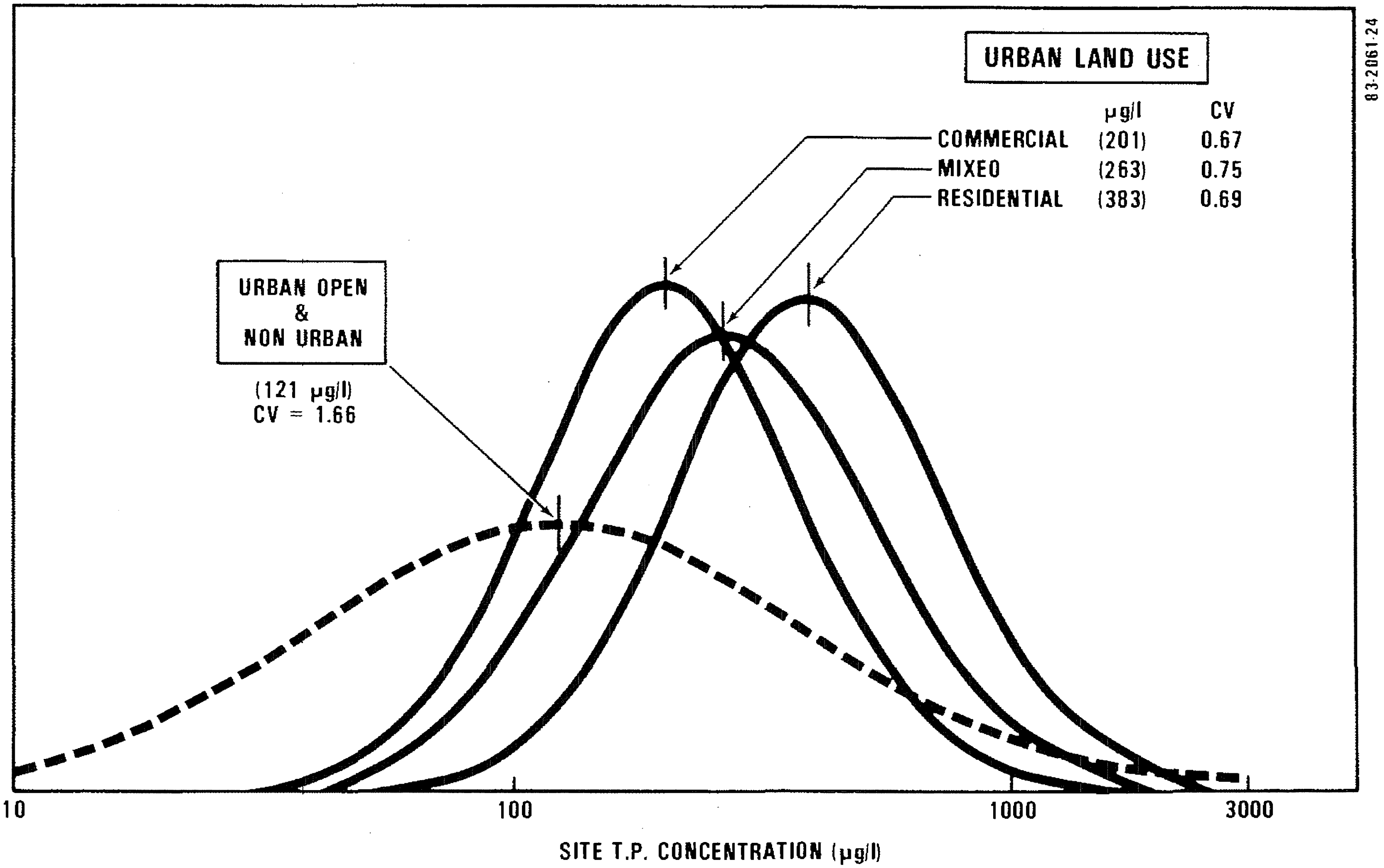


Figure 6-18. Site Median Total P EMC Probability Density Functions for Different Land Uses

The rejection of the null hypothesis means that there is evidence of a linear dependency between the two variables in the population, but it does not mean that a cause-and-effect relationship has been established.

General guidelines for the use of this test suggest that it be used with caution for values of n less than ten due to the high uncertainties associated with estimates of population variance with small samples. Furthermore, when n is 2 a perfect correlation will result but is meaningless. To include as many sites as possible in this examination, all constituents for which n was 5 or greater were included. At the other extreme, when n is very large, say over 100, correlation coefficients are almost always significant but can be so weak that they are meaningless. For n = 100 the critical value of r at the 90 percent confidence level is 0.164, meaning that the correlation explains less than 3 percent of the concentration variability.

A total of 67 sites from 20 of the NURP projects were examined for possible correlation for nine constituents. Of the 517 linear correlation coefficients calculated (not all constituents were measured at all sites), 116 (22 percent) were significant at the 95 percent confidence level and 154 (30 percent) were significant at the 90 percent confidence level. Of the r values that were significant, 83 and 87 percent were negative at the 90 and 95 percent confidence levels respectively. When sites with fewer than 10 events were dropped, the foregoing was essentially unchanged. Greater detail in terms of the number of significant linear correlation by constituent is provided in Table 6-13. There it can be seen that the greatest tendency for positive values of r occurs with TSS, followed by soluble phosphorus. The correlation coefficients for the other 7 constituents all strongly tend to be negative.

When the results are examined by sites, however, a clearer picture emerges. Although it can be correctly argued that unless a correlation coefficient is statistically significant the number is meaningless, it also follows that in such a case they are as likely to be positive as negative. On the other hand, if all the correlation coefficients (whether significant or not) have the same sign, it suggests a tendency for that site. The sign of the correlation coefficient (if greater than 0.1) for each site and constituent examined is given in Table 6-14. Giving appropriate weight to significant r values but considering others as well, some 37 of the sites tend to have negative correlations, 13 tend to be positive, and the remaining 17 tend to be mixed. Perusal of Table 6-14 reveals that this tendency for sites to have either positive or negative correlation coefficients is quite strong, especially for sites with a large number of significant correlations. Sites where erosion, scour, system lag, and such are present could be expected to exhibit a tendency towards positive correlations. Sites lacking such effects could be expected to have negative correlation due to dilution associated with larger runoff events.

The magnitude of the correlation coefficients is indicated in Table 6-15. Two points stand out in particular. First, the r values are not very large, averaging around 0.55. This means that the correlation is only able to explain about 30 percent of the concentration variability. The few high values are always associated with very few observations ($n<10$) for which the

TABLE 6-13. NUMBER OF SIGNIFICANT LINEAR CORRELATIONS BY CONSTITUENT

(a) ALL SITES							
POLLUTANT	TOTAL # OF SITES	90% SIGNIFICANT CORRELATION			95% SIGNIFICANT CORRELATION		
		TOTAL #	# NEG.	# POS.	TOTAL #	# NEG.	# POS.
TSS	67	13 (19%)	4	9	7 (10%)	3	4
COD	64	24 (38%)	23	1	19 (30%)	19	0
TOT. P	67	20 (30%)	16	4	15 (22%)	12	3
SOL. P	34	10 (29%)	6	4	7 (21%)	4	3
TKN	64	19 (30%)	18	1	14 (22%)	14	0
NO_{2+3}-N	57	17 (30%)	15	2	13 (23%)	11	2
TOT. Cu	49	17 (35%)	15	2	13 (27%)	12	1
TOT. Pb	59	15 (25%)	13	2	12 (20%)	11	1
TOT. Zn	56	19 (34%)	18	1	16 (29%)	15	1
TOTAL	517	154	128	26	116	101	15
PERCENT		30%	83%	17%	22%	87%	13%
(b) SITES WITH n ≥ 10							
TSS	56	9 (16%)	4	5	7 (12%)	3	4
COD	52	21 (40%)	20	1	16 (31%)	16	0
TOT. P	53	17 (32%)	15	2	12 (23%)	11	1
SOL. P	23	8 (35%)	5	3	6 (26%)	4	2
TKN	50	17 (34%)	16	1	12 (24%)	12	0
NO_{2+3}-N	41	14 (34%)	12	2	12 (29%)	10	2
TOT. Cu	31	13 (42%)	12	1	12 (39%)	11	1
TOT. Pb	45	13 (29%)	12	1	11 (24%)	10	1
TOT. Zn	37	14 (38%)	13	1	11 (30%)	10	1
TOTAL	388	126	109	17	99	87	12
PERCENT		32%	87%	13%	26%	88%	12%

TABLE 6-14. SIGN OF CORRELATION COEFFICIENTS BY SITES

83-2061-33

		TSS	COD	TOT. P	SOL. P	TKN	NO_2+3-N	TOT. CU	TOT. Pb	TOT. ZN
CA1	KNOX	+	−	+	⊕		⊕	−	−	
	S. VIEW.	⊕	+			⊕		+	−	+
CO1	ASBURY	⊕	+	⊕	+	+	−	⊕	+	+
	B. DRY C.		−	−	−	⊖	−	−		−
	CHERRY			+	⊕		−	+		
	N. AVE.		⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖
	ROONEY	−	⊖	−	−	−	−	−	−	⊖
	VILLA IT.	−	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖
	116/C	+	−	⊕			−	+		+
DC1	DUFIEF	−	⊖	+	−	−	−			−
	FAIRIDGE		+	+	+	+				+
	LAKERIDGE	+		+	⊕		⊖		−	⊖
	STEDWICK		−		+		⊖	+	−	⊖
	STRATTON	+	−			+		−		−
	WESTLEIGH		⊖			−	⊖	⊖	−	⊖
FL1	CHARTER/H	−	⊖	⊖		⊖	−	⊖	⊖	⊖
	YOUNG		−	−			−	+		
	NORMA P.	+	+				+			−
IL1	JOHN N.	+	⊖	⊖		⊖		−	−	
	JOHN S.	+	⊖	⊖		−		−		
	MATTIS N.		⊖	⊖		⊖		⊖	⊖	
	MATTIS S.	−	⊖	⊖		⊖		⊖	⊖	
KS1	92nd	−	+	−	+	+				

		TSS	COD	TOT P.	SOL P	TKN	NO 2+3-N	TOT. CU	TOT. Pb	TOT. ZN
KS1	LENAXA	+	⊖	⊖	−	−		⊖		
	METCALF		−	−	−	−		−		−
	NOLAND		⊖	−	⊖			+	−	−
	OVERTON	+		+				−	−	⊖
MA1	ANNA	+		+		+	−		−	+
	CONVENT	−	+		+	−	−	+		+
	JORDAN			+	+	−	⊖	−		⊖
	LOCUST	⊕	+	⊕	+	+	⊖	+	⊕	
	RT. 9	+			+	−	⊖	+	+	
MA2	ADDISON	⊕		−	−	+	−			
	HEMLOCK	⊕		+	⊕	+	−			
MO1	BOLTON	⊕	−	+		−	−	⊖	+	−
	HAMPDEN		−	⊖				⊖		−
	HOMELAND	+	+	+		−	+	−	+	+
	MT. WASH.	⊕	−	−		−	−	+	−	−
	RES. HILL	+	⊖			⊖		⊖	−	−
MI1	GRACE S.	+	−	−		−	−	⊖	−	−
	GRACE N.	+	−		+					⊖
	GRAND		−	−		−		−	−	⊖
	IND. DR.	+		+	+		−	−	−	−
	WAVERLY		−	−	−	−	−	−		−
NC1	1013		⊖	⊖		⊖	⊖	⊖	⊖	⊖
	1023	⊕		+			−	+		
NH1	PKG.	−	⊖	−		⊖	⊖	⊖	⊖	⊖

		TSS	COD	TOT. P	SOL. P	TKN	NO_2+3-N	TOT. CU	TOT. Pb	TOT. ZN
NY1	CARLL R.	+					⊖			
NY2	CEDAR				+		⊕		+	
NY3	CRANSTON	+	+	+		−			−	−
	E. ROCH.	−	⊖	⊖		⊖			⊖	⊖
	SOUTHGATE	+	−	+	−					−
TN1	CBD	⊖	−	⊖	⊖	⊖	−	⊖	⊖	⊖
	R1	⊕	+	+	⊖	+	−	⊕	⊕	⊕
	R2	+	−	−	−	⊖	−			−
	SC	+		−	⊖	−	⊖		+	
TX1	HART	+	⊕			+	+			
	R'WOOD.	−	+			⊖				
WA1	LAKE H.	−	⊖	−		⊖		+	⊖	⊖
	SURREY D.	−	⊖	⊖		⊖			⊖	⊖
WI1	BURBANK		−	⊕						+
	HASTINGS		⊖	−		+	+		⊖	−
	LINCOLN		−	−			−		+	
	POST O.	⊖	⊖	⊖		⊖	⊖		⊖	−
	RUSTLER	⊖	⊖	−		⊖	⊖			−
	STATE F.	⊖	⊖	⊖		−	⊖		−	+
	WOOD C.					−	−			+

\+ INDICATES A POSITIVE R VALUE

− INDICATES A NEGATIVE R VALUE

○ INDICATES A SIGNIFICANT R VALUE

BLANK INDICATES EITHER R LESS THAN 0.1 OR NO DATA

TABLE 6-15. CORRELATION COEFFICIENT VALUES BY SITE

83-2061-34

		TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
CA1	KNOX				.43		(.70)			
	S. VIEW.	(.57)				.49				
CO1	ASBURY	.58		(.84)				.58		
	B. DRY C.					-.47				
	CHERRY				(.10)					
	N. AVE.		(-.58)	(-.47)	(-.42)	(-.72)	(-.52)	(-.47)	(-.42)	(-.41)
	ROONEY		(-.78)							(-.75)
	VILLA IT.		(.70)	(-.58)	(-.67)	(-.69)	(-.44)	(-.48)	(-.55)	(-.61)
	116/C			(.85)						
DC1	DUFIEF		(.76)							
	FAIRIDGE									
	LAKERIDGE				(.42)		(-.28)			(-.41)
	STEDWICK						-.28			-.26
	STRATTON				-.2					
	WESTLEIGH		(.32)				-.38	(-.84)		(-.44)
FL1	CHARTER/H		(-.82)	.54	U	(.68)		-.54	(-.67)	-.58
	YOUNG				U					
	NORMA P.				U					
IL1	JOHN N.		-.31	(.38)	U	-.29	U			U
	JOHN S.		.36	(-.42)	U		U			U
	MATTIS N.		(-.84)	(.58)	U	(-.48)	U	(-.40)	(-.46)	U
	MATTIS S.		(-.81)	(-.56)	U	(.53)	U	(-.34)	(-.46)	U
KS1	92nd				U		U			

		TSS	COD	TOT P.	SOL P	TKN	NO 2+3-N	TOT. CU	TOT. Pb	TOT. ZN
KS1	LENAXA		(-.70)	(.51)	U		U	-.80		
	METCALF		.40	-.40	U		U			
	NOLAND		(-.77)		(-.82)	U	U			
	OVERTON					U	U			(-.57)
MA1	ANNA									
	CONVENT									
	JORDAN						(.68)			(.74)
	LOCUST	.80		(.91)			-.82		.78	
	RT. 9						-.87			
MA2	ADDISON	.83	U							
	HEMLOCK	.85	U		(.94)					
MO1	BOLTON	(.50)			U			(-.47)		
	HAMPDEN			.42	U			(-.61)		
	HOMELAND				U					
	MT. WASH.	.42			U					
	RES. HILL		(-.79)		U	(-.58)		(-.55)		
MI1	GRACE S.							.70		
	GRACE N.									(.80)
	GRAND									-.51
	IND. DR.									
	WAVERLY									
NC1	1013		(-.58)	(-.48)	U	(-.57)	(-.67)	(-.32)	(.29)	(.64)
	1023	(.32)			U					
NH1	PKG.		(-.58)		U	(.48)	(-.46)	(-.50)	(.41)	(-.58)

		TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	TOT. CU	TOT. Pb	TOT. ZN
NY1	CARLL R.		U		U		(-.70)	U		
NY2	CEDAR		U				(.42)	U		
NY3	CRANSTON				U		U	U		
	E. ROCH.		(.79)	(-.84)	U	.70	U	U	(-.72)	(-.72)
	SOUTHGATE				U		U	U		
TN1	CBD	.48		(.82)	-.47	(.56)		(.51)	(-.51)	(.85)
	R1	(.82)			(-.62)			(.72)	(.85)	(.82)
	R2					(.81)				
	SC				(-.49)		(.85)			
TX1	HART		.57		U			U		
	R'WOOD.				U	(-.77)		U		
WA1	LAKE H.		(.33)		U	(-.34)			(-.29)	(.37)
	SURREY D.		(-.38)	(-.30)	U	(-.21)		U	(-.18)	(-.23)
WI1	BURBANK			.26	U			U		
	HASTINGS		(.49)		U			U	(-.32)	
	LINCOLN				U	U		U		U
	POST O.	(-.39)	(-.28)	.24	U	(-.48)	(-.53)	U	.23	
	RUSTLER	(-.37)	(.55)		U	.39	.37	U		
	STATE F.	(-.47)	(-.48)	(-.47)	U		(.72)	U		
	WOOD C.				U			U		

◯ INDICATES 95% LEVEL OF SIGNIFICANCE, OTHERS ARE AT THE 90% LEVEL

U INDICATES AN UNMEASURED CONSTITUENT

BLANK INDICATES NO SIGNIFICANT CORRELATION test is suspect since one or two events may dominate the correlation or otherwise cause it to be overstated due to uncertainties in parameter estimation. Second, only 25 percent of the sites account for over two-thirds of the significant correlations. In fact, 33 of the 67 sites had at most one significant correlation, 16 had 2 or 3, and 18 had 4 or more significant r values.

Data for the sites with many significant correlations are presented in Table 6-16. It can be noted that the r values for all constituents are around 0.55. Thus, there is no overall tendency to have strong correlations for some constituents and weak correlations for others. On a site by site basis, the strength of the apparent correlation varies inversely with n as does the significance requirement. Discounting the sites with very low or high values of n, however, the r values for the remainder are again around 0.55, which is the average for all 19 of these sites. Turning to land use, it is significant that half of the sites with many significant correlations have a large commercial/industrial component. Discounting sites with a small number of observations ($n \leq 12$), the sites in Table 6-16 are smaller (average size is 41 acres vs 126 acres for all sites), more impervious (average of 65 percent vs 40 percent for all sites), and have higher runoff coefficients (0.5 vs 0.3 for all sites). Thus, one could conjecture that their responses might tend to be somewhat less random and more ameanable to deterministic analysis (i.e., with conventional modeling approaches). Since they represent only around 25 percent of the total number of sites, however, and the correlations are rather weak, any effect of EMC correlation with runoff volume can be ignored without serious overall error.

This finding of no significant linear correlation between EMCs and runoff volumes is important for several reasons. First, in stormwater monitoring programs there is a natural and appropriate bias that favors emphasizing resource allocation to larger storm events. This was generally the case with the NURP projects as well. However, because of differences in local meteorological conditions, degree of site imperviousness, and other factors, there are appreciable differences in the average sizes of storms monitored by site in the NURP database. Since no significant linear correlation was found, such biases and differences are not expected to influence EMC comparisons to any appreciable extent.

Secondly, the probabilistic methodologies for examining receiving water impacts identified in Chapter 5 assume, as they are now structured, that concentration and runoff volume are independent (i.e., that there is no significant correlation). Although the methods can be modified to account for such correlations if they exist, the finding of no significant correlation indicates that such refinement is not warranted at this time.

Other Factors. We have not exhaustively analyzed all potential effects of other factors that might influence and hence modify our interpretations and conclusions regarding site differences. Factors such as slope, population density, soil type, seasonal bias in monitored events, and precipitation characteristics (average rainfall intensity, peak rainfall intensity, rainfall duration, time since last storm event, etc.) all have a potential

TABLE 6-16. SITES WITH MANY SIGNIFICANT CORRELATIONS

		TSS	COD	TOT. P	SOL. P	TKN	NO_{2+3}-N	Cu	Pb	Zn	AVG r^2	AVG r	$\tilde{n}$	LAND USE	% IMPERVIOUS	RUNOFF COEFFICIENT
CO1	NORTH AVE.	–	–.58	–.47	–.42	–.72	–.52	–.47	–.42	–.46	.28	52	32	30%C	50%	.239
	VILLA IT.	–	–.70	–.5B	–.67	–.69	–.44	–.46	–.55	–.65	.35	.59	27	100%C	91%	.927
OC1	WESTLEIGH	–	–.32	–	–	–	–.39	–.84	–	–.44	.29	.54	35	93%R	21%	.119
FL1	CHARTER/H	–	–.62	–.54	U	–.68	–	–.54	–.67	–.56	.37	.60	12	89%R	16%	.153
IL1	MATTIS N.	–	–.64	–.59	U	–.48	U	–.40	–.46	U	.27	.52	35	50%C	58%	.639
	MATTIS S.	–	–.61	–.55	U	–.53	U	–.34	–.46	U	.26	.51	33	90%R	37%	.330
KS1	LENAXA	–	–.70	–.51	U	–	U	–.80	–	–	.46	.68	16	50%I	44%	.540
MA1	LOCUST	.80	–	.91	–	–	–.82	–	.78	–	.69	.83	6	85%R	16%	.209
MO1	RES. HILL	–	–.79	–	U	–.58	–	–.55	–	–	.42	.65	13	100%R	76%	.4B6
NC1	1013 (CBO)	–	–.58	–.46	U	–.57	–.67	–.32	–.29	–.54	.26	.51	61	100%C	69%	.791
NH1	PKG.	–	–.5B	–	U	–.49	–.46	–.50	–.41	–.58	.26	.51	33	100%C	90%	.658
NY3	E. ROCHESTER	–	–.79	–.84	U	–.70	U	U	–.72	–.72	.57	.76	8	100%R	38%	.195
TN1	CBO	–.48	–	–.62	–.47	–.56	–	–.51	–.51	–.65	.30	.55	15	100%C	99%	.206
	R1	.82	–	–	–.62	–	–	.72	.85	.82	.57	.77	11	91%R	33%	.032
WA1	LAKE H.	–	–.33	–	U	–.34	U	U	–.29	–.37	.11	.33	126	91%R	37%	.199
	SURREY O.	–	–.34	–.30	U	–.21	U	U	–.18	–.23	.07	.26	118	100%R	29%	.177
WI1	P.O.	–.39	–.28	–.24	U	–.46	–.53	U	–.23	–	.14	.37	40	100%C	95%	.899
	RUSTLER	–.37	–.55	–	U	–.39	–.37	U	–	–	.18	.43	20	100%C	95%	.793
	STATE FAIR	–.47	–.48	–.47	U	–	–.72	U	–	–	.30	.55	25	74%C	77%	.622
	AVERAGE r^2	.34	.33	.29	.31	.30	.30	.31	.28	.32						
	AVERAGE r	.58	.58	.53	.55	.55	.55	.56	.53	.57						

influence on the median and variability of pollutant concentrations at a site.

On the basis of limited screening, however, we have concluded that such factors do not appear to have any real consistent significance in explaining observed similarities or differences among individual sites. Therefore, although more detailed and rigorous analysis and evaluation of the NURP database may well provide additional useful insight and understanding of the influence of such other factors, we do not believe that the basic findings and conclusions presented in this report will be significantly altered by the results of such efforts. Furthermore, the value of any such insights as may be developed are likely to have limited influence on general decisions on control of urban runoff. For example, the finding of a strong seasonal effect on EMC values would have little influence on a decision to require detention basins in all newly developing urban areas, nor would it be likely to influence their design.

Urban Runoff Characteristics

Having determined, as discussed in the preceding section, that geographic location, land use category, or other factors appear to be of little utility in explaining overall site-to-site variability or predicting the characteristics of unmonitored sites, the best general characterization of urban runoff can be obtained by pooling the site data for all sites (other than the open/non-urban ones). This approach is appropriate, given the need for a nationwide assessment and the general planning thrust of this report. Recognizing that there tend to be exceptions to any generalization, however realistic and appropriate, in the absence of better information the data given in Table 6-17 are recommended for planning level purposes as the best description of the characteristics of urban runoff.

TABLE 6-17. WATER QUALITY CHARACTERISTICS OF URBAN RUNOFF

Constituent	Event to Event Variability in EMC's (Coef Var)	Site Median EMC	
		For Median Urban Site	For 90th Percentile Urban Site
TSS (mg/l)	1-2	100	300
BOD (mg/l)	0.5-1.0	9	15
COD (mg/l)	0.5-1.0	65	140
Tot. P (mg/l)	0.5-1.0	0.33	0.70
Sol. P (mg/l)	0.5-1.0	0.12	0.21
TKN (mg/l)	0.5-1.0	1.50	3.30
NO_{2+3}-N (mg/l)	0.5-1.0	0.68	1.75
Tot. Cu (µg/l)	0.5-1.0	34	93
Tot. Pb (µg/l)	0.5-1.0	144	350
Tot. Zn (µg/l)	0.5-1.0	160	500

Coliform Bacteria

Coliform bacteria counts in urban runoff were monitored for a significant number of storm events by seven of the NURP projects at 17 different sites. Data were collected at twelve of these sites for more than five and up to 20 storm events. Data on either Fecal Coliform or both Fecal and Total Coliform counts are available for a total of 156 separate storm events. Although the data base for bacteria is thus considerably more restricted than for other pollutants, useful results have been obtained.

Table 6-18 summarizes the results of an analysis of these data. Some variability exists from site to site, and data are too limited to identify any land use distinctions. However, results from the different sites and projects are consistent in showing a very dramatic seasonal effect. Coliform counts in urban runoff during the warmer periods of the year are approximately 20 times greater than those in urban runoff that occurs during colder periods.

The substantial seasonal differences which are observed do not correspond with comparable variations in urban activities. This suggests that seasonal temperature effects and sources of coliform unrelated to those traditionally associated with human health risk may be significant.

In addition to the summarized data presented here, special study reports prepared by the Long Island and Baltimore projects address the issue of animal and other sources of coliform bacteria using information derived from field monitoring and the technical literature. The Baltimore NURP project also conducted small scale site studies which simulated washoff by storms and identified that quite substantial differences in coliform levels can result from the general cleanliness of an area, which they associate with the socio-economic strata of the neighborhood. A special study by the Long Island NURP project examined salmonella counts in urban runoff and in an adjacent shellfish area influenced by urban runoff. The Knoxville, TN project also conducted a special study on Salmonella. These project reports may be obtained through NTIS.

Other issues related to bacteria as a health risk were raised and warrant further investigation. A better understanding is needed of the contribution of domestic animals or such wildlife as may be expected in urban areas to observed coliform levels.

Though high levels of indicator microorganisms were found in urban runoff, the analysis as well as current literature suggests that indicators such as fecal coliform may not be useful in identifying health risks from urban runoff pollutions.

PRIORITY POLLUTANTS

ackground

he NURP priority pollutant monitoring project was conducted to evaluate the resence, concentration, and potential water quality impacts of priority polutants in urban runoff. A total of 121 urban runoff samples were collected

TABLE 6-18. FECAL COLIFORM CONCENTRATIONS IN URBAN RUNOFF

Project and Site		Warm Weather			Cold Weather		
		Site No. Obs	Median EMC (1000/ 100 ml)	C.V.	Site No. Obs	Median EMC (1000/ 100 ml)	C.V.
DC1	Burke	1	4.6	-	1	0.02	-
	Westleigh	1	46	-	2	0.35	-
	Stedwick	2	10	-	1	0.2	-
MD1	Homeland	7	11	1.8	-	-	-
	Mt Wash	1	130	-	1	3.3	-
	Res Hill	1	281	-	1	330	-
NC1	(CBD) 1013	11	15	1.6	8	1.0	0.6
	Res 1023	2	23	-	4	2.6	1.1
NH1	Pkg Lot	20	0.3	0.5	-	-	-
NY1	Carll	12	24	0.9	15	1.4	1.5
	Unqua	7	11	1.6	4	0.9	14
SD1	Meade	9	57	0.7	-	-	-
TN1	CBD	7	54	1.5	7	1.0	1.4
	R1	6	56	2.0	4	1.6	1.9
	R2	6	19	6.2	4	0.5	2.4
	SC	7	12	2.8	4	0.9	1.7
		76 Events			52 Events		
All Sites*		11	21	0.8	9	1	0.7

Notes:

* For general characterization of urban runoff, exclude the following sites:

- NH1 - A small (0.9A) Parking Lot; concentrations low and atypical.
- Four sites with only one observation for season; variability is too high for any confidence in representativeness of a single value.

at 61 sites (two storm events per site) in 20 of the NURP projects that participated in this phase of the program. These sites were predominantly in the residential, mixed, or commercial land use areas as defined earlier. Thus, the results of this effort cannot be attributed to runoff from industrial facilities or complexes. Furthermore, an especially exhaustive quality control component, over and above the standard NURP QA/QC effort, was imposed on the priority pollutant portion of the program, resulting in the rejection of nearly 14 percent of the data. Therefore, there is a high level of confidence in the results of this project.

Since only two samples were collected at each site, no meaningful site statistic could be calculated. Therefore the data were pooled for analysis. In view of the discussion in the preceding section, however, this approach seems to be justified.

A detailed compilation of NURP priority pollutant analytical results including city and site where the sample was collected, date of collection; discrete or composite sample, pH, and pollutant concentration can be found in the final report on the NURP Priority Pollutant Monitoring Program soon to be issued by the Monitoring and Data Support Division of the agency. A summary of the findings taken from the December 5, 1983 draft of that report follows.

Pollutants Not Included in NURP. Asbestos and dioxin were excluded from the NURP program. However, standard laboratory methods will reveal the presence of dioxin at concentrations of 1 to 10 µg/l, and most laboratories did scan their chromatograms for the possible presence of this pollutant. All such scans were negative, and on this basis dioxin is included as "not detected".

Results Not Valid. The NURP results for seven priority pollutants cannot be considered valid. Recent EPA investigation has revealed that standard methods are not appropriate for the measurement of hexachlorocyclopentadiene, dimethyl nitrosamine, diphenyl nitrosamine, benzidine, and 1,2-diphenylhydrazine. Two other pollutants, acrolein and acrylonitrile, must be analyzed within three days of sample collection. Such a time constraint was an impractical one for the NURP program.

Pollutants Detected in Runoff

Seventy-seven priority pollutants were detected in the NURP urban runoff samples. This group includes 14 inorganic and 63 organic pollutants (Table 6-19).

Inorganic Pollutants. As a group, the toxic metals are by far the most prevalent priority pollutant constituents of urban runoff. All 14 inorganics (13 metals, plus cyanides; asbestos excluded) were detected, and all but three at frequencies of detection greater than 10 percent. Most often detected among the metals were copper, lead, and zinc, all of which were found in at least 91 percent of the samples. Their concentrations were also among the highest for any pollutant, and reached a maximum of 100, 460, and 2,400 µg/l, respectively. Other frequently detected inorganics included arsenic, chromium, cadmium, nickel, and cyanide (Table 6-20). Twelve of the thirteen toxic metals (antimony excluded) were also sampled in the special

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1]

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/ℓ)[4]
I. PESTICIDES			
1. Acrolein	Holding times exceeded		
2. Aldrin	4,7,26	6	0.002T-0.1M
3. α-Hexachlorocyclohexane (α-BHC) (Alpha)	7,8,22,26	20	0.0027-0.1M
4. β-Hexachlorocyclohexane (β-BHC) (Beta)	7,8	5	0.018-0.1M
5. γ-Hexachlorocyclohexane (γ-BHC) (Gamma) (Lindane)	7,8,22,26	15	0.007-0.1M
6. δ-Hexachlorocyclohexane (δ-BHC) (Delta)	7,26	6	0.004-0.1M
7. Chlordane	2,8,21,26	17	0.01L-10
8. DDD	Not detected		
9. DDE	26	6	0.007-0.027
10. DDT	7	1	0.1M
11. Dieldrin	26,27	6	0.007-0.1
12. α-Endosulfan (Alpha)	7,26,27	19	0.008-0.2
13. β-Endosulfan (Beta)	Not detected		
14. Endosulfan sulfate	Not detected		
15. Endrin	Not detected		
16. Endrin aldehyde	Not detected		
17. Heptachlor	7,8,27	6	0.01-0.1M
18. Heptachlor epoxide	7,26	2	0.003T-0.1M
19. Isophorone	7	3	10M
20. TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin)	Not included in NURP program		
21. Toxaphene	Not detected		
II. METALS AND INORGANICS			
22. Antimony	7,24,26	13	2.6-23A
23. Arsenic	2,3,7,12,19,20,21,22,26,27	52	1-50.5
24. Asbestos	Not included in NURP program		
25. Beryllium	7,12,20,21	12	1-49
26. Cadmium	1,2,3,7,12,20,21,27	48	0.1M-14
27. Chromium	1,2,7,8,12,17,19,20,21,22,26,27,28	58	1-190
28. Copper	1,2,3,4,7,8,12,17,19,20,21,22,23,26,27,28	91	1L-100
29. Cyanides	4,8,19,22,26,27	23	2-300
30. Lead	1,2,3,4,7,8,12,17,19,20,21,22,26,28	94	6-460
31. Mercury	7,20,28	9	0.6-1.2
32. Nickel	2,3,7,12,20,21,26,27	43	1-182
33. Selenium	7,19,23	11	2-77
34. Silver	3,17,27	7	0.2M-0.8
35. Thallium	7	6	1-14
36. Zinc	1,2,3,7,12,17,19,20,21,22,23,27,28	94	10-2400
III. PCBs AND RELATED COMPOUNDS			
37. PCB-1016 (Aroclor 1016)	Not detected		
38. PCB-1221 (Aroclor 1221)	Not detected		
39. PCB-1232 (Aroclor 1232)	Not detected		
40. PCB-1242 (Aroclor 1242)	Not detected		
41. PCB-1248 (Aroclor 1248)	Not detected		
42. PCB-1254 (Aroclor 1254)	Not detected		
43. PCB-1260 (Aroclor 1260)	2	1	0.03
44. 2-Chloronaphthalene	Not detected		

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/l)[4]
IV. HALOGENATED ALIPHATICS			
45. Methane, bromo- (methyl bromide)	Not detected		
46. Methane, chloro- (methyl chloride)	Not detected		
47. Methane, dichloro- (methylene chloride)	4,17,22	11	5-14.5A
48. Methane, chlorodibromo-	28	1	2
49. Methane, dichlorobromo-	28	1	2
50. Methane, tribromo - (bromoform)	28	1	1
51. Methane, trichloro- (chloroform)	4,17,20,22,23,27,28	9	0.2T-12t
52. Methane, tetrachloro- (carbon tetrachloride)	4,28	3	1-2
53. Methane, trichlorofluoro-[5]	2,4,24,28	5	0.61-27
54. Methane, dichlorodifluoro- (Freon-12)[5]	Not detected		
55. Ethene, chloro-	Not detected		
56. Ethane, 1,1-dichloro-	4,28	3	1.5A-3
57. Ethane, 1,2-dichloro-	28	1	4
58. Ethane, 1,1,1-trichloro-	4,2,7,22,24	6	1.6-30M
59. Ethane, 1,1,2-trichloro-	28	2	2-3
60. Ethane, 1,1,2,2-tetrachloro-	4	2	20-3
61. Ethane, hexachloro-	Not detected		
62. Ethene, chloro- (vinyl chloride)	Not detected		
63. Ethene, 1,1-dichloro-	28	2	1.5-4
64. Ethene, 1,2-<u>trans</u>-dichloro-	20,28	4	1-3
65. Ethene, trichloro-	2,4,8,24,28	6	0.3T-12
66. Ethene, tetrachloro-	8,17,22,28	5	19-43
67. Propane, 1,2-dichloro-	28	1	3
68. Propene, 1,3-dichloro-	28	2	1-2
69. Butadiene, hexachloro-	Not detected		
70. Cyclopentadiene, hexachloro-	Standard methods inappropriate		
V. ETHERS			
71. Ether, bis(chloromethyl)[5]	Not detected		
72. Ether, bis(2-chloroethyl)	Not detected		
73. Ether, bis(2-chloroisopropyl)	Not detected		
74. Ether, 2-chloroethyl vinyl	Not detected		
75. Ether, 4-bromophenyl phenyl	Not detected		
76. Ether, 4-chlorophenyl phenyl	Not detected		
77. Bis(2-chloroethoxy) methane	Not detected		
VI. MONOCYCLIC AROMATICS (EXCLUDING PHENOLS, CRESOLS, PHTHALATES)			
78. Benzene	4,17,27	5	1-13
79. Benzene, chloro-	7,20,26,28	5	10-10M
80. Benzene, 1,2-dichloro-	Not detected		
81. Benzene, 1,3-dichloro-	Not detected		
82. Benzene, 1,4-dichloro-	Not detected		
83. Benzene, 1,2,4-trichloro-	Not detected		
84. Benzene, hexachloro-	Not detected		
85. Benzene, ethyl-	4,8,17,20,26,28	6	1-7
86. Benzene, nitro-	Not detected		
87. Toluene	4,17	3	3-9
88. Toluene, 2,4-dinitro-	Not detected		
89. Toluene, 2,6-dinitro-	Not detected		

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (µg/l)[4]
VII. PHENOLS AND CRESOLS			
90. Phenol	4,7,26	14	11-15T
91. Phenol, 2-chloro-	28	1	2
92. Phenol, 2,4-dichloro-	Not detected		
93. Phenol, 2,4,6-trichloro-	Not detected		
94. Phenol, pentachloro-	4,8,19,20,26,27,28	19	1T-115
95. Phenol, 2-nitro-	8	1	1M
96. Phenol, 4-nitro-	4,7,8,20,26,28	16	1T-37
97. Phenol, 2,4-dinitro-	Not detected		
98. Phenol, 2,4-dimethyl-	4,7,8,26	8	1T-10M
99. m-Cresol, p-chloro-	4	1	1.5A
100. o-Cresol 4,6-dinitro-	Not detected		
VIII. PHTHALATE ESTERS			
101. Phthalate, dimethyl	8	1	1L
102. Phthalate, diethyl	3,4,17,20,21	6	1-10M
103. Phthalate, di-n-butyl	4,22,24	6	0.5T-11
104. Phthalate, di-n-octyl	8,20,26,27,28	6	0.4T-20
105. Phthalate, bis(2-ethylhexyl)	4,12,14,22,21,26	22	47-62
106. Phthalate, butyl benzyl	2,8,26	6	1-10M
IX. POLYCYCLIC AROMATIC HYDROCARBONS			
107. Acenaphthene	Not detected		
108. Acenaphthylene	Not detected		
109. Anthracene	2,17,20,21,26,28	7	1-10M
110. Benzo (a) anthracene	2,21,27	4	1-10M
111. Benzo (b) fluoranthene	26,27	5	1-5
112. Benzo (k) fluoranthene	2,21,27	3	4-14
113. Benzo (g,h,i) perylene	21	1	5
114. Benzo (a) pyrene	2,21,26,27	6	1-10M
115. Chrysene	2,7,17,21,26,27	10	0.6T-10M
116. Dibenzo (a,h) anthracene	21	1	1T
117. Fluoranthene	2,8,12,17,21,26,27,28	16	0.3T-21
118. Fluorene	20	1	1
119. Indeno (1,2,3-c,d) pyrene	21	1	4
120. Naphthalene	4,24,26,28	9	0.6T-2.3
121. Phenanthrene	2,8,17,20,21,26,27,28	12	0.3T-10M
122. Pyrene	2,3,8,12,17,21,26,27,28	15	0.3T-16

TABLE 6-19. SUMMARY OF ANALYTICAL CHEMISTRY FINDINGS FROM NURP PRIORITY POLLUTANT SAMPLES[1] (Cont'd)

(Includes information received through September 30, 1983)

Pollutant	Cities Where Detected[2]	Frequency of Detection[3]	Range of Detected Concentrations (μg/ℓ)[4]
X. NITROSAMINES AND OTHER NITROGEN-CONTAINING COMPOUNDS			
123. Nitrosamine, dimethyl (DMN)	Standard methods inappropriate		
124. Nitrosamine, diphenyl	Standard methods inappropriate		
125. Nitrosamine, di-n-propyl	Not detected		
126. Benzidine	Standard methods inappropriate		
127. Benzidine, 3,3'-dichloro-	Not detected		
128. Hydrazine, 1,2-diphenyl-	Standard methods inappropriate		
129. Acrylonitrile	Holding times exceeded		

[1] Based on 121 sample results received as of 9/30/83, adjusted for quality control review.

[2] Cities from which data are available:

1. Durham, NH
2. Lake Quinsigamond, MA
3. Mystic River, MA
4. Long Island, NY
7. Washington, DC
8. Baltimore, MD
12. Knoxville, TN
17. Glen Ellyn, IL
19. Austin, TX
20. Little Rock, AR
21. Kansas City, KS
22. Denver, CO
23. Salt Lake City, UT
24. Rapid City, SD
26. Fresno, CA
27. Bellevue, WA
28. Eugene, OR

Numbering of cities conforms to NURP convention.

[3] Percentages rounded to nearest whole number.

[4] Some reported concentrations are qualified by STORET quality control remark codes, to wit: A = Value reported is the mean of two or more determinations; G = Value reported is the maximum of two or more determinations; L = Actual value is known to be greater than value given; M = Presence of material verified but not quantified; T = Value reported is less than criteria of detection. One value in this column indicates one positive observation or that all observations were equal.

[5] No longer included as a priority pollutant.

TABLE 6-20. MOST FREQUENTLY DETECTED PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 75 Percent or More of the NURP Samples

Inorganics	Organics
30. Lead (94%)	None
36. Zinc (94%)	
28. Copper (91%)	

Priority Pollutants Detected in 50 percent to 74 percent of the NURP Samples

Inorganics	Organics
27. Chrominum (58%)	None
23. Arsenic (52%)	

Priority Pollutants Detected in 20 percent to 49 percent of the NURP Samples

Inorganics	Organics
26. Cadmium (48%)	105. Bis(2-ethylhexyl) phthalate (22%)
32. Nickel (43%)	3. α-Hexachlorocyclohexane (20%)
29. Cyanides (23%)	

Priority Pollutants Detected in 10 percent to 19 percent of the NURP Samples

Inorganics	Organics
22. Antimony (13%)	12. α-Endosulfan (19%)
25. Beryllium (12%)	94. Pentachlorophenol (19%)
33. Selenium (11%)	7. Chlordane (17%)
	5. γ-Hexachlorocyclohexane (Lindane) (15%)
	122. Pyrene (15%)
	90. Phenol (14%)
	121. Phenanthrene (12%)
	47. Dichloromethane (methylene chloride) (11%)
	96. 4-Nitrophenol (10%)
	115. Chrysene (10%)
	117. Fluoranthene (16%)

---

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review. Does not include special metals samples.

metals project in order to determine the relationships among dissolved, total, and total recoverable concentrations. The discussion and result of this separate effort are in a subsequent section of this chapter.

A comparison of individual urban runoff sample concentrations undiluted by stream flow (i.e., end of pipe concentrations) with EPA water quality criteria and drinking water standards reveals numerous exceedances of these levels, as shown in Table 6-21. Freshwater acute criteria were exceeded by copper concentrations in 47 percent of the samples and by lead in 23 percent. Freshwater chronic exceedances were common for lead (94 percent), copper (82 percent), zinc (77 percent), and cadmium (48 percent). One organ oleptic (taste and odor) criteria exceedance was observed. Regarding human toxicity, the most significant pollutant was lead. Lead concentrations violated drinking water criteria in 73 percent of the observations.

Whenever an exceedance is noted above, it does not necessarily imply that an actual violation of criteria did or will take place in receiving waters. Rather, the enumeration of exceedances is used as a screening procedure to make a preliminary identification of those pollutants for which their presence in urban runoff requires highest priority for further evaluation. Exceedances of freshwater chronic criteria levels may not persist for a full 24-hour period, for example. However, many small urban streams probably carry only slightly diluted runoff following storms, and acute criteria or other exceedances may in fact be real in such circumstances.

Among the inorganics, the most frequently detected pollutants are also those which are found at the highest concentrations, which most frequently exceed water quality criteria and which are the most geographically well-distributed. One additional observation can be made concerning the samples from Washington, D.C. These samples accounted for a preponderance of the detections of many of the less frequently detected inorganics, including antimony, beryllium, mercury, nickel, selenium, and thallium. No sampling or analytical irregularities have been identified which explain this result.

Organic Pollutants. In general, the organic pollutants were detected less frequently and at lower concentrations than the inorganic pollutants. Sixty-three of a possible 106 organics were detected. The most commonly found organic was the plasticizer bis (2-ethylhexyl) phthalate (22 percent) followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported with detection frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single haloginated aliphatic (Table 6-20).

Criteria exceedances were less frequently observed among the organics than the inorganics. One unusually high pentachlorophenol concentration of 115 μg/l resulted in the only exceedance of the organoleptic criteria (Table 6-21). This observation and one for the chlordane exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentochlorophenol, bis (2-ethylhexyl) phthalate, γ-hexachlorocyclohexane (Lindane), α-endosulfan, and chlordane. All other organic exceedances were in the human carcinogen category and were most serious for α-hexachlorocyclohexane (α-BHC), γ-hexachlorocyclohexane (γ-BHC or Lindane), chlordane, phenanthrene, pyrene, and chrysene.

TABLE 6-21. SUMMARY OF WATER QUALITY CRITERIA EXCEEDANCES FOR POLLUTANTS DETECTED IN AT LEAST 10 PERCENT OF NURP SAMPLES: PERCENTAGE OF SAMPLES IN WHICH POLLUTANT CONCENTRATIONS EXCEED CRITERIA[1]

Pollutant	Frequency of Detection (%)	Detections/ Samples[2]	Criteria Exceedances[1,3]						
			None	FA	FC	OL	HH	HC[4]	DW
I. PESTICIDES									
3. α-Hexachlorocyclohexane	20	21/106						8,18,20	
5. γ-Hexachlorocyclohexane (lindane)	15	15/100			8			0,10,15	
7. Chlordane	17	7/42		2	17			17,17,17	
12. α-Endosulfan	19	9/49			19				
II. METALS AND INORGANICS									
22. Antimony	13	14/106	X						
23. Arsenic	52	45/87						52,52,52	1
25. Beryllium	12	11/94			6*			12,12,12	
26. Cadmium[5]	48	44/91		8	48		1		1
27. Chromium[5,6]	58	47/81			1*				1
28. Copper[5]	91	79/87		47	82				
29. Cyanides	23	16/71		3	22		4		
30. Lead[5]	94	75/80		23	94		73		73
32. Nickel[5]	43	39/91			5		21		
33. Selenium	11	10/88			5		10		10
36. Zinc[5]	94	88/94		14	77				
IV. HALOGENATED ALIPHATICS									
47. Methane, dichloro-	11	3/28						0,0,11	
VII. PHENOLS AND CRESOLS									
90. Phenol	14	13/91	X						
94. Phenol, pentachloro-	19	21/111		1*	11*	1			
96. Phenol, 4-nitro-	10	11/107	X						
VIII. PHTHALATE ESTERS									
105. Phthalate, bis(2-ethylhexyl)	22	15/69			22*				
IX. POLYCYCLIC AROMATIC HYDROCARBONS									
115. Chrysene	10	11/109						10,10,10	
117. Fluoranthene	16	17/109	X						
121. Phenanthrene	12	13/110						12,12,12	
122. Pyrene	15	16/110						15,15,15	

* Indicates FTA or FTC value substituted where FA or FC criterion not available (see below).

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

[2] Number of times detected/number of acceptable samples.

[3] FA = Freshwater ambient 24-hour instantaneous maximum criterion ("acute" criterion).
FC = Freshwater ambient 24-hour average criterion ("chronic" criterion).
FTA = Lowest reported freshwater acute toxic concentration. (Used only when FA is not available.)
FTC = Lowest reported freshwater chronic toxic concentration. (Used only when FC is not available.)
OL = Taste and odor (organoleptic) criterion.
HH = Non-Carcinogenic human health criterion for ingestion of contaminated water and organisms.
HC = Protection of human health from carcinogenic effects for ingestion of contaminated water and organisms.
DW = Primary drinking water criterion.

[4] Entries in this column indicate exceedances of the human carcinogen value at the 10^{-5}, 10^{-6}, and 10^{-7} risk level, respectively. The numbers are cumulative, i.e., all 10^{-5} exceedances are included in 10^{-6} exceedances, and all 10^{-6} exceedances are included in 10^{-7} exceedances.

[5] Where hardness dependent, hardness of 100 mg/l $CaCO_3$ equivalent assumed.

[6] Different criteria are written for the trivalent and hexavalent forms of chromium. For purposes of this analysis, all chromium is assumed to be in the less toxic trivalent form.

An additional 50 organic pollutants were found in one to nine percent of the samples. These frequencies of detection are low, and the pollutant is noted in Table 6-22.

Among the PCB group, there was only a single detection of one PCB type among all the samples. Approximately two-thirds of the halogenated aliphatic compounds were detected. Among those cities reporting these compounds, the city of Eugene, Oregon, figured prominently. For example, eight pollutants from this group were found in Eugene only. None of the pollutants in the ethers group were detected.

Monocyclic aromatics were rarely detected in the samples. However, many reported detections of benzene and toluene, two commonly reported pollutants, had to be withdrawn due to contamination problems.

Of the 11 phenolics, four have not been reported in urban runoff, while three have been observed only once. The remaining four have been found fairly frequently but at low concentrations. Exceedances of criteria were noted only for pentachlorophenol.

All the phthalate esters were detected at least once in the NURP program, with bis (2-ethylhexyl) found most frequently. Several times the reported concentration exceeded the lowest observed freshwater acute toxic concentration for this pollutant. Given the significant blank contamination problems with the phthalates, however, these findings must be interpreted with caution.

Only two of the polycyclic aromatic hydrocarbons were not detected in at least one sample. Crysene, phenanthrene, pyrene, and fluoranthene were each found at least 10 percent of the time. All the observed concentrations for the first three of these pollutants exceeded the criteria for the protection of human health from carcinogenic effects (there are no such criteria for fluoranthene). Results for the polycyclic aromatics were generally free from quality control problems.

There were no detections of nitrosamines or other nitrogen-containing compounds. Due to methodological and holding time problems, however, results for only two compounds can be used. Moreover, for one of these compounds, 3,3-dichlorobenzidine, performance evaluation results were unacceptable in several cases.

Pollutants Not Detected In Urban Runoff

Some 43 priority pollutants were not detected in any acceptable runoff samples (Table 6-22). All of these pollutants are organics. This group of substances should be considered to pose a minimal threat to the quality of surface waters from runoff contamination.

While the priority pollutants which were not detected are of less immediate concern than those pollutants found often, they cannot safely be eliminated from all future consideration. Many of these pollutants have associated water quality criteria which are below the limits of detection of routine

TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1]

Priority Pollutants Detected in 1 percent to 9 percent of the NURP Samples

51. Trichloromethane (9%)
120. Naphthalene (9%)
98. 2,4-Dimethyl phenol (8%)
109. Anthracene (7%)
2. Aldrin (6%)
6. δ-Hexachlorocyclohexane (6%)
9. DDE (6%)
11. Dieldrin (6%)
17. Heptachlor (6%)
58. 1,1,1-Trichloroethane (6%)
65. Trichloroethene (6%)
85. Ethylbenzene (6%)
102. Diethyl phthalate (6%)
103. Di-n-butyl phthalate (6%)
104. Di-n-octyl phthalate (6%)
106. Butyl benzyl phthalate (6%)*
114. Benzo(a)pyrene (6%)
4. β-Hexachlorocyclohexane (5%)
53. Trichlorofluoromethane (5%)[2]
66. Tetrachloroethene (5%)
78. Benzene (5%)
79. Chlorobenzene (5%)
111. Benzo(b)fluoranthene (5%)*
64. 1,2-trans-dichloroethene (4%)
110. Benzo(a)anthracene (4%)
19. Isophorone (3%)
52. Tetrachloromethane (carbon tetrachloride) (3%)
56. 1,1-Dichloroethane (3%)
87. Toluene (3%)
112. Benzo(k)fluoranthene (3%)
18. Heptachlor epoxide (2%)*
59. 1,1,2-Trichloroethane (2%)*
60. 1,1,2,2-Tetrachloroethane (2%)*
63. 1,1-Dichloroethene (2%)
68. 1,3-Dichloropropene (2%)*
113. Benzo(g,h,i)perylene (2%)
10. DDT (1%)*
43. PCB-1260 (1%)*
48. Chlorodibromomethane (1%)*
49. Dichlorobromomethane (1%)*
50. Tribromomethane (bromoform) (1%)*
57. 1,2-Dichloroethane (1%)*
67. 1,2-Dichloropropane (1%)*
91. 2-Chlorophenol (1%)*
95. 2-Nitrophenol (1%)*
99. p-Chloro-m-creosol (1%)*
101. Dimethyl phthalate (1%)*
116. Dibenzo(a,h)anthracene (1%)*
118. Fluorene (1%)*
119. Indeno(1,2,3-cd)pyrene (1%)*

TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1] (Cont'd)

Priority Pollutants Not Detected in NURP Samples

8. DDD
13. β-Endosulfan
14. Endosulfan sulfate
15. Endrin
16. Endrin aldehyde
21. Toxaphene
37. PCB-1016
38. PCB-1221
39. PCP-1232
40. PCB-1242
41. PCB-1248
42. PCB-1254
44. 2-Chloronaphthalene
45. Bromomethane (methyl bromide)
46. Chloromethane (methyl chloride)
54. Dichlorodifluoromethane (Freon-12)[2]
55. Chloroethane
61. Hexachloroethane
62. Chloroethene (vinyl chloride)
69. Hexachlorobutadiene
71. Bis(chloromethyl) ether[2]
72. Bis(chloroethyl) ether
73. Bis(chloroisopropyl) ether
74. 2-Chloroethyl vinyl ether
75. 4-Bromophenyl phenyl ether
76. 4-Chlorophenyl phenyl ether
77. Bis(2-chloroethoxy) methane
80. 1,2-Dichlorobenzene
81. 1,3-Dichlorobenzene
82. 1,4-Dichlorobenzene
83. 1,2,4-Trichlorobenzene
84. Hexachlorobenzene
86. Nitrobenzene
88. 2,4-Dinitrotoluene
89. 2,6-Dinitrotoluene
92. 2,4-Dichlorophenol
93. 2,4,6-Trichlorophenol
97. 2,4-Dinitrophenol
100. 4,6-Dinitro-o-cresol
107. Acenaphthene
108. Acenaphthylene
125. Di-n-propyl nitrosamine
127. 3,3'-Dichlorobenzidine

TABLE 6-22. INFREQUENTLY DETECTED ORGANIC PRIORITY POLLUTANTS IN NURP URBAN RUNOFF SAMPLES[1] (Cont'd)

Priority Pollutants Not Analyzed for or Withdrawn for Methodological Reasons or Holding Time Violations

1. Acrolein
20. TCDD (Dioxin)
24. Asbestos
70. Hexachlorocyclopentadiene
123. Dimethyl nitrosamine (DMN)
124. Diphenyl nitrosamine
126. Benzidine
128. 1,2-Diphenyl hydrazine
129. Acrylonitrile

* Detected in only one or two samples.

[1] Based on 121 sample results received as of September 30, 1983, adjusted for quality control review.

[2] No longer on the priority pollutant list.

analytical methods. Some of these substances may in fact have been present in the NURP samples. Four priority pollutants not detected in runoff were found in street dust sweepings from Bellevue, Washington, suggesting that further urban runoff samplings can be expected to detect more priority pollutants. More sensitive analytical methodologies must be used and dilution effects considered before it can be said with assurance that these pollutants are not found in urban stormwater runoff at levels which, without dilution, pose a threat to human health or aquatic life.

DDD, chloromethane, 1,2-dichlorobenzene, and 2,4-dichlorophenol were detected in runoff samples at least once, but these observations had to be withdrawn for quality control reasons. Therefore, among the not detected pollutants, these four can be considered to have a slightly elevated possibility of actually being present in the runoff samples.

RUNOFF-RAINFALL RELATIONSHIPS

A runoff coefficient (Rv), defined as the ratio of runoff volume to rainfall volume, has been determined for each of the monitored storm events. As with the EMCs, the runoff coefficient values at a particular site are, with relatively few exceptions, well characterized by a lognormal distribution. Table 6-23 summarizes the statistical properties of Rv's at the loading sites in the data base.

Figure 6-19 illustrates the relationship between percent impervious area and the median runoff coefficient for the site. Sites which monitored fewer than 5 storms are excluded. The upper plot (a) groups the results from 16 of the

TABLE 6-23. RUNOFF COEFFICIENTS FOR LAND USE SITES

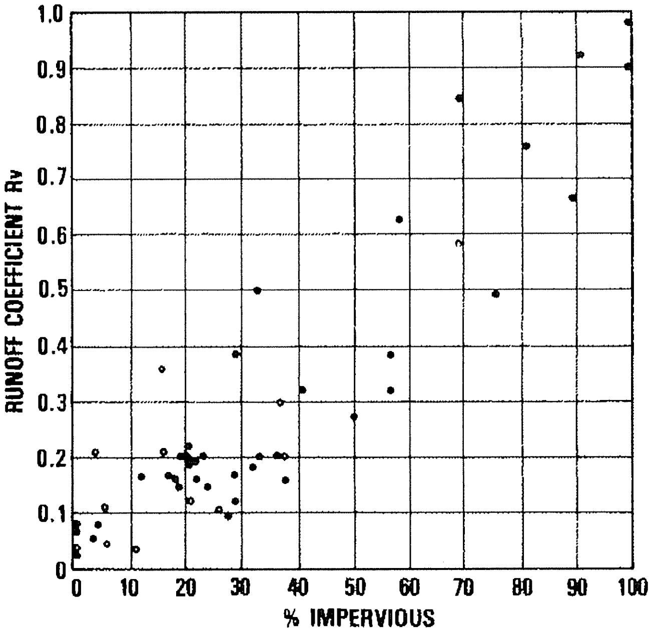
Residential								
	Site	Land Use (%)	No. of Events	Drainage Area (Ac)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv) Median	Coef Var
1	CO1 [illegible]	100	16	33	19	[illegible]	[illegible]	.27
2	DO1 Cherry	100	25	[illegible]	24	36	[illegible]	.48
3	DO1 [illegible]	100	24	167	14	[illegible]	.15	4
4	CO1 Gallat	100	57	17	9	19	[illegible]	[illegible]
5	NO1 Calebridge	100	49	86	1	[illegible]	.18	[illegible]
6	NO1 Stratton	100	31	2	-	[illegible]	[illegible]	.37
7	SL1 [illegible]	100	17	5	-	-	[illegible]	.64
8	[illegible]	100	47	53	16	19	.13	[illegible]
9	LS1 Overlap	100	31	58	[illegible]	18	.19	.11
10	MA2 Seldon	100	6	50	5	16	.16	.16
11	NO1 [illegible] Hill	100	15	14	30	11	.44	[illegible]
12	MD2 Homeland	100	25	29	9	26	.26	.74
13	MO1 Mt. Wash.	100	20	17	12	29	.14	1.25
14	MD1 Res. Hill	100	11	10	55	76	.41	.54
15	MD2 Carroll's W.	100	25	73	13	20	.22	.41
16	NI? Crimsdon	100	11	166	5	27	.18	.15
17	NI3 Ex. Tech.	100	9	146	18	35	.20	.42
18	[illegible] Hollinswood	100	9	60	3	[illegible]	.02	.79
19	WA1 Surrey	100	139	95	9	29	14	56
20	WI1 Burbank	100	44	13	15	50	.17	.47
21	WI1 Hastings	100	33	33	17	51	.21	.37
22	[illegible] Hart	95	14	175	4	40	.09	.35
23	WI1 [illegible]	93	14	30	10	57	.21	.52
24	TN1 17	86	11	89	4	13	.01	.67
25	DO1 [illegible]	85	19	41	3	21	.17	1.15
26	NS1 [illegible]	85	14	61	-	[illegible]	.25	1.09
27	[illegible] John S.	81	28	39	13	12	.17	.54
28	TN3 P1	81	9	59	11	32	.01	92
29	WA1 Lake Hills	81	111	102	12	37	.20	.41
30	[illegible]	80	20	25	22	27	.15	16
31	CL1 Charter M.	76	11	42	-	15	[illegible]	4.55
32	SL1 [illegible]	78	44	19	-	30	25	1.27
33	CO1 Asbury	76	16	127	9	-	.19	.92
34	[illegible]	75	20	574	8	[illegible]	.17	.48
35	MO1 Locust	75	6	158	11	16	71	.33
36	NC1 [illegible]	74	63	324	1	[illegible]	[illegible]	[illegible]
37	MA1 Jordan	79	9	1111	10	71	[illegible]	.65
38	DC1 [illegible]	72	45	[illegible]	15	14	.20	1.07

Urban Open and Nonurban								
	Site	Land Use (%)	No. of Events	Drainage Area (Ac)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv) Median	Coef Var
	TN1 [illegible]	[illegible]	[illegible]	633	-	1	.03	5.95
	[illegible] Gulch	[illegible]		105	-	1	.14	[illegible]
	[illegible]	100	13	[illegible]	-	2	[illegible]	[illegible]
[illegible]	[illegible]	98	[illegible]	[illegible]	-	1	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	1	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1?	[illegible]	1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	-	[illegible]		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]

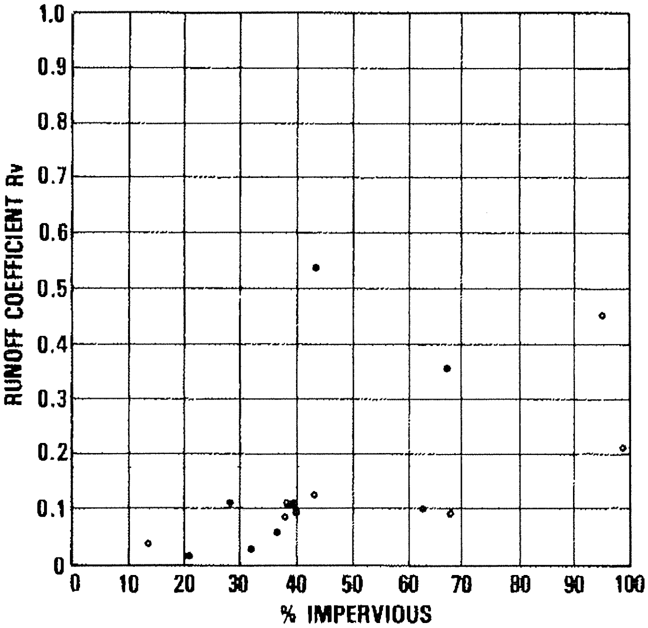
Mixed								
	Site	Land Use	No. of Events	Drainage Area (Ac)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv) Median	Coef Var
1	KS1 [illegible]	-	25	28	3	65	.09	1.04
2	[illegible]	-	[illegible]	[illegible]	40	72	.29	.51
3	IL1 [illegible]	-	26	17	[illegible]	56	64	57
4	MD? Waverly	-	35	32	11	68	.36	.25
5	TN1 [illegible]	-	12	127	3	43	.16	.46
6	WI? [illegible]	-	44	45	14	53	.20	.42
7	MA1 [illegible]	-	[illegible]	535	-	33	.20	.99
8	MA1 [illegible]	-	6	105	1	77	.50	.36
9	MI? Grand R. Dr.	-	23	453	5	35	.31	.50
10	IL1 [illegible]	-	15	194	-	-	.81	1.12
11	MI1 [illegible] AA-S	-	6	2001	-	31	.19	.41
12	NI? Cedar	-	1?	76	-	5	.08	1.05
13	IL1 [illegible]	-	15	30	-	12	.12	1.03
14	MA1 [illegible]	-	5	602	9	12	.11	1.64
15	MI1 [illegible] AA-N	-	6	3671	7	26	.18	.43
16	MI1 [illegible]	-	23	104	5	25	.11	.41
17	IL1 [illegible]	-	5	1707	1	4	21	.18
18	SD1 Meade	-	16	2030	-	-	10	.57
19	CA1 [illegible]	-	42	1690	12	-	.26	.71
20	CO1 North Ave	-	33	19	9	50	.24	.59

Commercial								
	Site	Land Use (%)	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv) Median	Coef Var
1	[illegible] Villa Italia	100	25	14	0	91	.93	.45
2	NC1 1017 (CBD)	100	112	21	0	69	.79	.49
3	NI3 Southgate	100	12	179	2	21	.20	.28
4	WI1 Post Office	100	54	12	0	100	.90	.19
5	WI1 Rustler	100	39	12	0	100	.79	.19
6	NO1 [illegible]	100	14	1	0	90	.66	.50
7	TN1 CBD	100	14	31	0	99	.77	.41
8	LS1 [illegible]	86	21	50	-	97	.46	.55
9	SD? [illegible] Park	93	17	47	-	84	.48	.86
10	WI1 State Fair	74	21	29	10	77	.62	.24

Industrial								
	Site	Land Use (%)	No. of Events	Drainage Area (Acs)	Population Density (Pers/Acre)	Imperv.	Runoff Coef (Rv) Median	Coef Var
1	MD? Addison	100	6	15	0	69	57	.53
2	NI1 [illegible]	100	18	61	0	64	.16	71
3	[illegible] Center	56	15	72	-	44	.54	.27
4	MI1 [illegible]	52	20	5	5	39	.11	.41



(a) 16 Projects



(b) 4 Projects (KS1, MI1, TN1, TX1)

83-1912

Figure 6-19. Relationship Between Percent Impervious Area and Median Runoff Coefficient

20 projects investigated. The lower plot (b) groups results from the remaining four projects (KS1, MI1, TN1, TX1). The reason for the difference is unexplained. However, the separate grouping is based on the fact that the relationship for these sites is internally consistent and significantly different than the bulk of the project results.

Figure 6-20 illustrates the same impervious area/runoff coefficient relationship, but shows the 90 percent confidence limits for median Rv's.

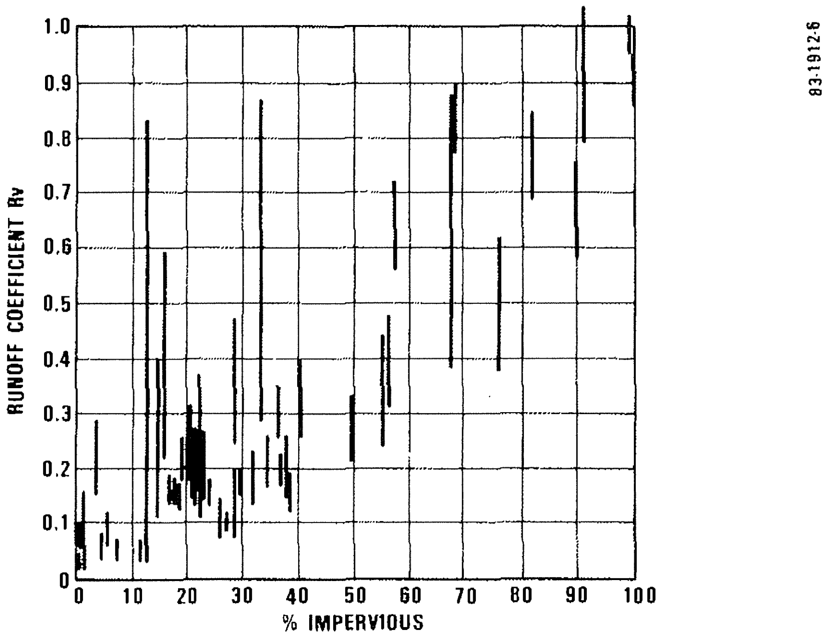
POLLUTANT LOADS

Although the EMC median concentration values are appropriate for many applications (e.g., assessing water quality impacts in rivers and streams), when cumulative effects such as water quality impacts in lakes and comparisons with other sources on a long-term basis (e.g., annual or seasonal loads) are to be examined, the EMC mean concentration values should be used. Taking the EMC median and coefficient of variation values given in Table 6-17, we have converted them into mean values using the relationship given in Chapter 5. These EMC mean concentrations and the values used in the load comparison to follow are listed in Table 6-24.

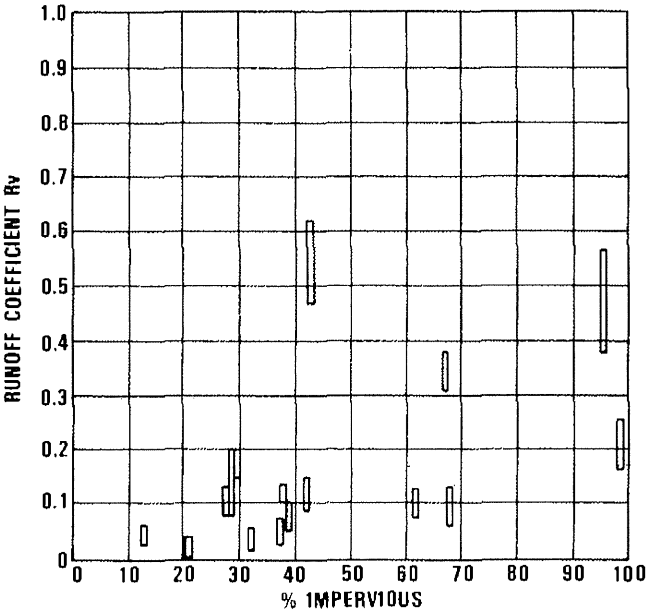
The range shown for site mean concentrations for both the median and 90th percentile urban sites reflects the difference in means depending on whether the higher or lower value of coefficient of variation listed in Table 6-17 is used to describe event-to-event variability of EMC's at urban sites. The range in values shown for use in the load comparisons below reflects the median and 90th percentile site mean concentrations, using the average of the range caused by coefficient of variation effects.

TABLE 6-24. EMC MEAN VALUES USED IN LOAD COMPARISON

Constituent	Site Mean EMC		
	Median Urban Site	90th Percentile Urban Site	Values Used in Load Comparison
TSS (mg/l)	141 - 224	424 - 671	180 - 548
BOD (mg/l)	10 - 13	17 - 21	12 - 19
COD (mg/l)	73 - 92	157 - 198	82 - 178
Tot. P (mg/l)	0.37 - 0.47	0.78 - 0.99	0.42 - 0.88
Sol. P (mg/l)	0.13 - 0.17	0.23 - 0.30	0.15 - 0.28
TKN (mg/l)	1.68 - 2.12	3.69 - 4.67	1.90 - 4.18
NO_{2+3}-N (mg/l)	0.76 - 0.96	1.96 - 2.47	0.86 - 2.21
Tot. Cu (μg/l)	38 - 48	104 - 132	43 - 118
Tot. Pb (μg/l)	161 - 204	391 - 495	182 - 443
Tot. Zn (μg/l)	179 - 226	559 - 707	202 - 633



(a) 16 Projects



(b) 4 Projects (KS1, MI1, TN1, TK1)

Figure 6-20. 90 Percent Confidence Limits for Median Runoff Coefficients

It is a straightforward procedure to calculate mean annual load estimates for urban runoff constituents on a Kg/Ha basis by assigning appropriate rainfall and runoff coefficient values and selecting EMC mean concentration values from Table 6-24. In and of themselves, however, such estimates seem to be of little utility. Therefore, it was decided to do a comparison of the mean annual loads from urban runoff with those of a "well run" secondary treatment plant. We chose to use TSS = 25 mg/l, BOD = 15 mg/l, and Tot. P = 8 mg/l for the effluents from such plants for the purposes of this order of magnitude comparison. For a meaningful comparison for a specific situation, locally appropriate values should be used. Based upon Table 6-24, the corresponding urban runoff mean concentrations used were TSS = 180 mg/l, BOD = 12 mg/l, and Total P = 0.4 mg/l as typical and TSS = 548 ug/l, BOD = 19 mg/l, and Tot. P = 0.88 mg/l as a "worst case" for comparison purposes.

The value of 0.35 was selected as a typical mean runoff coefficient. It is the median of the NURP mean runoff coefficient database for the twenty projects discussed earlier; their average is 0.42, but we believe that this number is overly weighted by the disproportionate number of highly impervious sites in the database. Assuming an average population density of 10 persons per acre (the average of the NURP sites) and a mean annual rainfall of 40 inches per year, urban runoff averages 104 gallons per day per capita. This is also a reasonable estimate of sewage generation in an urban area. Therefore, as a first cut, the ratio of mean pollutant concentrations of urban runoff and POTW effluents will also be the ratio of their annual loads. Thus, we have;

$$\text{TSS} = \frac{180}{25} \approx 7 \; ; \; \text{BOD} = \frac{12}{15} \approx 0.8 \; ; \; \text{Tot. P} = \frac{0.4}{8} \approx 0.05$$

using typical urban runoff values, and;

$$\text{TSS} = \frac{548}{25} \approx 22 \; ; \; \text{BOD} = \frac{19}{15} \approx 1.3 \; ; \; \text{Tot. P} = \frac{0.88}{8} \approx 0.1$$

using the "worst case" values. These numbers suggest that annual loads from urban runoff are approximately one order of magnitude higher than those from a well run secondary treatment plant for TSS, the same order of magnitude for BOD, and an order of magnitude less for Tot. P.

If the hypothetical urban area just described were to go to advanced waste treatment and achieve an effluent quality of TSS = 10 mg/l, BOD = 5 mg/l, and Total P = 1 mg/l and no urban runoff controls were instituted, the mean annual load reductions to the receiving water would be:

$$\text{TSS} = \frac{25 - 10}{180 + 25} \approx 7\% \; ; \; \text{BOD} = \frac{15 - 5}{12 + 15} \approx 37\% \; ; \; \text{Tot. P} = \frac{8 - 1}{0.4 + 8} \approx 83\%$$

for our typical case, and;

$$\text{TSS} = \frac{25 - 10}{548 + 25} \approx 3\% \; ; \; \text{BOD} = \frac{15 - 5}{19 + 15} \approx 29\% \; ; \; \text{Tot. P} = \frac{8 - 1}{0.88 + 8} \approx 79\%$$

for our "worst case." On the other hand, if urban runoff controls that reduced TSS by 90 percent, BOD by 60 percent, and Total P by 50 percent were instituted, (typical results from a well-designed detention basin), the mean annual load reductions to the receiving water would be:

$$\text{TSS} = \frac{180 - 18}{180 + 25} \approx 79\% \; ; \; \text{BOD} = \frac{12 - 7}{12 + 15} \approx 19\% \; ; \; \text{Total P} = \frac{0.4 - 0.2}{0.4 + 8} \approx 2\%$$

for our typical case, and;

$$\text{TSS} = \frac{548 - 55}{548 + 25} \approx 86\% \; ; \; \text{BOD} = \frac{19 - 8}{19 + 15} \approx 32\% \; ; \; \text{Total P} = \frac{0.88 - 0.44}{0.58 + 8} \approx 5\%$$

Thus, if these pollutants are causing receiving water quality problems, consideration of urban runoff control appears warranted for TSS, both urban runoff control and AWT might be considered for BOD, and only AWT would be effective for Total P.

The foregoing should be viewed as illustrative of a preliminary screening for trade-off studies that can be performed using appropriate values for a specific urban area, rather than as description of any particular real-world case. They are, however, believed useful in providing order of magnitude comparisons. Local values for annual rainfall, runoff coefficient, or point source characteristics that are different than those used in the illustration will of course change the results shown; although in most cases the changes would not be expected to cause a significant change in the general relationship.

As a final perspective on urban runoff loads, Table 6-25 presents an estimate of annual urban runoff loads, expressed as Kg/Ha/year, for comparison with other data summaries of nonpoint source loads which state results in this manner. Load computations are based on site mean pollutant concentrations for the median urban site and on the specified values for annual rainfall and runoff coefficient. Typical values for mean runoff coefficient (based on NURP data) have been assigned for residential land use ($Rv = 0.3$), commercial land use ($Rv = 0.8$), and for an aggregate urban area which is assumed to have representative fractions of the total area in residential, commercial, and open uses ($Rv = 0.35$).

Several useful observations can be made. The annual load estimates which results are comparable to values and ranges reported in the literature. Although the findings presented earlier in this chapter indicated that the land use category does not have a significant influence on site concentrations of pollutants, on a unit area basis total pollutant loads are significantly higher for commercial areas because of the higher degree of imperviousness typical of such areas. For broad urban areas, however, the relatively small fraction of land with this use considerably mitigates such an effect.

Finally, the annual loads shown by Table 6-25 have been computed on the basis of a 40 inch annual rainfall volume. For urban areas in regions with higher

TABLE 6-25. ANNUAL URBAN RUNOFF LOADS KG/HA/YEAR

Constituent	Site Mean Con.mg/l	Residential	Commercial	All Urban
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
Total P	0.42	1.3	3.4	1.5
Sol. P	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NO_{2+3}-N	0.86	2.6	7.0	3.6
Tot. Cu	0.043	0.13	0.35	0.15
Tot. Pb	0.182	0.55	1.48	0.65
Tot. Zn	0.202	0.62	1.64	0.72

NOTE. Assumes 40 inches/year rainfall as a long-term average.

or lower rainfall, these load estimates must be adjusted. The results presented earlier suggest that pollutant concentrations are not sensitive to runoff volume; however, total loads (the product of concentration and volume) are strongly influenced by the volume of runoff. For estimates using equivalent site conditions (Rv), loads for areas with other rainfall amounts are obtained by factoring by the ratio of local rainfall volume to the 40 inch volume used for the table. Planners who believe that the average annual runoff coefficients in their local areas are substantially different from those used in the table can make similar adjustments.

CHAPTER 7
RECEIVING WATER QUALITY EFFECTS OF URBAN RUNOFF

INTRODUCTION

The effects of urban runoff on receiving water quality are very site specific. They depend on the type, size, and hydrology of the water body, the designated beneficial use and the pollutants which affect that use, the urban runoff (URO) quality characteristics, and the amounts of URO dictated by local rainfall patterns and land use.

A number of the NURP projects examined receiving water impacts in some detail, others less rigorously. Because of the uniqueness of URO water quality impacts, individual project results are considered best used for confirmation and support, rather than as a basis for broad generalizations.

Accordingly, this chapter is structured to address each of the principal categories of receiving water bodies separately; streams and rivers, lakes, estuaries and embayments, and groundwater aquifers. Some can be addressed more thoroughly than others at this time. The approach taken to develop a general, national scale screening assessment of the significance of URO pollutant discharges is to compute anticipated effects using analysis methodologies identified in Chapter 5, where these are appropriate and to compare anticipated effects indicated by such generalizations to specific experiences and conclusions drawn by relevant individual NURP projects.

As with any generalization, there will be exceptions. Specific local situations can be expected which are either more or less favorable than the general case. The results presented herein should therefore be interpreted as representative estimates of a substantial percentage of urban runoff sites, but not all of them.

Receiving waters have distinctive general characteristics which depend on the water body type (e.g., stream, lake, estuary) and relatively unique individual characteristics which depend on geometry and hydrology. Given a minimum acceptable amount of data on water bodies and their setting, it appears possible to make useful generalizations regarding the quantitative effects of urban runoff on concentrations of various pollutants in the receiving waters and to draw inferences concerning the influence urban runoff may have on the beneficial uses of the water bodies. However extending the results of such an analysis to an assessment of the prevalence of urban runoff induced "problems" on a national scale cannot be accomplished in a way would provide an acceptable level of confidence in any conclusions drawn therefrom. In addition to the importance of local hydrology, meteorology, and urban characteristics, the emphasis placed on each of the three elements that influence problem definition;

(1) Denial or serious impairment of beneficial use;

(2) Violation of ambient water quality standards; and

(3) Local perception;

will result in a high degree of site-specificity to the determination of the existence of a problem.

RIVERS AND STREAMS

General

Flowing streams carry pollutant discharges downstream with the stream flow. For intermittent stormwater discharges, a specific stream location and the biota associated with it are exposed to a sequence of discrete pulses contaminated by the pollutants which enter with urban runoff. Because of the inherent variability of urban runoff (URO), the average concentrations in such pulses vary, as do their duration and the interval between successive pulses. Table 7-1 summarizes average values for storm duration and intervals between storm events for selected locations in the U.S., based on analysis of long term rainfall records using a methodology (SYNOP) presented in an earlier NURP document (the NURP Data Management Procedures Manual). The information presented provides a sense of the temporal aspects of such intermittent pulses and, by inference, the intermittent exposure patterns to which stream biota are subjected. For many locations, storm pulses are produced for about six hours every three days or more, on average.

A probabalistic methodology has been used to examine the concentration characteristics of the storm pulses produced in streams, given the variability of the relevant processes which are directly involved. Stream flow rates, runoff flow rates, and concentrations vary and result in variable stream concentrations. For streams, it is not the runoff volume per se that is important. The combination of stream and runoff flow rates (together with runoff concentration) determine the pollutant concentration in the stream pulse. The duration of the runoff event and the stream velocity dictate the spatial extent of the storm pulse in the stream. The analysis presented in this section addresses the frequency and magnitude of pollutant concentrations in the instream storm pulses which are produced.

Runoff and Stream Flow Rates

The local combination of stream and runoff flow rates for an urban location are, as indicated, important determinants of the stream concentrations which will result. For long-range projections, the most appropriate data sources for characterizing these parameters are long-term stream flow gauging records (USGS) and long-term rainfall records (USWS).

Figure 7-1(a) illustrates the regional variation of average daily stream flows expressed as cfs/sq mile of drainage area, based on long-term (50 years or more) gauging records at over 1000 stations. Figure 7-1(b) presents a somewhat simplified regional pattern for average rainfall intensity. The data base for this plot is considerably smaller, consisting of rainfall records (usually 10 to 30 years of record) for approximately 40 cities. Localized peturbations exist, but are smoothed out by contours presented.

TABLE 7-1. AVERAGE STORM AND TIME BETWEEN STORMS FOR SELECTED LOCATIONS IN THE UNITED STATES

Location	Average Annual Values in Hours	
	Storm Duration	Time Between Storm Midpoints
Atlanta, GA	8.0	94
Birmingham, AL	7.2	85
Boston, MA	6.1	68
Caribou, ME	5.8	55
Champaign-Urbana, IL	6.1	80
Chicago, IL	5.7	72
Columbia, SC	4.5	68
Davenport, IA	6.6	98
Detroit, MI	4.4	57
Gainesville, FL	7.6	106
Greensboro, SC	5.0	70
Kingston, NY	7.0	80
Louisville, KY	6.7	76
Memphis, TN	6.9	89
Mineola, NY	5.8	89
Minneapolis, MN	6.0	87
New Orleans, LA	6.9	89
New York City, NY	6.7	77
Steubenville, OH	7.0	79
Tampa, FL	3.6	93
Toledo, OH	5.0	62
Washington, DC	5.9	80
Zanesville, OH	6.1	77
Mean	6.1	81
Denver, CO	9.1	144
Oakland, CA	4.3	320
Phoenix, AZ	3.2	286
Rapid City, SD	8.0	127
Salt Lake City, UT	7.8	133
Mean	6.5	202
Portland, OR	15.5	83
Seattle, WA	21.5	101
Mean	18.5	92

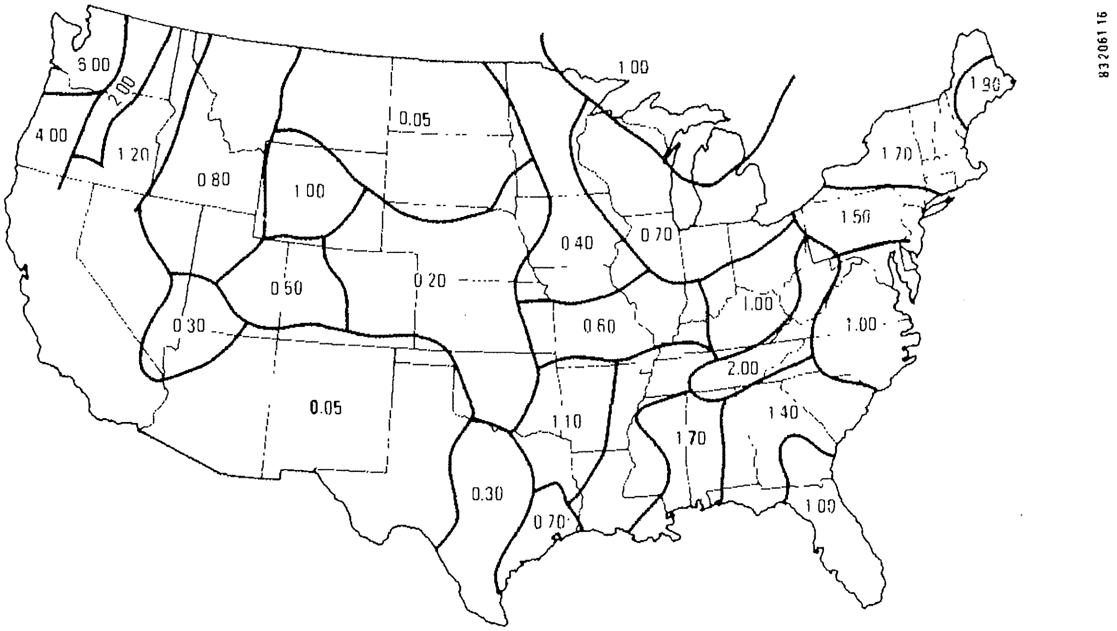


Figure 7-1(a). Regional Value of Average Annual Streamflow (cfs/sq mi)

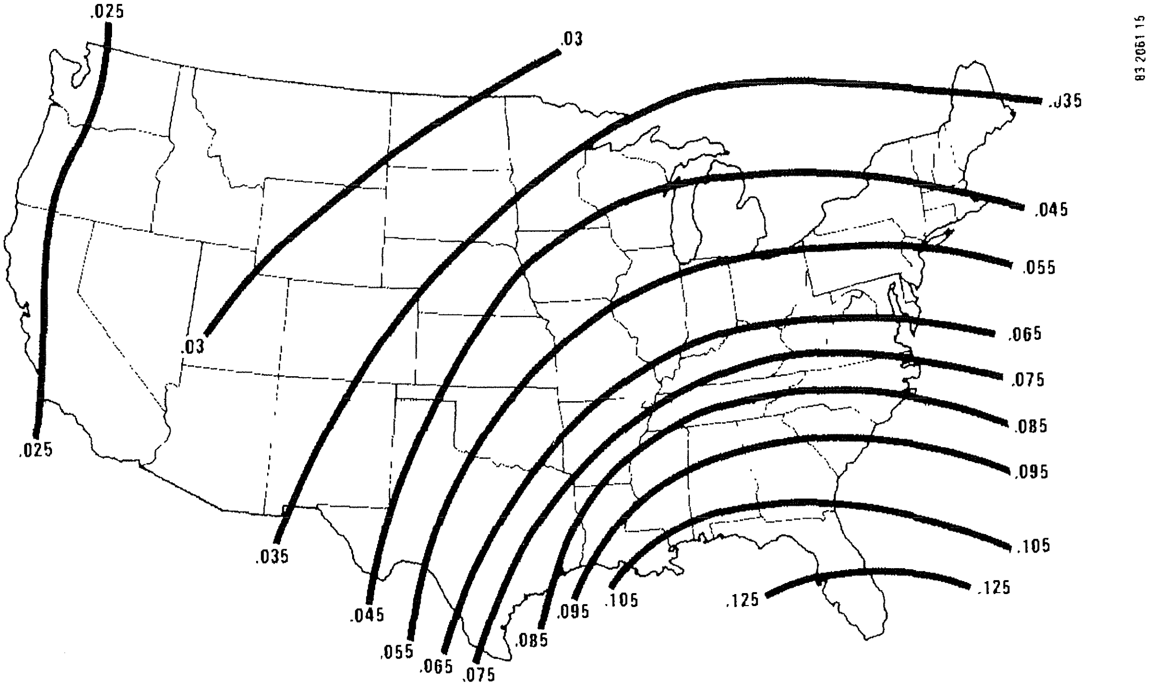


Figure 7-1(b). Regional Value of Average Storm Event Intensity (inch/hr)

Variability of daily stream flows was determined for a smaller sample (about 150 sites) of the stream sites. Variability of storm event average intensities was determined for all of the rain gauge locations in the current data base. These results are summarized in Table 7-2.

Total Hardness of Receiving Streams

Where the beneficial use of principal concern is the protection of aquatic life, the URO pollutants of major concern appear to be heavy metals, particularly copper, lead and zinc. The potential toxicity of these pollutants are strongly influenced by total hardness, as indicated by Table 5-1 in Chapter 5. Other beneficial uses deal with pollutants and effects that are not influenced by total hardness or (as with drinking water supplies) do not modify the assigned significance of heavy metal concentrations on the basis of total hardness.

As with stream flow and precipitation, distinct regional patterns also exist for receiving water total hardness concentrations. Figure 7-2 delineates the national pattern of regional differences. These patterns impose an additional regional influence on the potential of urban runoff to create problem conditions in streams and rivers.

Technical Approach To Screening Analysis

The magnitude and frequency of occurrence of intermittent stream concentrations of pollutants of interest, that result from urban runoff, has been computed using the probabilistic methodology discussed in Chapter 5.

The input data required for application of the methodology includes representative values for the mean and variability of stream flow, runoff flow, and runoff pollutant concentrations. The material presented earlier in this chapter provides the basis for assigning values for the flows; the results summarized in Chapter 6 provide the basis for specifying pollutant concentration inputs. In order to translate the probability distribution of stream concentrations (which is the basic output of the analysis methodology) to an average recurrence interval, which is considered to provide a more understandable basis for comparisons, the average number of storms per year is also required. This is estimated directly from the average interval between storm midpoints generated by the statistical analysis of hourly rainfall records.

For a general screening on a national scale, an estimate of typical values for a selected geographic location must be made. This has been done, and the set of input values considered to be typical of geographical location are described and summarized below. The values used should be considered reasonably representative of the majority of sites in the area, but it should be recognized that not all potential sites will have conditions either as favorable or unfavorable as those listed.

We have worked with a limited sample in assigning typical values. A greater data base on rainfall and stream flow would permit greater spatial definition

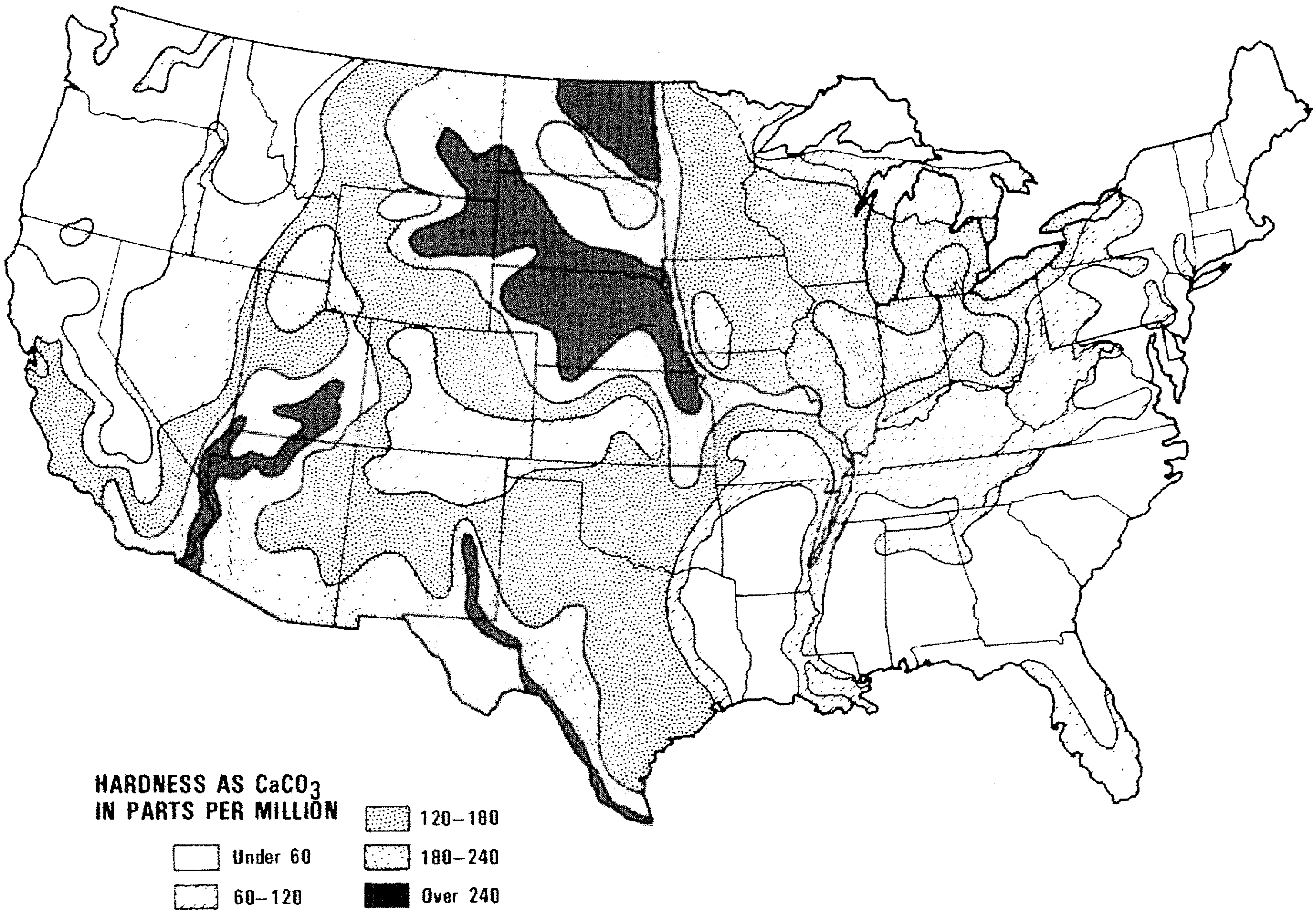


Figure 7-2. Regional Values for Surface Water Hardness

than shown in the results. Specific regions or states could, with development of a more detailed spatial definition of stream flows and rainfall, extend the analysis presented to provide a considerably more comprehensive assessment of problem potential for local areas. This would involve the development of input parameters (rainfall and streamflow) readily derived from available long term USGS stream flow records and USWS rainfall records and their use in the methodology with quality parameters based either on the NURP analysis presented in Chapter 6, or on local monitoring activities.

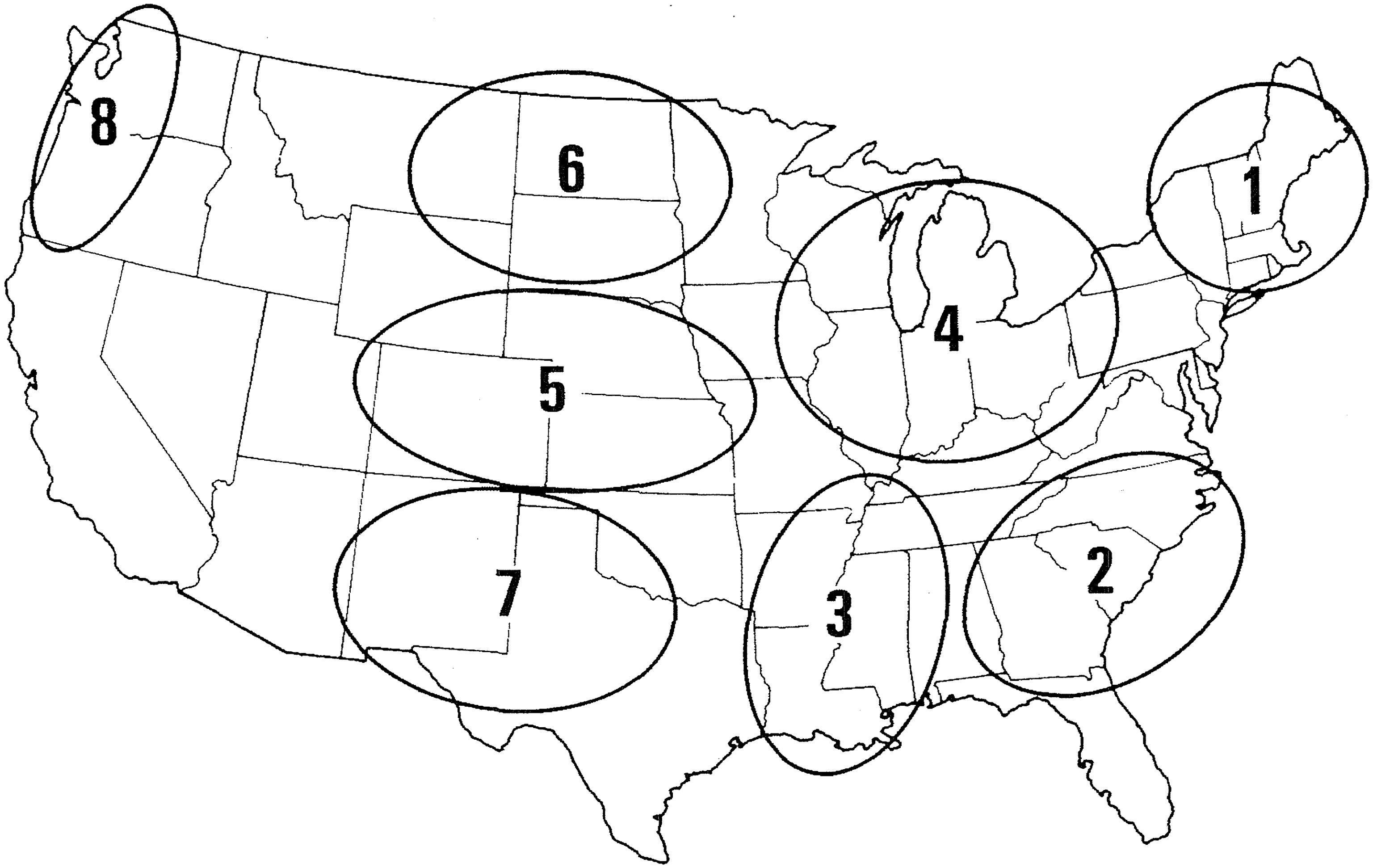
The analysis methodology presently available permits computation of the probability distribution of instream concentrations, incorporating the effect of upstream (background) concentrations of the pollutant of interest. The results presented here assume upstream concentrations of zero, principally because of our inability at present to make reliable estimates of typical values for the magnitude and variability for pollutants of interest, especially on the broad national scale being examined. As a result, the summaries will show the effects of urban runoff contributions only. In cases where the background is small relative to the URO contribution, the summaries will represent actual conditions quite closely. However, where background is high and has appreciable variability, the implications of the URO contribution will be overstated, particularly the inferred improvement which could result from control of URO.

In order to perform a national screening of regional influences on urban runoff impacts, eight geographical regions illustrated by Figure 7-3 have been delineated. Using the information summarized by Figures 7-1 and 7-2, typical values for the pertinent rainfall/runoff and stream parameters have been assigned for each of the regions. Table 7-2 summarizes the values for these parameters which are used in the screening analysis.

TABLE 7-2. TYPICAL REGIONAL VALUES

Area	Event Average Rainfall Intensity		Average Number of Events/year	Average Runoff Flow Rate		Stream Flow Rate (Daily Avg Flows)		Stream Total Hardness (mg/l)
	Mean (in/hr)	c.v.		Mean Event (cfs/sq mi)	c.v.	Mean (cfs/sq mi)	c.v.	
1	0.04	1.00	110	5	0.85	1.75	1.25	50
2	0.10	1.35	100	12	1.15	1.25	1.75	50
3	0.08	1.35	90	10	1.15	1.00	1.25	50
4	0.055	1.25	110	7	1.05	0.75	1.25	200
5	0.04	1.10	63	5	0.95	0.35	1.25	200
6	0.03	1.10	70	4	0.95	0.05	1.25	300
7	0.045	1.20	30	5	1.00	0.05	1.25	200
8	0.025	0.85	80	3	0.75	4.50	1.25	50

Average stream flow and rainfall intensity were taken from the plots, which are based on sources previously described. The estimate for variability of daily stream flows (coefficient of variation) is based on computed values for a sample of about 150 perennial streams. Results for a number of regional



83-2061-17

Figure 7-3. Geographic Regions Selected for Screening Analysis groupings indicated median values for coefficient of variation to fall between approximately 1 and 1.5. Since there were no clear regional patterns apparent, a uniform value for coefficient of variation of stream flows of 1.25 was assigned.

The coefficient of variation of rainfall intensities was taken directly from the statistical analysis of the rainfall records examined. This was reduced by 15 percent to provide estimates of the coefficient of variation of runoff flow rates, based on a recent published report, "Comparison of Basin Performance Modeling Techniques", Goforth, Heaney and Huber, ASCE JEED, November 1983, using the SWMM model on a long-term rainfall record.

The quality characteristics of urban runoff used in the screening analysis are listed in Table 7-3, and are based on the results summarized in Chapter 6. The analysis results have been rounded in the selection of representative site median EMCs and are interpreted as being representative of an array of urban sites discharging into the receiving stream being analyzed.

Average site conditions are based on the 50th percentile of all urban sites. Since the data analysis indicated that sites at some locations tend to cluster at either the higher or lower ends of the range for all sites, high range and low range site conditions were also selected for use in the screening analysis. High range site conditions are nominally based on the 90th percentile of all site median concentrations; the low range on the 10th percentile site. The variability of EMCs from storm to storm at any site is based on the median of the coefficients of variation of EMCs at sites monitored by NURP. This value was used for the low range and average site condition and was increased nominally for the high range site condition.

TABLE 7-3. URBAN RUNOFF QUALITY CHARACTERISTICS
USED IN STREAM IMPACT ANALYSIS
(Concentrations in μg/l)

	COPPER		LEAD		ZINC	
	Site Median EMC	Coef Var	Site Median EMC	Coef Var	Site Median EMC	Coef Var
Low Range of Site Conditions	15	0.6	50	0.75	75	0.7
Average Site Conditions	35	0.6	135	0.75	165	0.7
High Range of Site Conditions	90	0.7	350	0.85	450	0.8

An illustrative example of a site-specific application of the probabilistic analysis methodology employed is presented in order to:

1. Illustrate the nature of the computational results produced;

2. Assist in the interpretation of the tabulations presented later which summarize results of the national scale screening analysis;

3. Indicate how magnitude/frequency of instream concentrations may be interpreted for inferences concerning the absence or presence of a "problem" and where a problem is concluded to exist, its degree of severity; and

4. Demonstrate how alternative URO control options may be evaluated in terms of their expected impact on water quality and potential effect on problem severity.

From selected representative values for mean and variability of stream and runoff conditions, the probability distribution of resulting instream concentrations during storm events can be computed. Figure 7-4 illustrates a plot of such an output. Uncertainty in estimates for specific inputs can be accommodated by sensitivity analyses which incorporate upper and lower bounds for specific parameter values. Results are then presented as a band rather than a specific projection. The probabilities which are the basic output of the analysis may be converted to average recurrence intervals to provide what is believed to be a more understandable basis for interpreting and evaluating results.

Figure 7-5 presents results converted to the average recurrence interval at which specific stream concentrations will be produced during storm runoff periods.

The significance of a particular magnitude/frequency pattern of stream concentrations caused by urban runoff can be evaluated by comparing them with concentrations which are significant for the beneficial use of the water body. In the example presented, we have excluded comparisons with drinking water criteria on the basis that urban streams are not generally used as domestic water sources, and in any event, the criteria relate to finished water, and surface water supplies almost invariably receive treatment.

Protection of aquatic life is selected for the screening analysis of the impact of urban runoff because it is believed to be the predominant potential beneficial use for urban streams on a national scale. The concentrations which result from urban runoff are compared with stream target concentrations associated with different degrees of adverse impact, as discussed and tabulated in Chapter 5.

In the site specific situation illustrated, the stream concentrations of copper caused by untreated urban runoff discharges exceed the "EPA Maximum" criterion more than ten times per year on average. The concentration level suggested by the NURP analysis to be the Threshold level of adverse biological impacts is exceeded an average of five times per year (recurrence interval 0.2 year), and significant mortality of more sensitive biological species occurs about once every three years on average. Although this stress level may not be great enough to result in a total denial of the use, there are many who would argue that it represents an unacceptably severe degree of impairment of this beneficial use.

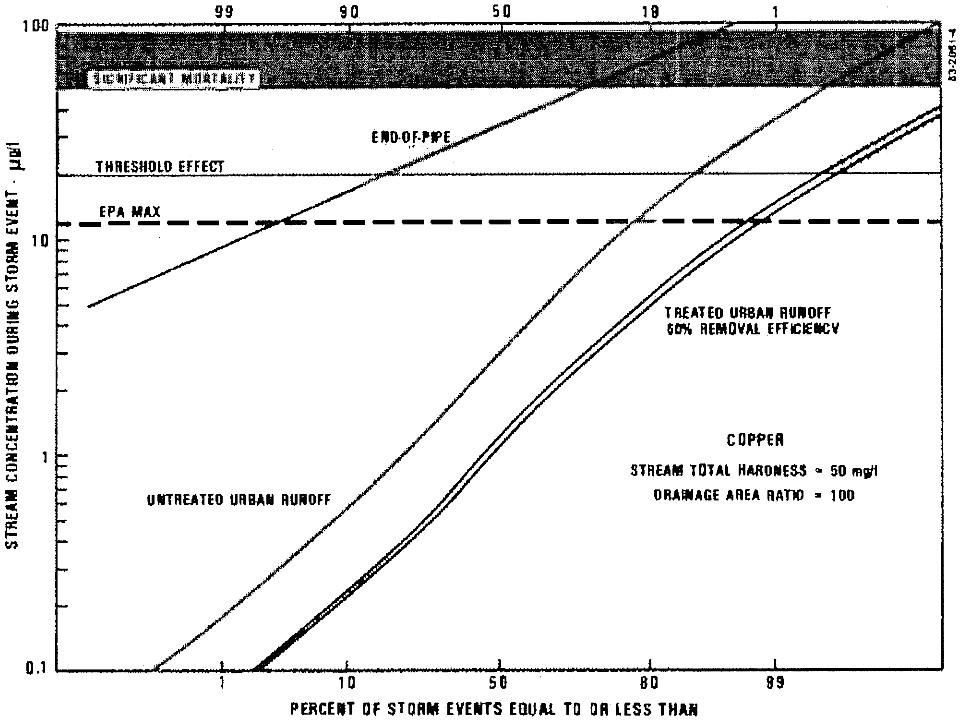


Figure 7-4. Probability Distributions of Pollutant Concentrations During Storm Runoff Periods

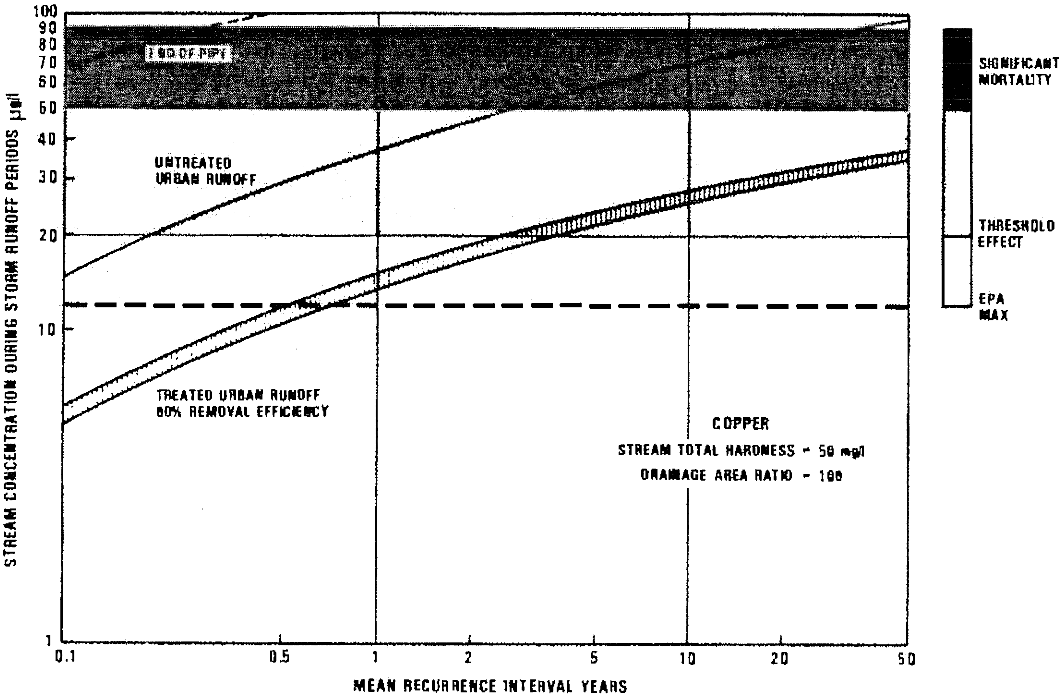


Figure 7-5. Recurrence Intervals for Pollutant Concentrations

The projection labeled "treated urban runoff" may be taken to represent the in-stream result for either the originally considered discharge following the application of controls which effect a 60 percent reduction, or of an uncontrolled urban runoff site with lower levels of copper in the runoff. In this case, threshold levels are reached only once every 3 or 4 years on average, and significant mortality levels are virtually never reached. Even though the ambient "EPA MAX" criterion is exceeded once or twice a year on average, one might conclude that the implied degree of stress is tolerable and is not interpreted to represent a significant degree of impairment of the use.

The Threshold and Significant Mortality levels are estimates, which have been explained earlier. In addition, the "acceptable" frequency at which specific adverse effects can be tolerated is subjective at this time, since there are no formal guidelines. However, an approach of this nature must be taken in any evaluation of the significance of urban runoff and the importance of applying control measures. There are two reasons why this is necessary. First, because of the stochastic nature of the system we are dealing with, virtually any target concentration we elect to specify will be exceeded at some frequency, however rare. Secondly, from a practical point of view, there are limits to the capabilities of controls, however rigorously applied. In the illustration presented, the untreated urban runoff site assigned urban runoff copper concentrations equivalent to the average urban site. Since NURP analysis data indicate that the copper in urban runoff has a soluble fraction of about 40 percent, the level of removal used in the example reflects a control efficiency approaching the practical limit. Receiving water impacts are significantly reduced, but not totally eliminated.

Results of Screening Analysis

A projection of stream water quality responses has been made for each of the eight geographical areas shown by Figure 7-3. The rainfall, runoff, and stream flow estimates used in the computations are those summarized in Table 7-2. The urban runoff quality characteristics used are those presented in Table 7-3.

To consolidate screening analysis results for easier comparison, results are not presented as continuous concentration/frequency curves as used in the illustrative example presented above. Instead, the comparison plots which follow show only the recurrence interval at which specified biological effects levels are exceeded. The concentrations which correspond with these effects are strongly influenced by stream total hardness, and hence vary regionally. Table 7-4, based on information presented in Chapter 5, summarizes the stream target concentrations used in the screening analysis summary.

Analysis results are presented for Copper (Figure 7-6), Lead (Figure 7-7) and Zinc (Figure 7-8). Each individual bar represents a different geographical region, and the analysis is performed for two drainage area ratios. Since regional stream flow differences are based on unit flows (cfs/sq mile of drainage area), actual flow in a receiving stream at a particular location is

TABLE 7-4. REGIONAL DIFFERENCES IN TOXIC CONCENTRATION LEVELS
(Concentrations in µg/l)

Pollutant	Stream Total Hardness µg/l	Geo-graphic Regions	EPA MAX	Suggested Values For		
				Threshold Effects[1]	Significant Mortality[2] (a)	(b)
Copper	50	1,2,3,8	12	20	50	90
	200	4,5,7	42	80	180	350
	300	6	62	115	265	500
Lead	50	1,2,3,8	74	150	350	3200
	200	4,5,7	400	850	1950	17,850
	300	6	660	1400	3100	29,000
Zinc	50	1,2,3,8	180	380	870	3200
	200	4,5,7	570	1200	2750	8000
	300	6	800	1700	3850	11,000

[1] Threshold Effects - mortality of the most sensitive individual of the most sensitive species.

[2] Significant Mortality

Level (a) - mortality of 50 percent of the most sensitive species.

Level (b) - mortality of the most sensitive individual of 25th percentile sensitive species.

a function of both the unit flow rate and the size of the contributing drainage area. The "drainage area ratio" (DAR) used in the analysis is

$$\text{DAR} = \frac{\text{Urban Area Contributing Runoff}}{\text{Stream Drainage Area Upstream of Urban Input}}$$

It is a measure of the location of the urban area relative to the headwaters of the receiving stream.

The shading scheme used on the bars duplicates that used earlier in the illustrative example (Figure 7-5), and identifies the recurrence interval for each of the target concentrations. For example, instream copper concentrations during storm runoff periods in geographic region 1, with average site conditions for copper concentrations in urban runoff, and a DAR = 10, are projected to be as follows (middle plot, Figure 7-6).

- EPA MAX - ambient criterion is exceeded at a frequency of 0.02 year (= 50 times/year) or about every other storm event on average.

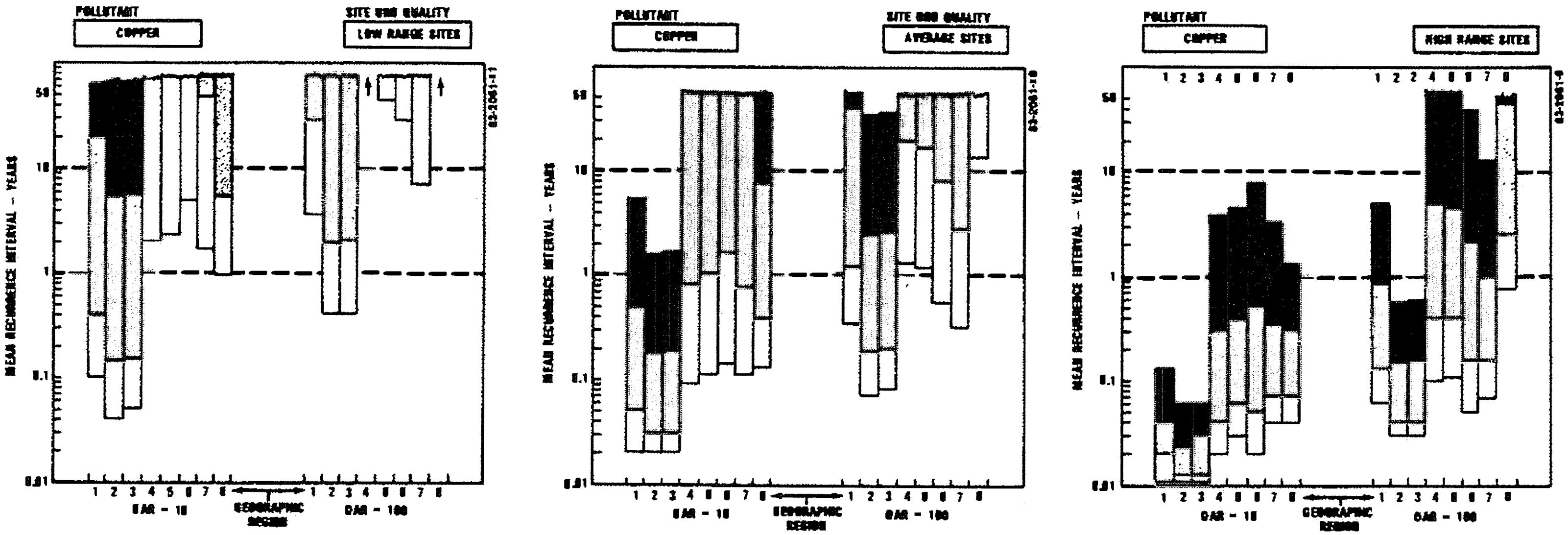


Figure 7-6. Exceedance Frequency for Stream Target Concentration
COPPER

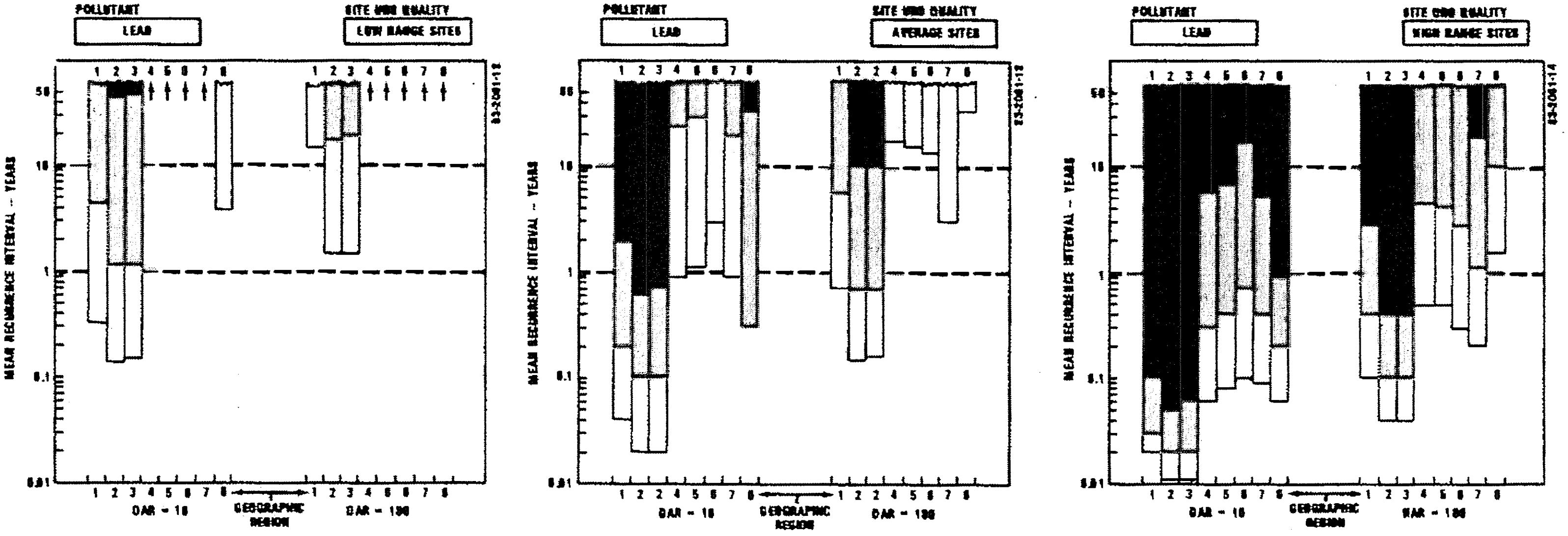


Figure 7-7. Exceedance Frequency for Stream Target Concentration
LEAD

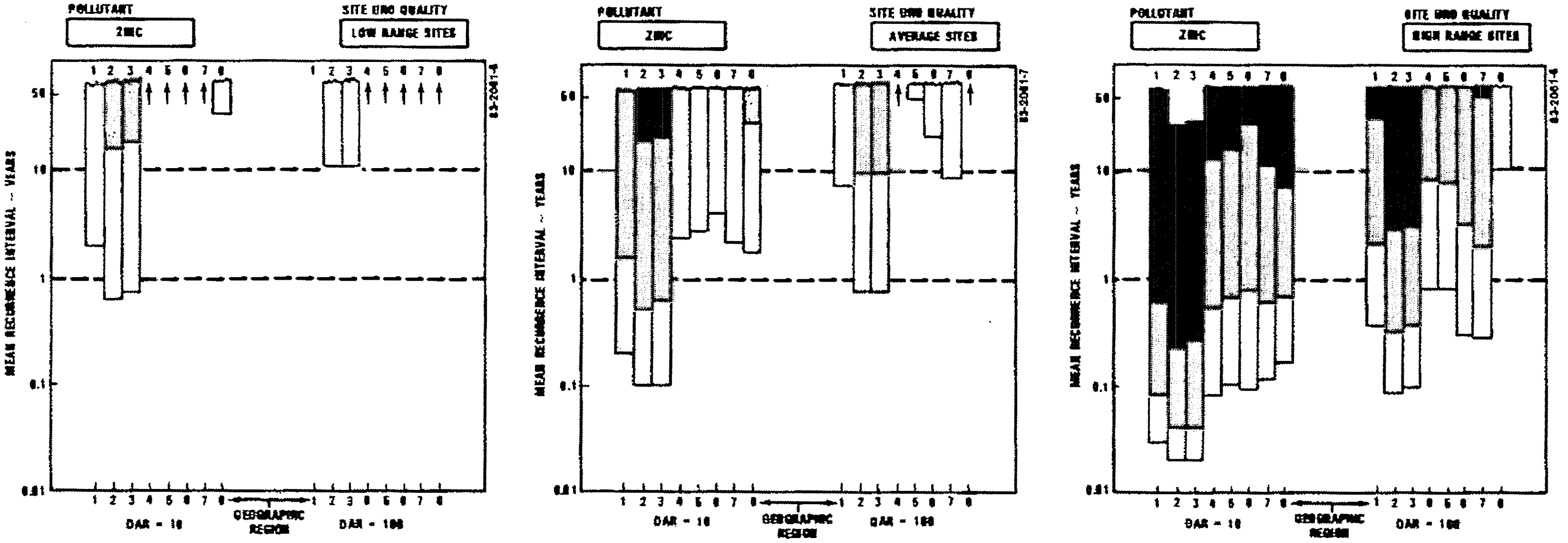


Figure 7-8. Exceedance Frequency for Stream Target Concentration
ZINC

- Threshold concentration levels at which adverse biological stress for short duration exposures is projected to occur have a recurrence interval of about 0.05 years (20 times/year).
- Significant mortality levels are exceeded at intervals of about 0.5 year (twice/year) for the less severe effect, to about once in 5.5 year for the more severe impact specified.

The plot is terminated at an upper level for recurrence interval of 50 years. Although the analysis procedure computes specific recurrence intervals in excess of this value, a realistic interpretation suggests that such conditions are for practical purposes quite unlikely to ever be reached or exceeded. At computed recurrence intervals of about 10 years or more estimates are not considered to be reliable and are very probably conservative. Therefore, indicated mean recurrence intervals in excess of 10 years probably (and 50 years certainly) should be interpreted as "unlikely" or "highly unlikely".

Discussion

An inspection of the screening analysis results (Figures 7-6 through 7-8) indicates the reason why it is unrealistic to attempt a broad generalization on whether urban runoff is, or is not a "problem" in rivers and streams. Water quality impacts can vary widely, depending on regional rainfall and stream hydrology, urban site quality characteristics, drainage area ratio (reflecting the size of the receiving stream relative to the urban area), and the total hardness of the receiving stream. While the screening analysis results provide an informative and useful perspective on the issue, it should be recognized that any specific site may differ considerably from the typical conditions used to characterize rainfall and stream flow for the area, and further, that local variations in runoff quality characteristics within the range defined by the NURP data can also have significant influence. The dominant indication of the analysis is that the problem potential for urban runoff is highly site-specific. Nevertheless some useful generalizations can be made.

Perhaps the major factor which dictates whether urban runoff discharges of copper, lead, or zinc will adversely impact aquatic life is the natural hardness of the receiving streams. As a result, the southeast and gulf coast areas are consistently indicated to be more sensitive than other areas of the country. Of the remaining soft water areas, the northeast is somewhat less sensitive; the Pacific northwest markedly less. This is attributed to significantly lower storm intensities in these areas, coupled in the northwest with appreciably higher stream flows.

Drainage area ratios have an important effect, reflecting as they do the magnitude of stream flow at the urban location. The effect is much greater for geographical regions with high unit flow (cfs/sq mile) than for lower stream flow regions.

Finally, the quality characteristics of the urban sites have a significant influence. Stream concentrations differ markedly depending on whether the local urban sites tend to cluster toward the lower or higher end of the range of site median concentrations indicated by the NURP data base.

A comparison of the relative position of the bars on Figures 7-6, 7-7 and 7-8, is sufficient to indicate the comparative sensitivity to urban runoff pollutant discharges. However, it is also desirable to decide whether a given stream effect constitutes a serious degree of impairment of an aquatic life beneficial use. There are no formal guidelines, and interpretations that are either more liberal or more restrictive than those suggested below may be preferred by others dealing with specific stream segments. For the interpretation of the national scale screening analysis, the following decision basis has been used to identify the situations in which urban runoff is likely to result in a water use "problem", (i.e., cause an unacceptable degree of use impairment):

- Threshold effects - (mortality of the most sensitive individual of the most sensitive species) occur more often than about once a year on average.

- Significant mortality - using the lower of the two levels (i.e., 50 percent mortality of the most sensitive species), occurs more often than about once every 10 years on average.

Using these guidelines for assessing the occurrence of problem situations, copper is shown to be the most significant of the three heavy metals consistently found in urban runoff at elevated concentration levels. Where site concentrations are at the high range of observed urban site conditions, problems are expected in all geographic regions at a DAR = 10, and in all geographic regions except region 8 at DARs as high as 100. When site concentrations are in the average range of observed conditions, problem situations are restricted to geographic regions 2 and 3 (plus region 1 at DAR = 10). When site copper concentrations are in the lower range of observed site conditions, problem situations are restricted to geographic regions 2 and 3 at low DARs. They are marginal (significant mortality once every 5 years) but remain a problem according to the definition adopted. The "marginal" attribution is used here, because the more severe degree of significant mortality (most sensitive individual of 25th percentile sensitive species) is indicated by the analysis virtually never to occur.

Thus, copper discharges in urban runoff are indicated to represent a significant threat to aquatic life use in regions 2 and 3 (southeast and Gulf Coast) under almost all possibilities for urban site runoff quality. In region 1 (northeast), problems would be expected at all but the lower range of site concentrations. In the hard water areas (regions 4, 5, 6, 7) problems are expected only where site runoff quality is in the high end of the range of observed site median concentrations.

It should be noted that the analysis has been based on <u>total</u> copper concentrations in urban runoff. Toxic effects are usually considered to be exerted by the soluble form of the metal, and EPA defines an "active" fraction based on a mild digestion which converts some of the inactive particulates to soluble forms, to account for transformations which may occur in the natural water systems. Copper in urban runoff has a typical soluble fraction of about 50 percent, and the active fraction would therefore fall somewhere between 50 and 100 percent of the total concentration used in the analysis. The analysis has been performed using the total fraction, since adequate information is not available at present to reliably adjust these values. However, although the problem assessment presented above may be somewhat conservative, further refinement along these lines would not change the inferences drawn from the screening analysis results.

Zinc, like copper, has an indicated soluble fraction in the order of 50 percent, and the screening analysis indications will also be unaffected by this consideration. It is indicated to be unlikely to pose a significant threat to aquatic life in most urban runoff situations. Exceptions are restricted to soft water areas in the east and south, lower DARs, and sites with high zinc concentrations in urban runoff.

Lead results must be viewed with greater caution, because soluble fractions in urban runoff are indicated to be quite low (less than 10 percent). Problem indications are therefore likely to be reasonably conservative, i.e., overstate the problem potential. Problem situations may be expected to be restricted to soft water areas in the east and Gulf areas when urban sites have average site concentrations and DARs are low, and even at high DARs when site concentrations are in the high range. Lead is not indicated to be a threat to aquatic life in the hard water areas of the country or in the Pacific northwest, except for the combination of low DAR and high site concentration.

In performing the screening analysis, upstream concentrations were assumed to be zero; that is, the receiving stream had only a diluting effect on the urban runoff pollution. In actual cases background concentrations will be greater than zero, and in some instances upstream contributions (e.g., agricultural runoff, another city) could be significant and result in more severe conditions than those identified in the screening analysis.

On the basis of the foregoing, it appears appropriate to identify copper as the key toxic pollutant in urban runoff, for the following reasons:

- Problem situations anticipated for lead and zinc do not occur under any conditions for which copper does not show up as a problem as well - and with more severe impacts. On the other hand, copper is indicated to be a problem in situations where lead or zinc are not.

- Based on the ratios between concentrations producing increasingly severe effects, copper is suggested to be a more generic toxicant. It has an effect on a broad range of species. This is in contrast to lead and zinc for which a substantially greater degree of species selectivity is indicated. Some species are sensitive, others relatively insensitive to lead and zinc.

- From the NURP data, locations which tend to have site median concentrations in the low, average, or high end of the range have generally consistent patterns for each of the three heavy metals.

- Control measures which produce reductions in copper discharges to receiving waters could be expected to result in equivalent reductions in zinc, and greater reductions in lead, by virtue of its significantly greater particulate fraction.

Copper is accordingly suggested to be an effective indicator for all heavy metals in urban runoff relative to aquatic life. It might be used as the focus for control evaluations, site specific bioassays, monitoring activities, and the like.

It should be noted that while immediate water column impacts of lead are not as significant as those for copper, the high particulate fraction of lead would tend to result in greater accumulations in the stream bed. This aspect has not been addressed by the NURP program in sufficient detail to warrant any comment on its potential significance.

The results of the screening analysis summarized by Figures 7-6 through 7-8 are approximate, because they are influenced by the suitability of the typical values for stream and runoff flows which were assigned. This however can be refined by the use of appropriate values which can be developed from readily available data bases, and thus adjusted for local variations which are to be expected. A second issue relative to the reliability of the projections is the validity of the computations, given that the input parameters are representative. This has been confirmed by a number of validation tests, discussed in the NURP supporting document referenced earlier, which addresses the stream analysis methodology.

The remaining issue for evaluating the reliability of the indications of problem potential produced by the screening analysis is the reasonableness of the intermittent exposure concentration levels, which have been associated with various biological effects levels, and the guidelines adopted for this discussion, which determine whether or not a problem is expected. While rather tenuous at this time, the information available does provide support.

Two of the NURP projects examined aquatic life effects in streams receiving runoff from monitored sites.

- Bellevue, WA concluded that whatever adverse effects were observed were attributable to habitat impacts (stream bed scour and deposition) as opposed to chemical toxicity. For this project, heavy metal concentrations in the monitored urban runoff sites were typical of the average for all urban sites. The screening analysis results under these conditions do not indicate the expectation of a problem.

- Tampa, FL conducted extensive bioassay tests but failed to show any adverse effect of water column concentrations of pollutants in urban runoff. The screening analysis results presented in Figure 7-6 indicate marginal problem conditions at low DAR for this geographic region. At this project however, all monitored sites show heavy metal concentrations significantly lower than the low range conditions used in the screening analysis. When the screening analysis is repeated using site concentrations representative of Tampa monitoring results, a problem situation is not predicted, even at DARs lower than is probably the case for this location.

LAKES

Because lakes provide extended residence times for pollutants, the significant time scale for evaluating urban runoff impacts is at least seasonal, and usually annual or longer, rather than the storm event scale used for streams. The screening methodology identified in Chapter 5, uses annual nutrient loads to assess the tendency for development of undesirable eutrophication effects.

Figure 7-9 illustrates the effect of urban runoff on average lake phosphorus concentration. The very significant influence of area ratio is evident. The larger the urban area which drains into a lake of a given size, the greater the annual loading, and the higher will be the lake phosphorus concentration and the eutrophication effects produced.

The phosphorus concentrations characteristic of the urban sites surrounding a particular lake are also seen to be significant. The three bands shown reflect the range of possibilities, based on the NURP data. The same basis is used to estimate the phosphorus loads from average urban sites and those at the higher and lower ends of site conditions, as was described for heavy metals in the previous section. In this case, because it is annual mass loads which are of interest, site median concentrations have been converted to site mean values for use in the computations.

Lake phosphorus concentrations are also influenced by the annual runoff volume (annual precipitation and runoff coefficient). The results illustrated are based on an annual rainfall of 30 inches and an overall average runoff coefficient of 0.2. Plotted results may be scaled up or down in proportion to the ratio between local values for these parameters and those used in the illustration.

Finally, the lake morphology and hydrology influence the outcome; specifically depth (H) and residence time (τ). This is reflected by the width of each of the bands, which are based on a range of values for H/τ (1 to 10) estimated to be fairly typical for lakes in urban settings.

If an average lake phosphorus concentration of 20 µg/l is used as a reference concentration to assess the tendency for producing undesirable levels of biostimulation, it is apparent that only lakes with rather small area ratios are likely to be unaffected by urban runoff nutrient discharges. Since the three bands represent different concentration levels of phosphorus in urban runoff, qualitative inferences may be drawn concerning the beneficial use impacts of control activities. More detailed estimates may of course be made by use of the methodology with site specific parameters.

The salient feature of the situation, as generalized by the analysis summarized by Figure 7-9, is that the problem potential of urban runoff for lakes is quite site specific. The illustration considers only urban runoff loads; in an actual situation, all nutrient sources (point and nonpoint)

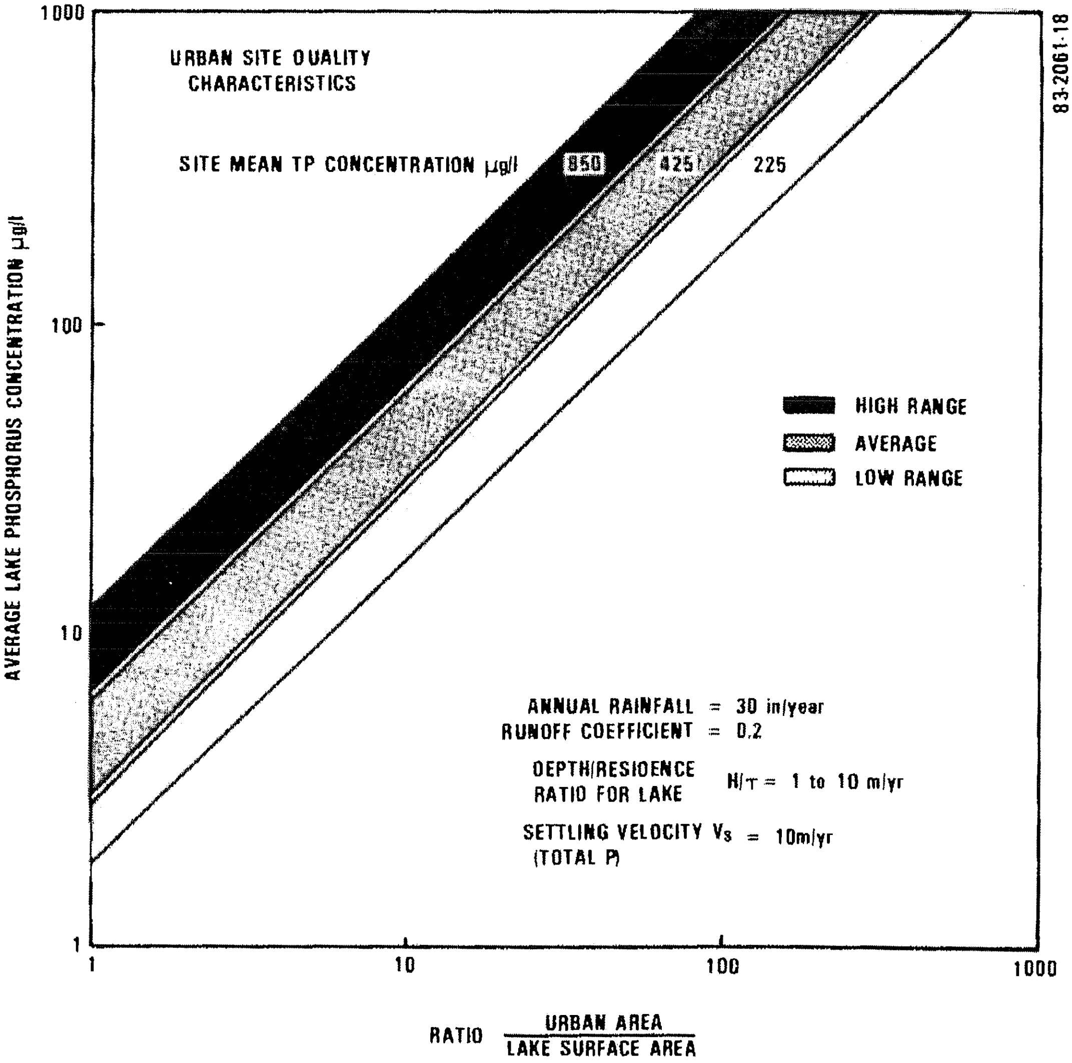


Figure 7-9. Effect of Urban Runoff on Lake Phosphorus Concentrations

would be considered, and this would tend to modify the relative significance of urban runoff on lake conditions.

Several of the NURP projects addressed impacts on lake quality in some depth. These projects include the following:

- Irondequoit Bay, NY - Lake has been highly eutrophic, due to point and nonpoint discharges. Sewage treatment plant and combined sewer overflow discharges have been removed, so that residual sources are recycle from lake sediments and nonpoint sources, including urban runoff, from the contributing drainage area. Further reductions are considered necessary to meet targets. (Area ratio is high at this location.)

- Lake George, NY - Lake is oligotrophic; the study addressed the concern that urban runoff from present and potential future development would unacceptably accelerate degradation of existing water quality. (Area ratio is low at this location.)

- Lake Quinsigamond, MA - Urban runoff was determined to be one of a number of sources preventing water quality objectives from being met. Some control of urban runoff phosphorus loads was recommended as one of the elements of an overall management plan.

Each of the above situations is sufficiently unique, and the mix of urban runoff and other load sources is sufficiently different to suggest that it is inappropriate to attempt a broad generalization. The interested reader may refer to the individual project documents which are available through NTIS for more information.

ESTUARIES AND EMBAYMENTS

These water bodies are normally of sufficient size and complexity that simple screening analyses have not been considered to be sufficiently useful or effective to justify their use.

The Long Island, NY NURP project examined and confirmed that urban runoff sources of coliform bacteria are the principal contributors to the water column concentrations that result in closure of shellfish beds in a number of embayments (principally the Great South Bay). Estimates of control activities that would allow the opening of presently closed areas were also made. The reader is referred to the project documents for further information.

The significance of urban runoff and other nonpoint source loads on eutrophic levels in the Potomac estuary is being investigated under a study which is not associated with the NURP program. However, among other objectives of the WASHCOG NURP project, estimates of urban nonpoint source loads have been developed to support this study.

Although specific situations where urban runoff is significant have been identified, no general assessment for water bodies of this type can be made at this time.

GROUNDWATER AQUIFERS

Much of the precipitation which falls on an area either percolates directly into the ground, or does so after relatively short overland flow distances. This condition is essentially uncontrollable and distinctly different from the case where urban runoff from impervious areas is deliberately collected and routed to a recharge device which causes it to percolate to groundwaters.

This type of control approach is a practical and effective technique for reducing pollutant loads which would otherwise reach surface waters as discussed in Chapter 8. The concern addressed here is with the extent to which groundwater aquifers may be contaminated by this practice.

The Long Island, NY and Fresno, CA NURP projects examined this issue through extensive tests utilizing recharge basins ranging from recent installations to others which have been in service in excess of 20 years. A somewhat simplified consolidation of the salient findings of these two projects is presented below. The interested reader is referred to the individual project report documents, available through NTIS, for the important details and qualifications.

- Most pollutants of importance in urban runoff are intercepted during the process of infiltration and quite effectively prevented from reaching the groundwater aquifers underlying recharge basins. The pollutants tested and found to behave in this manner include the heavy metals, an appreciable number of the organic priority pollutants and pesticides, and coliform bacteria.

- Chlorides, which are sometimes present in urban runoff at elevated concentrations due to road deicing practices, are not attenuated during recharge.

- Pollutants accumulate in the upper soil layers. The concentrations found are a function of the length of time a basin has been in service. Effective retention of pollutants takes place with all soil types tested, ranging from clays to sands. The depth of pollutant penetration is affected by soil type; however in no case did contaminant enrichment of soil exceed several meters depth, and highest concentrations were found near the surface.

- The limit of the ability of the soil to retain the pollutants of interest is unknown. Additional study of this aspect is appropriate. However given the long service periods of a number of the recharge basins studied, this does not appear to represent an imminent concern.

- At both of these NURP locations, groundwater surfaces were at least 20 feet, and often appreciably more, below the base of the recharge device. The indicated findings may not be applicable at locations with shallow depths to groundwater.

- No significant differences in interception/retention of pollutants is apparent for basins with bare versus vegetated recharge surfaces. However vegetation does apparently help to maintain infiltration rates normal for the soil type.

- Surface soil accumulations of priority pollutants in dual purpose installations used for both recharge and recreational use warrants further investigation to determine whether such practice creates unacceptable health risks or requires appropriately designed and conducted maintenance procedures.

CHAPTER 8
URBAN RUNOFF CONTROLS

INTRODUCTION

This chapter summarizes the information developed by the individual NURP project studies relating to performance characteristics of selected techniques for the control of urban runoff quality. The number of control practices addressed here is considerably smaller than the array of best management practices suggested in prior studies and publications. This is not intended to exclude consideration of other approaches. However, the techniques discussed in this chapter may be taken as an expression of controls considered by the agencies involved to be potentially attractive and practicable at localized planning levels. They represent the practices for which performance data were obtained under the NURP program and which can be analyzed and evaluated in this report.

Most of the NURP projects provide in their project reports a detailed analysis and evaluation of the controls that were studied. These reports are available through NTIS. In addition to this information source, an analysis was performed by EPAs NURP headquarters team, using results available from all project studies. The objective was to provide an overview and a generic description of performance characteristics in a format considered to be useful for planning activities. Thus, in addition to providing a consolidated summary of project results, this chapter presents a summary of the results of applying analysis methodologies developed under the NURP program. Further detail on the former can be obtained by reference to relevant project report documents; a more comprehensive development of the latter is provided in separate NURP documents ("Detention and Recharge Basins for Control of Urban Runoff Quality", and "Street Sweeping for Control or Urban Runoff Quality").

The types of control techniques which received attention (to a greater or lesser degree) in the NURP program can be grouped into four general categories.

- Detention Devices - These include normally dry detention basins typically designed for runoff quantity control, normally wet detention basins, dual purpose basins, over-sized drain pipes, and catchbasins.

- Recharge Devices - These include infiltration pits, trenches, and ponds; open-bottom galleries and catchbasins; and porous pavements.

- Housekeeping Practices - These are principally street sweeping, but also include sidewalk cleaning, litter containers, catchbasin cleaning, etc.

- Other - These include the so-called "living filter" approaches, grassed swales, wetlands, etc.

DETENTION DEVICES

General

Detention basins proved to be one of the most popular approaches to urban runoff quality control selected at the local level, based on the number of individual projects which elected to study them and the number of detention devices tested in the study. It is perhaps instructive to note that nearly all the detention facilities studied were either already in place, or required only modifications of outlet structures before initiation of the NURP-supported studies. In general, detention devices proved to provide a highly effective approach to control of urban runoff quality, although the design concept has a significant bearing on performance characteristics.

Table 8-1 lists the NURP projects that included detention devices as elements of their study program. Both the number of devices, and the number of storms analyzed vary considerably, as indicated in Table 8-1, depending on project priorities and other relevant activities. As a result, not all of the sites are incorporated in the summary presented below. The Washington Area Council of Governments (WASHCOG) conducted a particularly thorough and comprehensive investigation of control techniques, particularly detention basins. They have prepared several useful and informative analyses of performance results on these devices.

Dry Basins

This is a type of detention basin which is currently in fairly extensive service in various parts of the country. The performance objective of such basins is commonly called "peak shaving", that is, to limit the maximum rate of runoff to some preselected magnitude, usually a maximum pre-development rate. The purpose is to control flooding and erosion potential in areas downstream of new development. Such basins employ a bottom outlet having a hydraulic capacity restricted to the maximum allowable flow. Runoff from smaller storms flows along the bottom of the basin and is discharged without restriction. Flows in excess of design are backed up in the basin temporarily and ponding occurs only during larger storms and for relatively short periods of time. This class of retention basin is thus normally dry.

Performance of such basins, from a pollutant removal aspect, range from insignificant to quite poor. Accordingly, the limited data available are not discussed in this chapter.

Wet Basins

This designation covers detention basins which maintain a permanent pool of water. They may vary considerably in appearance, ranging from natural ponds or small lakes dedicated urban runoff control to enlarged sections in

TABLE 8-1. DETENTION BASINS MONITORED BY NURP STUDIES

Project	Site	Design Type	No. Events in/out
CO1 Denver	North Ave	Dry Basin	39/21
DC1 Washington, D.C.	Burke	Wet Basin	60/35
	Lakeridge	Dry Basin	49/41
	Stedwick	Dual-Purpose	48/34
	Westleigh	Wet Basin	41/45
IL2 N. Illinois	Lake Ellyn	Wet Basin	29/23
MI1 Lansing	Dryer Farms	Dry Basin	2/8
	Grace St. N*	Wet Basin	23/21
	Grace St. S*	Wet Basin	20/22
	Waverly Hills	Wet Basin	35/30
MI3 Ann Arbor	Pitt-AA	Wet Basin	6/6
	Traver	Wet Basin	5/5
	Swift Run	Wet Basin	5/5
NY1 Long Island	Unqua Pond	Wet Basin	8/8

* These are oversized storm drains installed below street level. Inverts of control sections are below the general grade line, so a permanent pool is maintained.

constructed drainage systems. Runoff from an individual storm displaces all or part of the prior volume, and the residual is retained until the next storm event. This pattern may or may not be modified by natural base inflows during dry weather depending on the local situation.

Detention basins utilizing this design concept have been shown by the NURP studies to be capable of highly effective performance in urban runoff applications, as summarized below. Although performance characteristics of individual basins ranged from poor to excellent, analysis shows these differences to be attributable to the size of the basin relative to the connected urban area and local storm characteristics. Performance data also indicate that in addition to removal of particulate forms or pollutants by sedimentation, some basins exhibit substantial reductions in soluble nutrients (soluble phosphorus, nitrate + nitrite nitrogen). This is attributed to biological processes which are permitted to proceed in the permanent water pool.

There are a number of ways to characterize detention basin performance. The primary basis selected by NURP for doing so is to define performance efficiency on the basis of the total pollutant mass removed over all storms. This provides a meaningful general measure for comparison, is relevant for water quality effects associated with extended time scales (e.g., nutrient load impacts on lakes), and conforms with the capabilities of the NURP analysis methodology developed to provide a planning-level basis for estimating cost/benefit differences in size or application density of this type control.

Table 8-2 tabulates performance in terms of reduction in pollutant mass loads over all monitored storm events. The analysis methodology developed under the NURP program activities suggests that performance should be expected to improve as the overflow rate (QR/A = mean runoff rate ÷ basin surface area) decreases and as the volume ratio (VB/VR = basin volume ÷ mean runoff volume) increases. The NURP basins used in the analysis are listed in increasing order of expected performance capabilities.

The wide range of relative basin sizes provided by this data base is apparent, and performance is seen to generally correspond with expectations. The poorest performance occurs in a basin with an average overflow rate during the mean storm of about six times the median settling velocity (1.5 ft/hr) of particles in urban runoff. In addition, less than 5 percent of the mean storm runoff volume remains in this basin following the event, to be susceptible to additional removal by quiescent settling during the interval between storms. The basins which exhibit high removal efficiencies, at the other end of the scale, have size relationships which result in the mean storm displacing only about 10 percent of the available volume, and producing overflow rates which are only a small fraction of the median particle settling velocity.

This rationale is described more completely in the supporting NURP document on detention basins identified earlier. The testing of the methodology against the NURP monitoring data is presented, and the basis for the performance projections illustrated below is documented.

Figure 8-1 presents a projection of removal efficiency of urban runoff detention devices as a function of basin size relative to the contributing catchment area and regional differences in typical rainfall patterns. The removal rates apply for TSS, which are all settleable, and must be factored by the particulate/soluble fraction of other pollutants which have significant soluble fractions in urban runoff. It applies for the specific basin average depth and area runoff coefficient indicated (which are fairly typical based on NURP data). However performance relationships could be different than indicated based on relevant local values for the controlling parameters.

An alternate approach for characterizing performance of detention basins concentrates on the variable characteristics of individual storm events and how these are modified by the detention device. A comparison of the mean and coefficient of variation of basin inflow and discharge concentrations provides another measure of performance of an urban runoff detention device.

TABLE 8-2. OBSERVED PERFORMANCE OF WET DETENTION BASINS
REDUCTION IN PERCENT OVERALL MASS LOAD

Project and Site	No. of Storms	Size Ratios		Average Mass Removals - All Monitored Storms (Percent)									
		QR/A	VB/VR	TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	18	8.75	0.05	(-)	14	(-)	(-)	(-)	(-)	(-)	(-)	9	(-)
Lansing Grace St. S.	18	2.37	0.17	32	3	(-)	12	23	7	1	(-)	26	(-)
Ann Arbor Pitt-AA	6	1.86	0.52	32	21	23	18	(-)	14	7	•	62	13
Ann Arbor Traver	5	0.30	1.16	5	(-)	15	34	56	20	27	•	•	5
Ann Arbor Swift Run	5	0.20	1.02	85	4	2	3	29	19	80	•	82	(-)
Long Island Unqua	8	0.08	3.07	60	(TOC=7)		45	•	(-)	(-)	•	80	•
Washington, D.C. Westleigh	32	0.05	5.31	81	•	35	54	71	27	•	•	•	26
Lansing Waverly Hills	29	0.04	7.57	91	69	69	79	70	60	66	57	95	71
NIPC Lake Ellyn	23	0.10	10.70	84	•	•	34	•	•	•	71	78	71

Notes: (-) Indicates apparent negative removals.

• Indicates pollutant was not monitored.

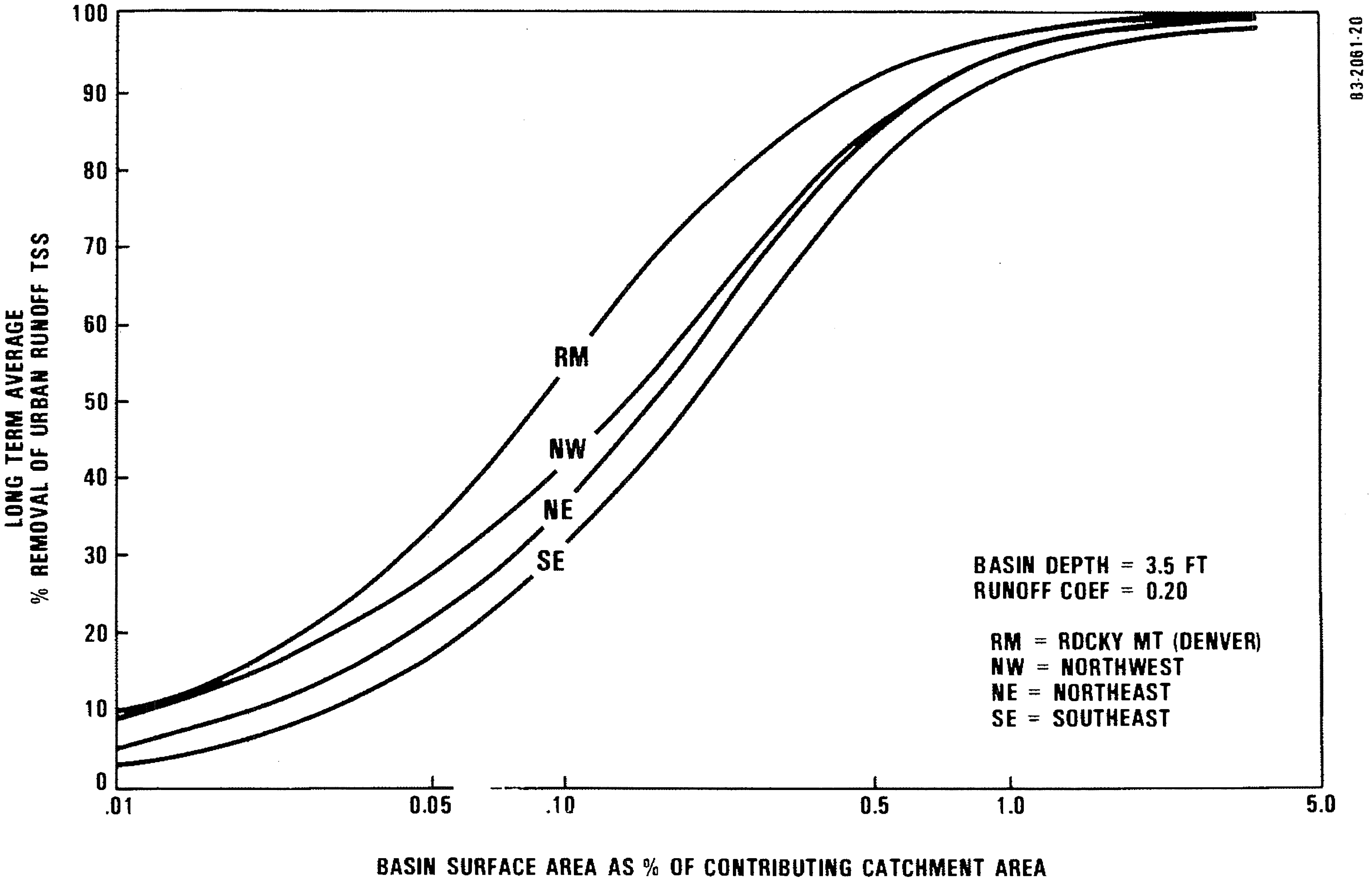


Figure 8-1. Regional Differences in Detention Basin Performance

This approach provides more useful information for subsequently evaluating the effect of controls on water quality impacts on rivers and streams. As evident from the discussion in Chapter 6, reductions in the mean and variability of runoff concentrations (and the inferred reduction in mean and variability of runoff rates) will have a significant beneficial effect on the severity of impacts on flowing streams.

Table 8-3 summarizes detention basin performance when assessed in this manner. It should be noted that in most cases more inlet storm events were monitored than discharge events, and that some inlet events do not have a matching discharge event and vice-versa. Further, for the larger basins where storm inflow displaces only a fraction of the basin volume, it is unlikely that influent and effluent for a specific event represent the same volume of water. The tacit assumption in this analysis is that the inflow events which were monitored provide a representative sample of the total population of all influent event mean concentrations (EMCs). Similarly, the monitored effluent events are assumed to be a representative sample of all basin discharge EMCs. The appropriateness of this assumption is obviously more uncertain where the number of individual storm events monitored is small.

For each basin influent and effluent, the arithmetic mean and variance were computed based on the relationships for lognormal distributions. The percent reduction in the mean concentration and the coefficient of variation are tabulated (Table 8-3). Note that where the number of monitored events shown in this table differ from those listed in Table 8-2, it is because the mass removal computations were restricted to synoptic storms (i.e., matching influent and effluent results were available for an event).

Performance characteristics are generally consistent using either approach, even though each displays a different type of information. Performance improves with detention basin size relative to catchment size and hence the magnitude of the runoff processed. Giving greater weight to the sites monitoring large numbers of storms, indications are that for most pollutants wet ponds also generally result in a considerable reduction in the variability of pollutant concentrations.

A significant exception to this tendency to reduce variability is shown for the soluble nitrogen forms (NO_2 + NO_3). The positive removal efficiency indicated by reduction of mean concentrations must be attributed to biological processes rather than sedimentation. A substantial increase in variability is consistently indicated by the data. Among the heavy metals, lead which is nearly all in particulate form shows significant reductions in variability. Copper and zinc which have high (40 to 60 percent) soluble fractions show an ambiguous pattern with regard to changes in variability.

In a few of the cases where atypical results are indicated, unique local conditions suggest plausible explanations. For example, at the Ann Arbor (Traver) site, erosion from an unstabilized bank at the outlet of this newly constructed basin is attributed to the poor suspended solids removal observed. The poor removal characteristics at the Unqua site for TKN and nitrate may be associated with the significant wildfowl population at this site.

TABLE 8-3. OBSERVED PERFORMANCE OF WET DETENTION BASINS (PERCENT REDUCTION IN POLLUTANT CONCENTRATIONS)

(a) Mean EMC

Project and Site	No. of Storms (1)	Percent Reduction in Mean EMC									
		TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	23/20	(6)	(26)	15	(10)	(26)	11	(1)	(9)	39	(9)
Lansing Grace St. S.	18/17	22	4	(3)	6	0	(5)	(20)	25	14	7
Ann Arbor Pitt-AA	6/6	38	17	23	28	(2)	11	8	•	59	22
Ann Arbor Traver	5/5	0	(66)	12	37	63	19	28	•	•	19
Ann Arbor Swift Run	5/5	83	11	(3)	(38)	21	25	77	•	86	•
Long Island Unqua	8/8	34	(TOC=26)		38	•	(31)	(10)	•	78	•
Washington, D.C. Westleigh	40/40	83	•	33	59	70	19	28	10	•	10
Lansing Waverly Hills	35/30	87	52	52	69	56	30	54	53	93	58
NIPC Lake Ellyn	25/20	92	•	64	61	62	•	82	88	91	87

(b) Coefficient of Variation of EMCs

Project and Site	No. of Storms (1)	Percent Reduction in Coef of Variation of EMCs									
		TSS	BOD	COD	TP	Sol.P	TKN	NO_{2+3}	T.Cu	T.Pb	T.Zn
Lansing Grace St. N.	23/20	14	49	35	(7)	(13)	30	0	0	45	(31)
Lansing Grace St. S.	18/17	(7)	(59)	39	13	0	20	21	17	18	15
Ann Arbor Pitt-AA	6/6	17	(6)	10	28	(84)	37	0	•	53	(5)
Ann Arbor Traver	5/5	14	(109)	58	(3)	42	(150)	(82)	•	•	0
Ann Arbor Swift Run	5/5	(5)	39	50	(150)	0	20	(150)	•	26	•
Long Island Unqua	8/8	(87)	(TOC=66)		47	•	19	(66)	•	65	•
Washington, D.C. Westleigh	40/40	46	•	(26)	15	20	41	(280)	0	•	(14)
Lansing Waverly Hills	35/30	38	5	69	34	26	(8)	(198)	(22)	34	(36)
NIPC Lake Ellyn	25/20	44	•	41	71	48	•	(115)	60	19	41

Notes: (1) In/Out; numbers are approximate, and vary with pollutant. Removals in parentheses indicate negative removal.

Dot (•) indicates pollutant either not monitored or number of observations is too small for reliable estimate of percent reduction.

The ability of detention basins to reduce coliform bacteria concentrations is also of considerable interest because of the significant impact these urban runoff contaminants exert on recreational or shellfish harvesting beneficial uses. Other than at the Unqua site of the Long Island NURP project, the number of observations made for indicator bacteria were too few to support a reliable assessment of the ability of detention basins to effect quality improvements. However, extensive data of this nature were secured on detention basin influent and effluent during all monitored storms at the Unqua site.

Since coliform bacteria have a high rate of die-off in natural waters, performance characteristics based on total mass reductions are not particularly meaningful. The Unqua site data were analyzed to evaluate performance in terms of reductions in concentration levels. Over eight monitored storms at this site, covering a wide range in storm size, the mean EMC (MPN/100 ml) was reduced by 94 percent for total coliform, 91 percent for fecal coliform, and 95 percent for fecal streptococcus bacteria. Variability of bacteria concentrations in the pond outlet increased, with effluent coefficients of variation ranging from about 10 to 100 percent greater than influents. Accordingly, detention basins employing permanent pools (wet ponds) are indicated to be capable of substantial reductions in indicator bacteria.

Dual Purpose Basins

In the absence of a well defined terminology, we have adopted this designation to define basins that are normally dry, and hence retain their full potential for flood control, but which have outlet designs that result in a slow release rate for detained storm flows. Detention time is extended considerably compared with that provided by dry basins employing conventional outlet designs.

One of the detention basins examined by the WASHCOG NURP project, was of this type. This project designates such designs as "Extended Detention Dry Ponds." The pond was converted from a conventional dry pond by replacing the outlet pipe with a perforated riser enclosed in a gravel jacket. The modification was designed to detain stormwater runoff for up to 24 hours, instead of the 1 to 2 hours typically observed in conventional dry ponds.

For undetermined reasons, average detention periods during the study were in the order of 4 to 8 hours, and hence considerably shorter than the design objective. Nevertheless, based on monitoring of more than 30 storm events, the removal of particulate forms of urban pollutants was typically high and comparable to the performance efficiency of wet ponds.

Observed removals for this site (Stedwick) are summarized by Table 8-4, showing percent reductions in both mass and concentration distributions. The principal differences in performance of dual purpose basins compared with wet basins are suggested by the available data to consist of the following:

- Soluble pollutants (e.g., soluble P and Nitrate/Nitrite) are not effectively reduced because of the absence of a permanent pool within which biological reactions have an opportunity to occur in addition to sedimentation.

- The variability of pollutant EMC's does not appear to be modified to the extent that this occurs in wet ponds.

TABLE 8-4. PERFORMANCE CHARACTERISTICS OF A DUAL-PURPOSE DETENTION DEVICE

(Stedwick Site - Washington Area NURP Project)

Pollutant	Percent Reduction In Pollutant Mass Load Over All Monitored Storms	Pollutant EMC's Mean	Coef Var
TSS	64	63	(31)
COD	30	41	17
Total P	< 15	11	0
Sol P	1	(4)	(13)
TKN	•	8	(11)
Organic N	30	•	•
NO_{2+3}	10	13	6
T. Cu	•	•	•
T. Pb	84	•	•
T. Zn	57	43	33

Although the performance characteristics of basins of this type are indicated to be somewhat inferior to the potential offered by wet ponds, there are a number of considerations which make dual purpose basins highly attractive candidates for quality control of urban runoff. These include the fact that flood control requirements are likely to be more economically obtained than with wet basins and that many existing stormwater management basins may be readily modified to significantly enhance their capability for improving the quality of urban runoff. In areas where ordinances requiring conventional stormwater management ponds are already in existence, the only changes required would be an alternate specification of the outlet design.

Costs

The information presented here is intended to provide an order of magnitude estimate of the cost of providing different levels of control of urban runoff pollutant discharges, when wet detention devices are used as the best management practice (BMP). The summary is based on the size versus performance relationship presented earlier in Figure 8-1 and on the size versus cost relationships presented below.

The analysis is based on cost information developed by the WASHCOG NURP project and discussed in detail in one of their project reports produced for the NURP effort. Construction cost estimates as a function of basin volume are shown by Figure 8-2, adopted from this source. This estimate compares quite favorably with a similar cost/size relationship developed previously by the Soil Conservation Service (SCS).

The cost relationship shown by this figure applies to "dry pond" designs and relates only to expected cost of construction activities. For specific cost estimates, the results derived from Figure 8-2 should be modified as appropriate, in accordance with the following:

- The highly variable capital cost of land acquisition is not included in the construction costs.
- Outlet modifications to provide a dual purpose basin design will increase construction costs by about 10 to 12 percent.
- Pond designs which meet the peak shaving requirements of conventional (dry) pond designs, but also provide a permanent pool of water may have costs up to 40 percent greater than indicated by the cost relationship shown by Figure 8-2.
- An additional allowance equal to 25 percent of construction costs is suggested to allow for planning, design, administration, and construction related contingencies.
- Operation and maintenance costs are estimated to involve an annual expenditure of approximately 3 to 5 percent of base construction cost, that is, before application of the 25 percent factor for design, planning, and administration. The total is composed of two elements: 2 to 3 percent of construction cost estimates the annual cost of routine maintenance and upkeep; an additional 1 to 2 percent of construction cost estimates the annualized cost of sediment removal operations for a 10 year clean-out cycle.

Planning agencies often distinquish between "on-site" controls, which are applied to relatively small urban catchments, often installed by the developer of an urban property, and "off-site" controls, which involve larger basins and serve substantially larger urban drainage areas. Because of the appreciable economy of scale inherent in the cost relationship defined by Figure 8-2, this factor must be taken into account in developing cost/performance summaries for urban runoff quality control using detention basins. Accordingly, the control costs presented below for wet basin designs indicate the differences based on the size of the urban catchment the basin is designed to serve.

Figure 8-3 presents a planning level approximation of both present value and annual cost of wet detention basins. Amoritization of costs is based on a 20 year basin life and an interest rate of 10 percent.

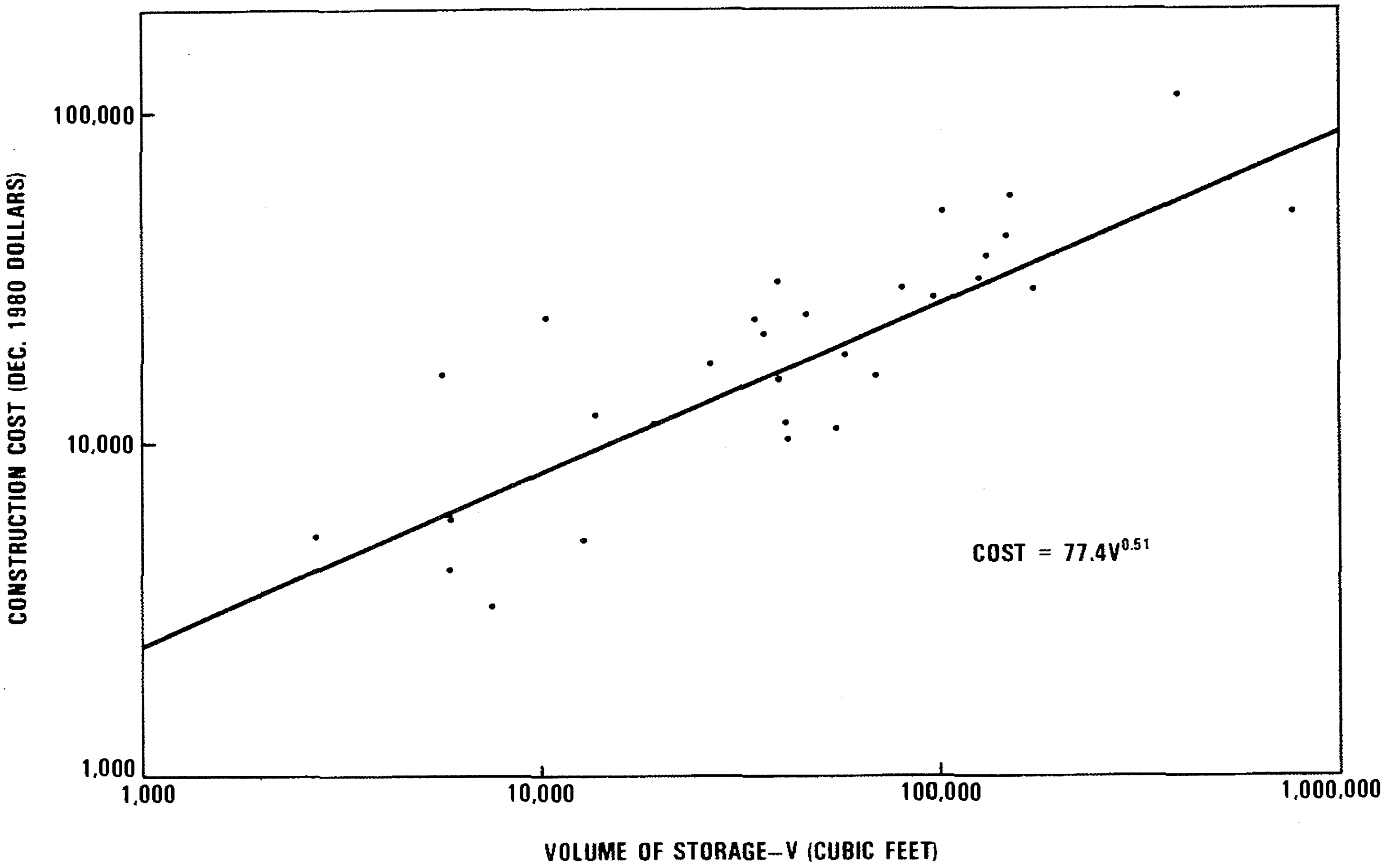
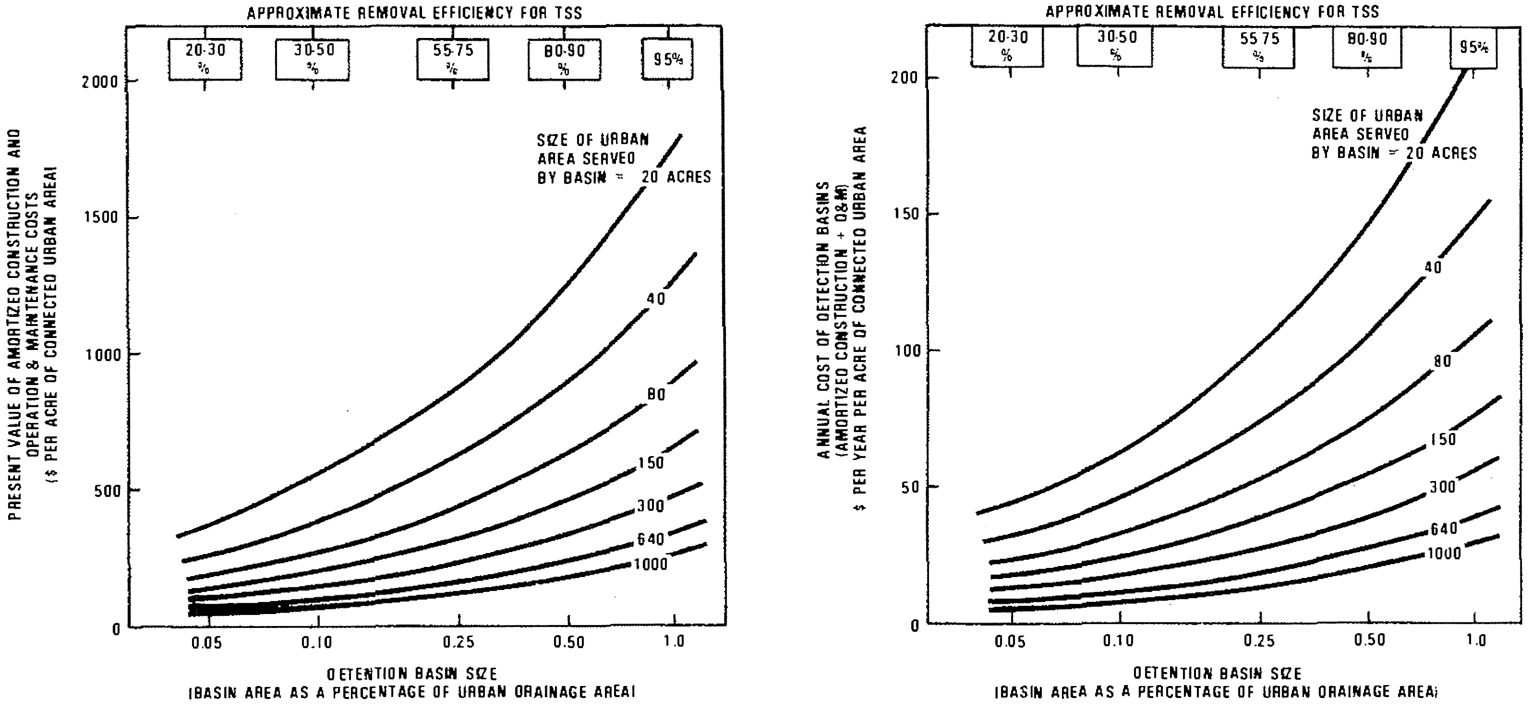


Figure 8-2. Average Stormwater Management (Dry) Pond Construction Cost Estimates Vs. Volume of Storage



83-2061 35

BASIS WET BASINS--CONSTRUCTION COSTS 40% GREATER THAN FIGURE 8 2
ANNUAL O&M COST--5% OF BASE CONSTRUCTION COST
BASIN AVG DEPTH 3.5 FEET
INTEREST RATE 10%
BASIN LIFE 20 YEARS

Figure 8-3. Cost of Urban Runoff Control Using Wet Detention Basins

The performance levels associated with a particular basin size are shown at the top of the plots as a range for long-term average removal efficiencies for TSS. The range associated with a particular size reflects the regional differences in performance which can be expected (Figure 8-1) as a result of regional differences in storm characteristics. Approximate removal efficiencies for pollutants other than TSS can be estimated by factoring the indicated TSS removal by the particulate fraction of the pollutant of interest. The supplementary NURP document dealing with detention basins provides information to permit further refinement. A more concise local summary of cost/performance relationships can be developed using the NURP data and analysis methods, if local rainfall and land use characteristics, and design and planning preferences are utilized.

The generalized relationships shown by Figure 8-3 can be summarized as follows, if an urban catchment size of 20 to 40 acres is taken to represent a typical "on-site" control application, and an "off-site" application is reflected by detention basins serving 640 to 1000 acres.

Control Application	Approximate Level of Control (% TSS Reduction)	Cost Per Acre of Urban Area (Approximate)	
		Present Value	Annual Cost
On-site	50 90	\$500 - \$700 \$1000 - \$1500	\$60 - \$80 \$125 - \$175
Off-site	50 90	\$100 \$250	\$10 \$25

RECHARGE DEVICES

Control measures which enhance the infiltration of urban runoff are indicated by the NURP studies to be techniques which are practical to apply and capable of effective reductions in urban runoff quantity and quality. This finding is based on project reports and on the results of a screening analysis using a probabilistic methodology described in a supplementary NURP document on detention basins.

The issue of the potential contamination of groundwater aquifers due to enhanced infiltration of urban storm runoff has been discussed in the previous chapter dealing with receiving water impacts. The favorable findings support further consideration of this technique. At the same time, it must be emphasized that specific local conditions may make recharge inappropriate. Such conditions can include steep slopes, soil conditions, depth to groundwater, and the proximity of water supply wells. Sound planning and engineering judgement must be applied to determine the acceptability of this control approach in a local situation.

However, where local conditions premit, a wide variety of design concepts are available for use. These range from off-site applications consisting of large retention basins, to small individual on-site units which include infiltration pits and trenches, percolating catch basins, and porous pavement. The operating principle is the same regardless of size or design concept. The important elements are the surface area provided for sub-surface percolation and the storage volume of the device. Overall performance will be related to the size of the recharge device relative to the urban catchment it serves and the permeability (infiltration rate) of the soil.

The context in which the performance capabilities of recharge devices are evaluated is the extent to which urban runoff is "captured" and prevented from discharging directly to surface waters. Pollutant removals are reduced in direct proportion to the runoff volume which is intercepted and recharged. Load reductions will be further enhanced if quality improvements occur in the portion of the runoff which is not captured. The combination of soil infiltration rate and percolating area provided determines the "treatment rate" of a specific recharge device. When storm runoff is applied to the device at rates of flow equal to or less than this rate, 100 percent of the runoff is captured during that event. At higher applied rates, the fraction of the runoff flow in excess of the treatment rate will escape and discharge to surface waters.

Most recharge devices other than porous pavement also provide storage volume. This improves performance capability because portions of the excess runoff can be retained for subsequent percolation when applied rates subside. Overflow to surface water occurs only when the available storage is exceeded.

The Long Island and Metropolitan Washington, D.C. (WASHCOG) NURP projects examined the performance of on-site recharge devices. An interconnected system of percolating catch basins in Long Island was estimated to reduce surface water discharges of storm runoff by more than 99 percent. The WASHCOG project found that a porous pavement site produced pollutant load reductions on the order of 85 to 95 percent depending on the specific pollutant considered. An infiltration trench studied by this project produced reductions in the order of 50 percent.

The NURP analysis methodology was employed in a screening analysis to assist planning evaluations by establishing the relationship between performance level and device size and soil percolation rates. Figure 8-4 presents a planning level estimate of the influence of size, soil characteristics, and regional rainfall differences on the performance of recharge devices.

The upper plot illustrates the significant effect regional differences in rainfall characteristics can have on the performance of identical recharge devices. Basin depth, soil percolation rate, and runoff coefficient for the urban catchment are the same for each case. The performance differences result from differences in the intensity and volume of the average storms in each region. Basin size is represented on the horizontal axis by expressing the percolation area that is provided as a percentage of the area of the contributing urban catchment. For example, a recharge device with a percolating surface area equal to 0.10 percent of an urban catchment represents a design which provides (43,560 sq ft/acre x 0.10/100% =) 43.5 square feet of

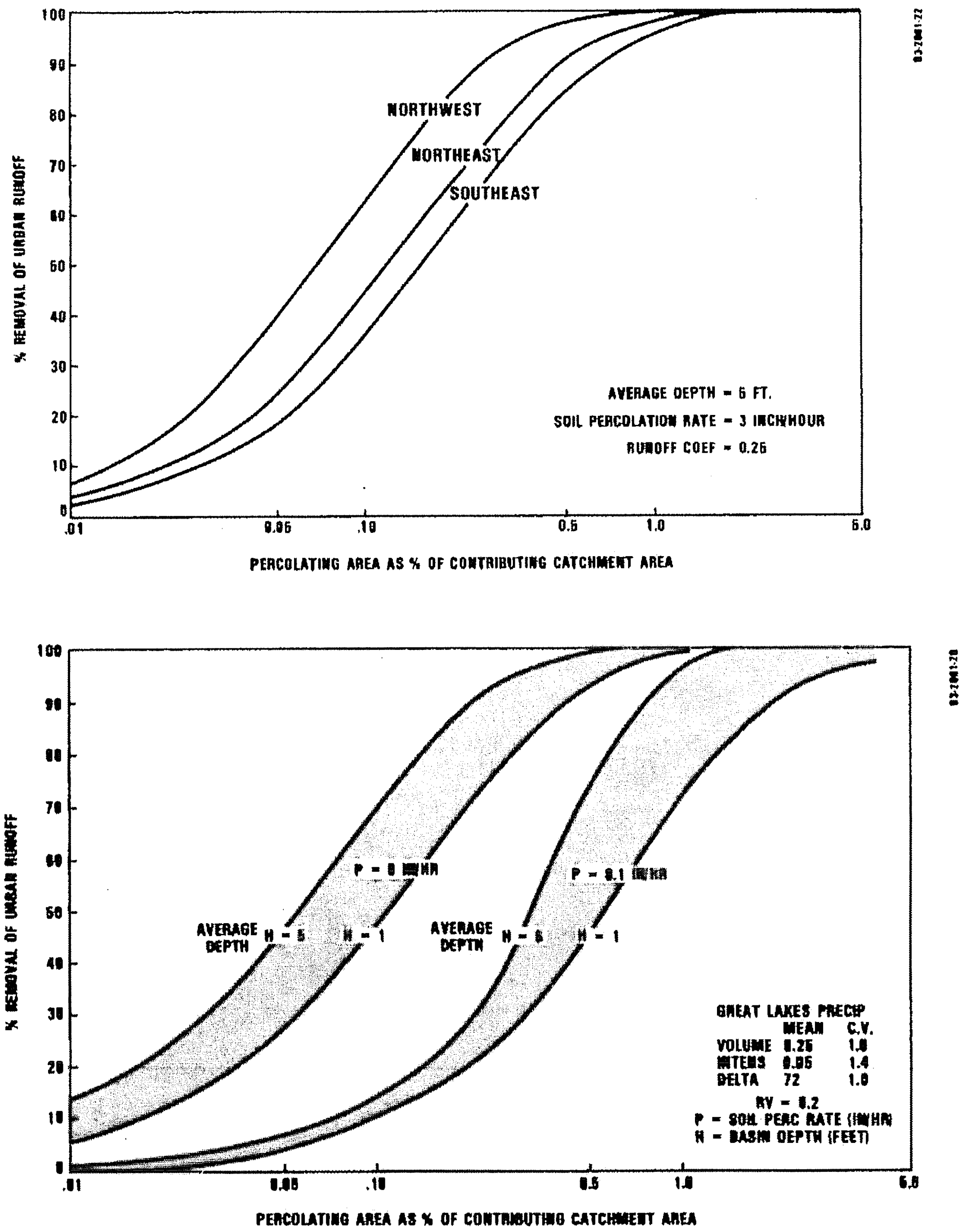


Figure 8-4. Long Term Average Performance of Recharge Devices

percolating surface area for each acre of urban catchment it serves. The long-term average reductions in urban runoff volume and pollutant load which can be expected will be approximately 35 percent in the southeast, 45 percent in the northeast and 65 percent in the Pacific northwest.

The lower plot illustrates the much more significant influence of the amount of storage volume provided (incidated by basin average depth), and the permeability of the soil through which the storm runoff must percolate. The rainfall characteristics used in this analysis are typical of the Great Lakes region of the United States and are roughly comparable to those in the northeastern part of the country. As might be expected, the permeability of the soil in which the recharge device is constructed has a dominant influence on performance capability. However significant compensation for low percolation rates can be achieved by increases in percolation area and storage volume.

When the screening analysis results are considered along with the favorable results from the NURP studies, the NURP findings indicate that with a reasonable degree of design flexibility to compensate for soils with lower percolation rates, recharge devices provide a very effective method for control of urban runoff.

STREET SWEEPING

End-of-pipe urban runoff pollutant concentrations have been commonly viewed as being a function of two prime factors -- accumulation of contaminants on street surfaces and rainfall/runoff washoff. The postulated beneficial effect of street sweeping was to reduce contaminant accumulation. Prior to NURP, emphasis of street sweeping investigations was placed on street surface mechanisms (e.g., accumulation and washoff) and sweeper equipment performance in removing street dirt. While these studies provided valuable insights into the possible benefits of street sweeping, measurements of end-of-pipe concentrations are the only direct measures of street sweeping effectiveness in water quality terms.

Recognizing this, NURP was designed to provide a large data base of urban runoff water quality concentrations for both swept and unswept conditions. In addition, the NURP street sweeping projects gathered and evaluated data on atmospheric deposition (i.e., wetfall and dryfall), street surface accumulation and washoff, and street sweeper removal rates and costs. The individual project reports look at these other issues, and the results are not repeated herein. Of prime interest and provided below is the effectiveness of street sweeping in reducing end-of-pipe urban runoff pollutant concentrations (and ultimately receiving water impacts). The findings presented below are based upon the analyses performed by the individual projects, as well as other statistical techniques, and are generally consistent with the projects' conclusions.

Five of the 28 NURP prototype projects had the evaluation of street sweeping as a central element of their work plans. These projects were as follows:

Project	Number of Sites
Castro Valley, CA	1
Milwaukee, WI	8
Champaign-Urbana, IL	4
Winston-Salem, NC	2
Bellevue, WA	2

Long Island, NY and Baltimore, MD also collected limited street sweeping data. The experimental designs of the projects varied in detail, but essentially followed either a paired basin or serial basin approach to gather test and control data, with some projects using both approaches. The general concept was that during a test period street sweeping would be more intensive (up to daily) and thorough (e.g., with operator training, parking bans, etc.) than during control periods when the streets were to be swept as usual or not at all.

In the paired basin approach, two adjacent or close-by basins were operated in a "control" or unswept mode for certain periods of time to establish a baseline comparison, and then street sweeping was performed in a "test" basin while the other remained as a control. The data provided an overall comparison between basins as well as a series of synoptic events for both basins. In the serial approach, a basin was periodically operated in either a control or test mode, with the periods adjusted so that all seasons of the year were represented in each mode. Here, rather than synoptic data pairs, one has data strings for both "swept" and "unswept" conditions.

There are no well established or prescribed procedures for evaluating the possible reduction in runoff concentrations due to street sweeping. Issues of concern include storm size and intensity effects, time since last rain, ability to select truly paired basins, seasonal effects, etc. In an attempt to sort out these issues, an exploratory data analysis was performed, and the following findings were established:

- Street sweeping has not been found to change the basic probability distribution of event mean concentrations. That is, the fundamental assumption of random, lognormal behavior is valid during sweeping operations.

- The runoff quality characteristics of a basin during swept or unswept conditions is best measured by the maximum likelihood estimator of the median EMC, with the uncertainty indicated by the 90 percent confidence interval of the median.

- There is in most cases no significant correlation (and in a few cases a weak negative correlation) between EMCs and storm runoff volume. EMCs and storm runoff intensities are also generally uncorrelated (but in isolated cases exhibit a weak positive correlation). The implication of these findings is that differences in concentrations between swept and unswept conditions will be largely unaffected by the size of the storms during the monitoring periods. Because of this independence between concentration and volume, effects of sweeping on EMCs will also indicate effects on mass pollutant loads.

- EMCs for synoptic events on paired basins are, in general, not significantly correlated or in some cases are weakly correlated; however, over the longer term (e.g., mean, frequency distribution, etc.), there are no significant differences between the distribution of EMCs of paired basins. These results show that basins are independent from storm to storm, and thus, comparisons between basins should not be attempted using synoptic events, but the basins do have similar statistical properties and thus can be considered paired.

To evaluate the effectiveness of street sweeping, a series of bivariate plots were constructed for projects using the serial basin approach. The site median EMCs for swept and unswept conditions form the data pairs of the plots. Bivariate plots are presented in Figure 8-5 for TSS, COD, TP, TKN, and Pb concentrations, respectively. Each plot contains swept or unswept conditions for multiple project sites. The assumption of the analysis is that a large enough data base was collected to negate any temporal effects such as seasonal, land use conditions, parking patterns, and other possible factors (as noted earlier, storm volume and intensity effects are not believed to be significant). Examining the bivariate plots, it is observed that, for the NURP data, the median concentrations are as likely to be increased as decreased by street sweeping. Further, street sweeping never produced a dramatic (e.g., >50 percent) reduction in concentrations (or loads).

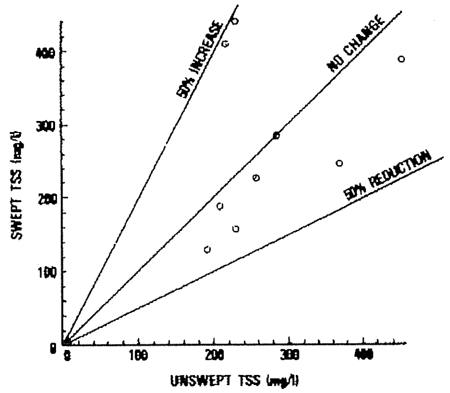
Street sweeping performance, as measured by the percent change in the site median EMC, for selected NURP sites is graphically displayed in Figure 8-6. The results are for five constituents (TSS, COD, TP, TKN, and Pb) at 10 sites nationwide). For each site, the median EMC is based on data from between 10 and 60 events, with 30 events typical. Based on Figure 8-6 a number of important observations are evident.

- Performance as measured by change in site median EMC is highly variable.

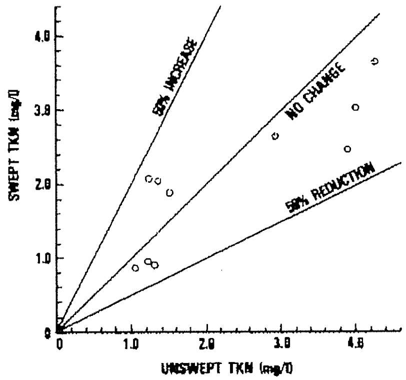
- Where reductions occur, they generally occur for all constituents.

- Reductions never exceed 50 percent.

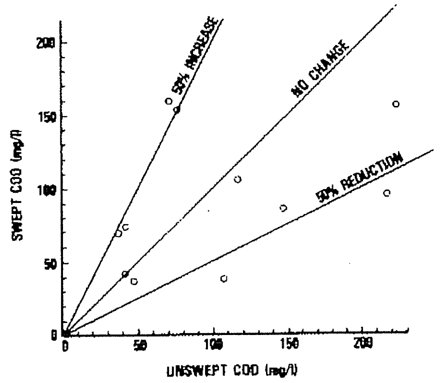
(TSS Concentrations)



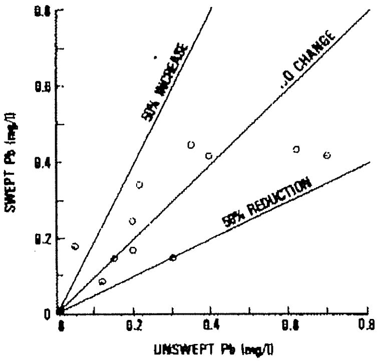
(TKN Concentrations)



(COD Concentrations)



(Pb Concentrations)



(TP Concentrations)

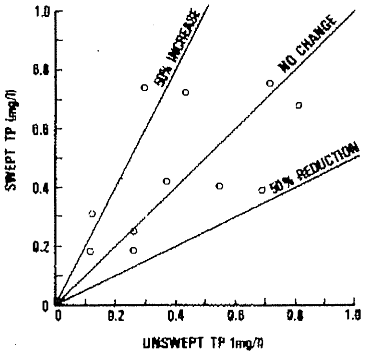


Figure 8-5. Bivariate Plots of Median EMCs for Swept and Unswept Conditions

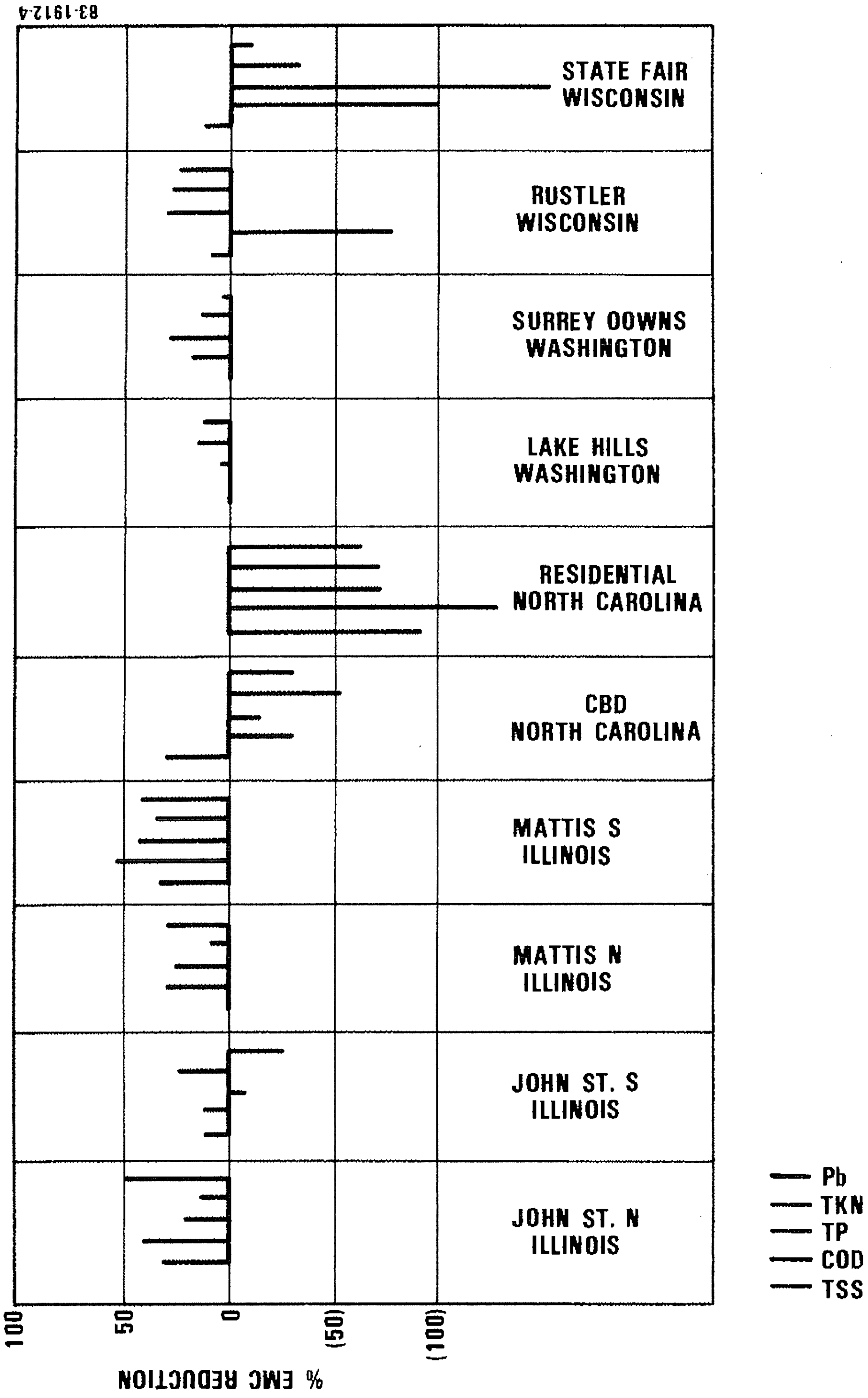


Figure 8-6. Street Sweeping Performance

In evaluating the results, it is critical that the uncertainty in the estimate of median EMCs based on limited observed data, and thus the uncertainty in performance estimates, be assessed. This is especially true for the cases of apparent increases in concentrations indicated by Figure 8-6.

For each of the 10 sites considered, the 90 percent confidence intervals of the site median EMCs were computed as indicated in Figure 8-7. This analysis indicates that there is generally no significant difference between median EMCs for swept and unswept conditions. The implications of this analysis of uncertainty are as follows:

- Based on statistical testing, no significant reductions in EMCs are realized by street sweeping.

- The indicated changes in site median EMCs (increases or decreases) are much more likely due to random sampling than actual effects of sweeping operations.

- Benefits of street sweeping (if any) are masked by the large variability of the EMCs, therefore the benefit is certainly not large (e.g., >50 percent), and an even larger site data base is required to further identify the possible effect.

- In the above context, the hypothesis that street sweeping increases EMCs is generally not shown by the data, though it could occur in isolated, site specific cases.

Urban runoff loads are the product of long term (e.g., annual) runoff volume and event mean concentration. Under this definition, statements concerning EMCs also hold for loads.

OTHER CONTROL APPROACHES

Several best management practices (BMPs) in addition to those discussed above should be identified on the basis that local planning efforts determined them to be practical to apply and to have the potential to provide significant improvements in the quality characteristics of urban runoff. They are grouped together in this section and discussed only briefly, principally because, for one reason or another, sufficient data to characterize their performance capabilities was not developed during the NURP program.

Grass Swales

Three grass swales were monitored by the Washington, D.C. area NURP project. No significant improvement is urban runoff quality was indicated for pollutants analyzed. Increases in zinc concentration which were observed were attributed to mobilization of zinc from the galvanized culverts which carried runoff under the driveways at the monitored residential sites. However the project study report concluded that modifications which would increase residence of runoff in the swales and enhance infiltration capability could make this BMP effective for control of urban runoff.

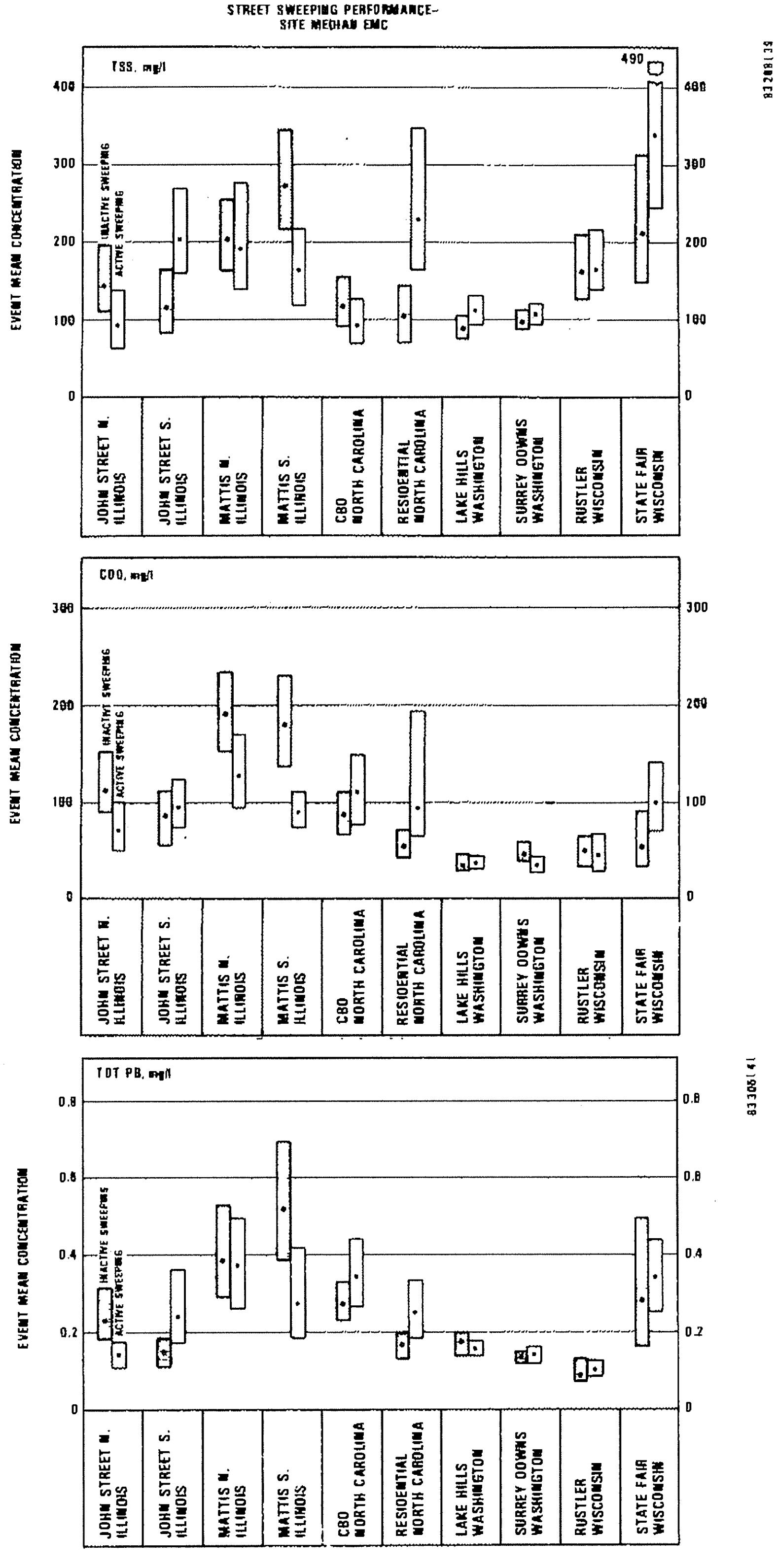


Figure 8-7. Effect of Street Sweeping on Site Median EMC Values

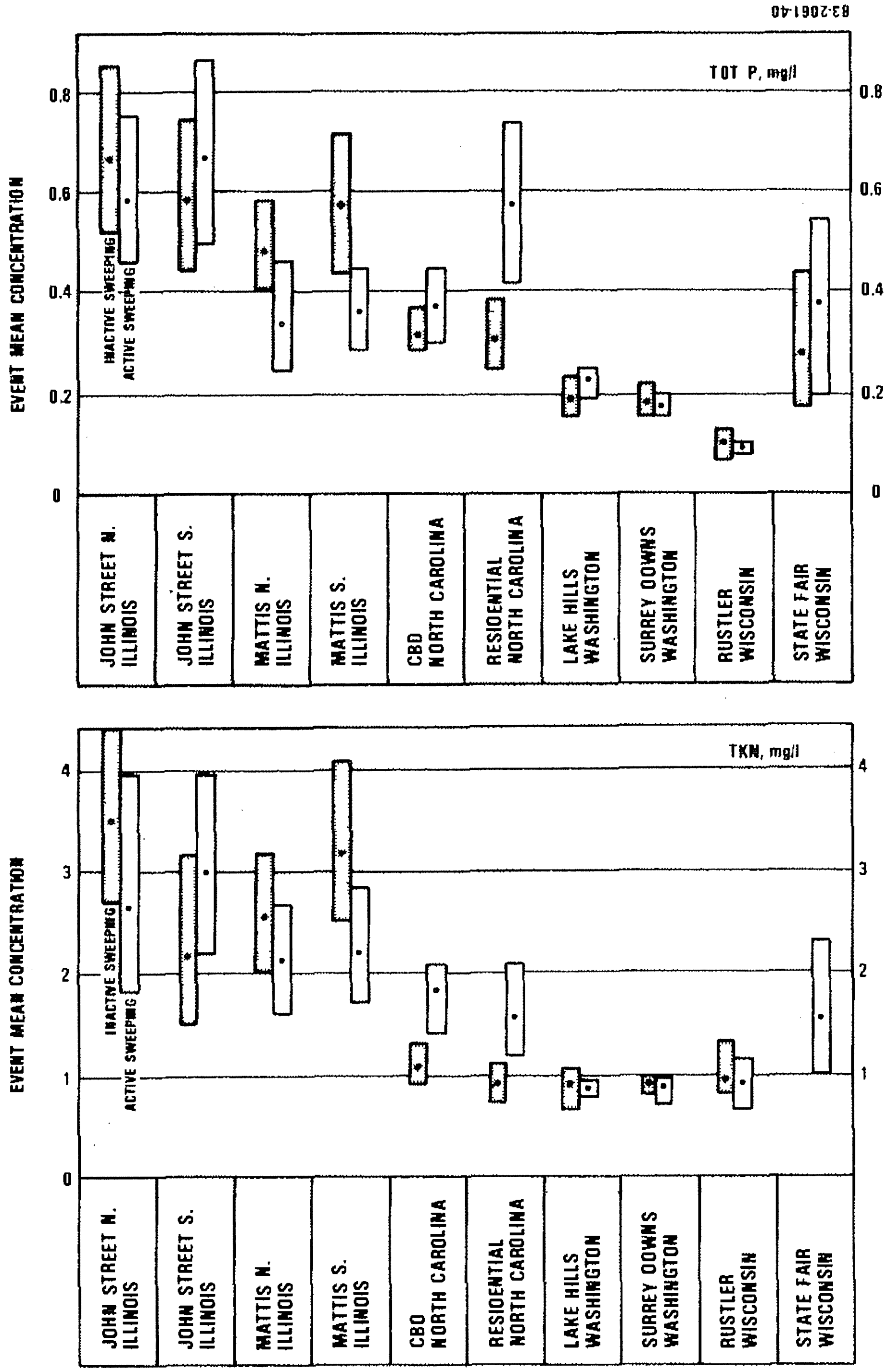


Figure 8-7. Effect of Street Sweeping on Site Median EMC Values (Cont'd)

The Durham, New Hampshire NURP project monitored performance of a carefully designed artificial swale which received runoff from a commercial parking lot. Over 11 monitored storms, both soluble and particulate fractions of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. Reductions in COD, nitrate, and ammonia were on the order of 25 percent. The swale did not prove to be effective in reducing concentrations or organic nitrogen, phosphorus, or bacterial species. It should be noted that the performance capabilities indicated are based only on the concentration changes produced in the stormwater which passes completely through the swale. To the extent that infiltration of a portion of the runoff is effected by a swale, load reductions would be increased in proportion.

The NURP results suggest that grass swales represent a practical and potentially effective technique for control of urban runoff quality; that design conditions are of major significance; and that additional study is necessary to establish such parameters.

Wetlands

The potential of either natural or artificially created wetland areas to effect favorable modification of urban runoff pollutant loads (particularly sediment, nutrients, and heavy metals) has been widely suggested. The NURP experience reinforces this expectation, but has not developed the detailed performance data to permit either characterizing general performance capabilities or identifying general design principles and parameters. Additional study will be required to develop such information.

Miscellaneous

This category encompasses a variety of BMPs which were identified at the local level as techniques of quality control which appeared to be relevant for the circumstances which were operative. They are grouped under this category because (a) their applicability tends to be site-specific rather than general, and (b) while their effectiveness as a BMP may be substantial on a relatively small spatial scale, the broad-scale effect on urban runoff loads has not been possible to document.

BMPs in this category include erosion control practices and urban housekeeping practices. As an example of the former, the Little Rock, Arkansas NURP project widened and stabilized (with rip rap) a segment of an urban stream to reduce erosion potential. The Baltimore NURP project data clearly indicated the substantial difference in urban runoff quality that can result from the general level of cleanliness maintained in an urban neighborhood.

CHAPTER 9
CONCLUSIONS

INTRODUCTION

The Nationwide Urban Runoff Program has addressed such issues as quantifying the characteristic of urban runoff, assessing the water quality effects on receiving water bodies attributable to urban runoff discharges, and examining the effectiveness of control practices in removing the pollutants found in urban runoff. This chapter summarizes NURP's conclusion relating to these issues and is based on the results presented in Chapters 6, 7, and 8 of this report. Conclusions reached by the individual NURP projects are also presented to further support the results of the national level analysis.

URBAN RUNOFF CHARACTERISTICS

General

Field monitoring was conducted to characterize urban runoff flows and pollutant concentrations. This was done for a variety of pollutants at a substantial number of sites distributed throughout the country. The resultant data represent a cross-section of regional climatology, land use types, slopes, and soil conditions and thereby provide a basis for identifying patterns of similarities or differences and testing their significance.

Urban runoff flows and concentrations of contaminants are quite variable. Experience shows that substantial variations occur within a particular event and from one event to the next at a particular site. Due to the high variability of urban runoff, a large number of sites and storm events were monitored, and a statistical approach was used to analyze the data. Procedures are available for characterizing variable data without requiring knowledge of or existence of any underlying probability distribution (nonparametric statistical procedures). However, where a specific type of probability distribution is known to exist, the information content and efficiency of statistical analysis is enhanced. Standard statistical procedures allowed probability distributions or frequency of occurrence to be examined and tested. Since the underlying distributions were determined to be adequately represented by the lognormal distribution, the log (base e) transforms of all urban runoff data were used in developing the statistical characterizations.

The event mean concentration (EMC), defined as the total constituent mass discharge divided by the total runoff volume, was chosen as the primary water quality statistic. Event mean concentrations were based on flow weighted composite samples for each event at each site in the accessible data base. EMCs were chosen as the primary water quality characteristic subjected to detailed analysis, even though it is recognized that mass loading characteristics of urban runoff (e.g., pounds/acre for a specified time interval) is ultimately the relevant factor in many situations. The reason is that, unlike EMCs, mass loadings are very strongly influenced by the amount of precipitation and runoff, and estimates of typical annual mass loads will be biased by the size of monitored storm events. The most reliable basis for characterizing annual or seasonal mass loads is on the basis of EMC and site-specific rainfall/runoff characteristics.

Establishing the fundamental distribution as lognormal and the availability of a sufficiently large population of EMCs to provide reliability to the statistics derived has yielded a number of benefits, including the ability to provide:

- Concise summaries of highly variable data
- Meaningful comparisons of results from different sites, events, etc.
- Statements concerning frequency of occurrence. One can express how often values will be expected to exceed various magnitudes of interest.
- A more useful method of reporting data than the use of ranges; one which is less subject to misinterpretation
- A framework for examining "transferability" of data in a quantitative manner

Conclusions

1. Heavy metals (especially copper, lead and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff. End-of-pipe concentrations exceed EPA ambient water quality criteria and drinking water standards in many instances. Some of the metals are present often enough and in high enough concentrations to be potential threats to beneficial uses.

   All 13 metals on EPA's priority pollutant list were detected in urban runoff samples, and all but three at frequencies of detection greater than 10 percent. Most often detected among the metals were copper, lead, and zinc, all of which were found in at least 91 percent of the samples.

   Metal concentrations in end-of-pipe urban runoff samples (i.e., before dilution by receiving water) exceeded EPA's water quality criteria and drinking water standards numerous times. For example, freshwater acute criteria were exceeded by copper concentrations in 47 percent of the samples and by lead in 23 percent. Freshwater chronic exceedances were common for lead (94 percent), copper (82 percent), zinc (77 percent), and cadmium (48 percent). Regarding human toxicity, the most significant pollutants were lead and nickel, and for human carcinogenesis, arsenic and beryllium. Lead concentrations violated drinking water criteria in 73 percent of the samples.

It should be stressed that the exceedances noted above do not necessarily imply that an actual violation of standards will exist in the receiving water body in question. Rather, the enumeration of exceedances serves a screening function to identify those heavy metals whose presence in urban runoff warrants high priority for further evaluation.

Based upon the much more extensive NURP data set for total copper, lead, and zinc, the site median EMC values for the median urban site are: Cu = 34 µg/l, Pb = 144 µg/l, and Zn = 160 µg/l. For the 90th percentile urban site the values are: Cu = 93 µg/l, Pb = 350 µg/l, and Zn = 500 µg/l. These values are suggested to be appropriate for planning level screening analyses where data are not available.

Some individual NURP project sites (e.g., at DC1, MD1, NH1) found unusually high concentrations of certain heavy metals (especially copper and zinc) in urban runoff. This was attributed by the projects to the effect of acid rain on materials used for gutters, culverts, etc.

2. <u>The organic priority pollutants were detected less frequently and at lower concentrations than the heavy metals.</u>

Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Criteria exceedances were less frequently observed among the organics than the heavy metals. One unusually high pentachlorophenol concentration of 115 µg/l resulted in exceedances of the freshwater acute and organoleptic criteria. This observation and one for chlordane also exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentachlorophenol, bis (2-ethylhexyl) phthalate, gamma-BHC, chlordane, and alpha-endosulfan. All other organic exceedances were in the human carcinogen category and were most serious for alpha-hexachlorocyclohexane (alpha-BHC), gamma-hexachlorocyclohexane (gamma-BHC or Lindane), chlordane, phenanthrene, pyrene, and chrysene.

The fact that the NURP priority pollutant monitoring effort was limited to two samples at each site leaves us unable to make many generalizations about those organic pollutants which occurred only rarely. We can speculate that their occurrences tend to be very site specific as opposed to being a generally widespread phenomena, but much more data would be required to conclusively prove this point.

3. <u>Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in many surface waters, even those providing high degrees of dilution.</u>

Fecal coliform counts in urban runoff are typically in the tens to hundreds of thousand per 100 ml during warm weather conditions, with the median for all sites being around 21,000/100 ml. During cold weather, fecal coliform counts are more typically in the 1,000/100 ml range, which is the median for all sites. Thus, violations of fecal coliform standards were reported by a number of NURP projects. High fecal coliform counts may not cause actual use impairments, in some instances, due to the location of the urban runoff discharges relative to swimming areas or shellfish beds and the degree of dilution/dispersal and rate of die off. The same is true of total coliform counts, which were found to exceed EPA water quality criteria in undiluted urban runoff at virtually every site every time it rained.

The substantial seasonal differences noted above do not correspond with comparable variations in urban activities. The NURP analyses as well as current literature suggest that fecal coliform may not be the most appropriate indicator organism for identifying potential health risks when the source is stormwater runoff.

4. Nutrients are generally present in urban runoff, but with a few individual site exceptions, concentrations do not appear to be high in comparison with other possible discharges to receiving water bodies.

   NURP data for total phosphorus, soluble phosphorus, total kjeldahl nitrogen, and nitrate plus nitrite as nitrogen were carefully examined. Median site EMC median concentrations in urban runoff were TP = 0.33 mg/l, SP = 0.12 mg/l, TKN = 1.5 mg/l, and NO2+3 - N = 0.68 mg/l. On an annual load basis, comparison with typical monitoring data, literature values, and design objectives for discharges from a well run secondary treatment plant suggests that mean annual nutrient loads from urban runoff are around an order of magnitude less than those from a POTW.

5. Oxygen demanding substances are present in urban runoff at concentrations approximating those in secondary treatment plant discharges. If dissolved oxygen problems are present in receiving waters of interest, consideration of urban runoff controls as well as advanced waste treatment appears to be warranted.

   Urban runoff median site EMC median concentrations of 9 mg/l BOD5 and 65 mg/l COD are reflected in the NURP data, with 90th percentile site EMC median values being 15 mg/l BOD5 and 140 mg/l COD. These concentrations suggest that, on an annual load basis, urban runoff is comparable in magnitude to secondary treatment plant discharges.

   It can be argued that urban runoff is typically well oxygenated and provides increased stream flow and, hence, in view of relatively long travel times to the critical point, that dissolved oxygen problems attributable solely to urban runoff should not be widespread occurrences. No NURP project specifically identified a low DO condition resulting from urban runoff. Nonetheless, there will be some situations where consideration of urban runoff controls for oxygen demanding substances in an overall water quality management strategy would seem appropriate.

6. Total suspended solids concentrations in urban runoff are fairly high in comparison with treatment plant discharges. Urban runoff control is strongly indicated where water quality problems associated with TSS, including build-up of contaminated sediments, exist.

   There are no formal water quality criteria for TSS relating to either human health or aquatic life. The nature of the suspended solids in urban runoff is different from those in treatment plant discharges, being higher in mineral and man-made products (e.g., tire and street surface wear particles) and somewhat lower in organic particulates. Also, the solids in urban runoff are more likely to have other contaminants adsorbed onto them. Thus, they cannot be simply considered as benign, nor do they only pose an aesthetic issue. NURP did not examine the problem of contaminated sediment build-up due to urban runoff, but it undeniably exists, at least at some locations.

   The suspended solids in urban runoff can also exert deleterious physical effects by sedimenting over egg deposition sites, smothering juveniles, and altering benthic communities.

   On an annual load basis, suspended solids contributions from urban runoff are around an order of magnitude or more greater than those from secondary treatment plants. Control of urban runoff, as opposed to advanced waste treatment, should be considered where TSS-associated water quality problems exist.

7. A summary characterization of urban runoff has been developed and is believed to be appropriate for use in estimating urban runoff pollutant discharges from sites where monitoring data are scant or lacking, at least for planning level purposes.

   As a result of extensive examination, it was concluded that geographic location, land use category (residential, commercial, industrial park, or mixed), or other factors (e.g., slope, population density, precipitation characteristics) appear to be of little utility in consistently explaining overall site-to-site variability in urban runoff EMCs or predicting the characteristics of urban runoff discharges from unmonitored sites. Uncertainty in site urban runoff characteristics caused by high event-to-event variability at most sites eclipsed any site-to-site variability that might have been present. The finding that EMC values are essentially not correlated with storm runoff volumes facilitates the transfer of urban runoff characteristics to unmonitored sites. Although there tend to be exceptions to any generalization, the suggested summary urban runoff characteristics given in Table 6-17 of the report are recommended for planning level purposes as the best estimates, lacking local information to the contrary.

RECEIVING WATER EFFECTS

General

The effects of urban runoff on receiving water quality are highly site-specific. They depend on the type, size, and hydrology of the water body; the urban runoff quantity and quality characteristics; the designated beneficial use; and the concentration levels of the specific pollutants that affect that use.

The conclusions which follow are based on screening analyses performed by NURP, observations and conclusions drawn by individual NURP projects that examined receiving water effects in differing levels of detail and rigor, and NURP's three levels of problem definition. Conclusions are organized on the basis of water body type: rivers and streams, lakes, estuaries and embayments, and groundwater aquifers. Site-specific exceptions should be expected, but the statements presented are believed to provide an accurate perspective on the general tendency of urban runoff to contribute significantly to water quality problems.

Rivers and Streams

1. Frequent exceedances of heavy metals ambient water quality criteria for freshwater aquatic life are produced by urban runoff.

   The Denver NURP project found that in-stream concentrations of copper, lead, zinc, and cadmium exceeded State ambient water quality standards for the South Platte River during essentially all storm events.

   NURP screening analyses suggest that frequent exceedances of both EPA 24-hour and maximum water quality criteria for heavy metals should be expected on a relatively general basis.

2. Although a significant number of problem situations could result from heavy metals in urban runoff, levels of freshwater aquatic life use impairment suggested by the magnitude and frequency of ambient criteria exceedances were not observed.

   Based upon the magnitude and frequency of freshwater aquatic life ambient criteria exceedances, one would expect to observe impairment of this beneficial use in most streams that receive urban runoff discharges. However, those NURP project studies which examined this issue did not report significant use impairment problems associated with urban runoff.

   The Bellevue, Washington NURP project concluded that toxic effects of urban runoff pollutants did not appear to be a significant factor.

   The Tampa, Florida NURP project conducted biological studies of the impact of stormwater runoff upon the biological community of the Hillsborough River. They conducted animal bioassay experiments on five sensitive species in two samples of urban runoff from the Arctic Street drainage basin. Thirty-two bioassay experiments were completed including 22 acute tests and 10 chronic tests. Neither sample of stormwater was acutely toxic to test organisms. Long-term chronic experiments were undertaken with two species and resulted in no significant effects attributable to stormwater exposure.

NURP screening analyses suggest that the potential of urban runoff to seriously impair this beneficial use will be strongly influenced by local conditions and the frequency of occurrence of concentration levels which produce toxic effects under the intermittent, short duration exposures typically produced by urban runoff.

While the application of the screening analysis to the Bellevue and Tampa situations supports the absence of a problem situation in these cases, it also suggests that a significant number of problem situations should be expected. Therefore, although not the general, ubiquitous problem situation that criteria exceedances would suggest, there are site-specific situations in which urban runoff could be expected to cause significant impairment of freshwater aquatic life uses.

Because of the inconsistency between criteria exceedances and observed use impairments due to urban runoff, adaptation of current ambient quality criteria to better reflect use impacts where pollutant exposures are intermittent and short duration appears to be a useful area for further investigation.

3. Copper, lead and zinc appear to pose a significant threat to aquatic life uses in some areas of the country. Copper is suggested to be the most significant of the three.

Regional differences in surface water hardness, which has a strong influence on toxicity, in conjunction with regional variations in stream flow and rainfall result in significant differences in susceptibility to adverse impacts around the nation.

The southern and southeastern regions of the country are the most susceptible to aquatic life effects due to heavy metals, with the northeast also a sensitive area, although somewhat less so.

Copper is the major toxic metal in urban runoff, with lead and zinc also prevalent but a problem in more restricted cases. Copper discharges in urban runoff are, in all but the most favorable cases, a significant threat to aquatic life uses in the southeast and southern regions of the country. In the northeast, problems would be expected only in rather unfavorable conditions (large urban area contribution and high site concentrations). In the remainder of the country (and for the other metals) problems would only be expected under quite unfavorable site conditions. These statements are based on total metal concentrations.

4. Organic priority pollutants in urban runoff do not appear to pose a general threat to freshwater aquatic life.

This conclusion is based on limited data on the frequency with which organics are found in urban runoff discharges and measured end-of-pipe concentrations relative to published toxic criteria. One unusually high pentachlorophenol concentration of 115 µg/l resulted in the only exceedance of the organoleptic criteria. This observation and one for chlordane exceeded the freshwater acute criteria. Freshwater chronic criteria exceedances were observed for pentochlorophenol, bis (2-ethylhexyl) phlhalate, γ-hexachlorocyclohexane (lindane), α-endosulfan, and chlordane.

5. The physical aspects of urban runoff, e.g., erosion and scour, can be a significant cause of habitat disruption and can affect the type of fishery present. However, this area was studied only incidentally by several of the projects under the NURP program and more concentrated study is necessary.

   The Metropolitan Washington Council of Governments (MWCOG) NURP project did an analysis of fish diversity in the Seneca Creek Watershed, 20 miles northwest of Washington, D.C. In this study, specific changes in fishery diversity were identified due to urbanization in some of the sub-watersheds. Specifically, the number of fish species present are reduced and the types of species present changed dramatically, e.g., environmentally sensitive species were replaced with more tolerant species. For example, the Blacknose Dace replaced the Mottled Sculpin. MWCOG concluded that the changes in fish diversity were due to habitat deterioration caused by the physical aspects of urban runoff.

   The Bellevue, Washington NURP project concluded that habitat changes (streambed scour and sedimentation) had a more significant effect than pollutant concentrations, for the changes produced by urbanization.

6. Several projects identified possible problems in the sediments because of the build-up of priority pollutants contributed wholly or in part by urban runoff. However, the NURP studies in this area were few in number and limited in scope, and the findings must be considered only indicative of the need for further study, particularly as to long-term impacts.

   The Denver NURP project found significant quantities of copper, lead, zinc, and cadmium in river sediments. The Denver Regional Council of Governments is concerned that during periods of continuous low flow, lead may reach levels capable of adversely affecting fish.

   The Milwaukee NURP project reported the observation of elevated levels of heavy metals, particularly lead, in the sediments of a river receiving urban runoff.

7. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in most rivers and streams.

   Violations of the fecal coliform standard were reported by a number of NURP projects. In some instances, high fecal coliform counts may not cause actual use impairments due to the location of the urban runoff discharge relative to swimming areas and the degree of dilution or dispersal and rate of die off.

   Coliform bacteria are generally accepted to be a useful indicator of the possible presence of human pathogens when the source of contamination is sanitary sewage. However, no such relationship has been demonstrated for urban runoff. Therefore, the use of coliforms as an indicator of human health risk when the sole source of contamination is urban runoff, warrants further investigation.

8. Domestic water supply systems with intakes located on streams in close proximity to urban runoff discharges are encouraged to check for priority pollutants which have been detected in urban runoff, particularly those in the organic category.

   Sixty-three of a possible 106 organics were detected in urban runoff samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22 percent), followed by the pesticide α-hexachlorocyclohexane (α-BHC) (20 percent). An additional 11 organic pollutants were reported at frequencies between 10 and 20 percent; 3 pesticides, 3 phenols, 4 polycyclic aromatics, and a single halogenated aliphatic.

Lakes

1. Nutrients in urban runoff may accelerate eutrophication problems and severely limit recreational uses, especially in lakes. However, NURP's lake projects indicate that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff component.

   The Lake Quinsigamond NURP project in Massachusetts identified eutrophication as a major problem in the lake, with urban runoff being a prime contributor of the critical nutrient phosphorus. Point source discharges to the lake have been eliminated almost entirely. However, in spite of the abatement of point sources, survey data indicate that the lake has shown little improvement over the abatement period. In particular, the trophic status of the lake has shown no change, i.e., it is still classified as late mesotrophic-early eutrophic. Substantial growth is projected in the basin, and there is concern that Lake Quinsigamond will become more eutrophic. A proposed water quality management plan for the lake includes the objective of reducing urban runoff pollutant loads.

   The Lake George NURP project in New York State also identified increasing eutrophication as a potential problem if current development trends continue. Lake George is not classified as eutrophic, but from 1974 to 1978 algae production in the lake increased logarithmically. Lake George is a very long lake, and the limnological differences between the north and south basins provide evidence of human impact. The more developed, southern portion of the lake exhibits lower transparencies, lower hypolimnetic dissolved oxygen concentrations, higher phosphorus and chlorophyll a concentrations, and a trend toward seasonal blooms of blue-green algae. These differences in water quality indicators are associated with higher levels of cultural activities (e.g., increased sources of phosphorus) in the southern portion of the lake's watershed, and continued development will tend to accentuate the differences.

The Lake George NURP project estimated that urban runoff from developed areas currently accounts for only 13.6 percent of the annual phosphorus loadings to Lake George as a whole. In contrast, developed areas contribute 28.9 percent of the annual phosphorus load to the NURP study areas at the south end of the Lake. Since there are no point source discharges, this phosphorus loading is due solely to urban runoff. These data illustrate the significant impact of urbanization on phosphorus loads.

The NURP screening analysis suggests that lakes for which the contributions of urban runoff are significant in relation to other nonpoint sources (even in the absence of point source discharges) are indicated to be highly susceptible to eutrophication and that urban runoff control may be warranted in such situations.

2. <u>Coliform bacteria discharges in urban runoff have a significant negative impact on the recreational uses of lakes.</u>

As was the case with rivers and streams, coliform bacteria in urban runoff can cause violations of criteria for the recreational use of lakes. When unusually high fecal coliform counts are observed, they may be partially attributable to sanitary sewage contamination, in which case significant health risks may be involved.

The Lake Quinsigamond NURP project in Massachusetts found that bacterial pollution was widespread throughout the drainage basin. In all cases where samples were taken, fecal coliforms were in excess of 10,000 counts per 100 ml, with conditions worse in the Belmont street storm drains. This project concluded that the very high fecal coliform counts in their stormwater are at least partially due to sewage contamination apparently entering the stormwater system throughout the local catchment.

The sources of sewage contamination are leaking septic tanks, infiltration from sanitary sewers into storm sewers, and leakage at manholes. In the northern basin, the high fecal coliform counts are attributed to known sewage contamination sources on Poor Farm Brook. The data from the project suggest that it would be unwise to permit body contact recreation in the northern basin of the lake during or immediately following significant storm events. The project concluded that disinfection at selected storm drains should be considered in the future, especially if the sewage contamination cannot be eliminated.

The Mystic River NURP project in Massachusetts found various areas where fecal coliform counts were extremely high in urban stormwater. Fecal coliform levels of up to one million with an average of 178,000/100 ml were recorded in Sweetwater Brook, a tributary to Mystic River, during wet weather. These high fecal coliform levels were specifically attributed to surcharging in their sanitary sewers, which caused sanitary sewage to overflow into their storm drains via the combined manholes present in this catchment. Fecal coliform levels above the class B fecal coliform standard of 200 per 100 ml were found in approximately one-third of the samples tested in the upper and lower forebays of the Upper Mystic Lake and occasionally near the lake's outlet. In addition, Sandy Beach, a public swimming area on Upper Mystic Lake, exceeded the State fecal coliform criteria in July of 1982, and warnings that swimming may be hazardous to public health were posted for several days. It is important to note that sewage contamination of surface waters is a major problem in the watershed. The project concluded that urban runoff contributes to the bacteria load during wet weather but, comparatively, is much less significant than the sanitary sources.

Estuaries and Embayments

1. Adverse effects of urban runoff in marine waters will be a highly specific local situation. Though estuaries and embayments were studied to a very limited extent in NURP, they are not believed to be generally threatened by urban runoff, though specific instances where use is impaired or denied can be of significant local and even regional importance. Coliform bacteria present in urban runoff is the primary pollutant of concern, causing direct impacts on shellfish harvesting and beach closures.

   The significant impact of urban runoff on shellfish harvesting has been well documented by the Long Island, New York NURP project. In this project, stormwater runoff was identified as the major source of bacterial loading to marine waters and, thus, the indirect cause of the denial of certification by the New York State Department of Conservation for about one-fourth of the shellfishing area. Much of this area is along the south shore, where the annual commercial shellfish harvest is valued at approximately $17.5 million.

   The Myrtle Beach, South Carolina NURP project found that stormwater discharges from the City of Myrtle Beach directly onto the beach showed high bacterial counts for short durations immediately after storm events. In many instances these counts violated EPA water quality criteria for aquatic life and contact recreation. The high bacteria counts, however, were associated with standing pools formed at the end of collectors for brief periods following the cessation of rainfall and before the runoff percolated into the sand. Consequently, the threat to public health was not considered great enough to warrant closure of the beach.

Groundwater Aquifers

1. Groundwater aquifers that receive deliberate recharge of urban runoff do not appear to be imminently threatened by this practice at the two locations where it was investigated.

   Two NURP projects (Long Island and Fresno) are situated over sole source acquifers. They have been practicing recharge with urban runoff for two decades or more at some sites, and extensively investigated the impact of this practice on the quality of their groundwater. They both found that soil processes are efficient in retaining urban runoff pollutants quite close to the land surface, and concluded that no change in the use of recharge basins is warranted.

   Despite the fact that some of these basins have been in service for relatively long periods of time and pollutant breakthrough of the upper soil layers has not occurred, the ability of the soil to continue to retain pollutants is unknown. Further attention to this issue is recommended.

CONTROL EFFECTIVENESS

General

A limited number of techniques for the control of urban runoff quality were evaluated by the NURP program. The set is considerably smaller than previously published lists of potential management practices. Since the control approaches that were investigated were selected at the local level, the choices may be taken as an initial indication of local perceptions regarding practicality and feasibility from the standpoint of implementation.

Conclusions

1. There is a strong preference for detention devices, street sweeping, and recharge devices as reflected by the control measures selected at the local level for detailed investigation. Interest was also shown in grass swales and wetlands.

   Six NURP projects monitored the performance of a total of 14 detention devices. Five separate projects conducted in-depth studies of the effectiveness of street sweeping on the control of urban runoff quality. A total of 17 separate study catchments were involved in this effort. Three NURP projects examined either the potential of recharge devices to reduce discharges of urban runoff to surface waters or the potential of the practice to contaminate groundwaters. A total of 12 separate sites were covered by this effort.

   Grass swales were studied by two NURP projects. Two swales in existing residential areas, and one experimental swale constructed to serve a commercial parking lot were studied.

   A number of NURP projects indicated interest in wetlands for improving urban runoff quality at early stages of the program. Only one allocated monitoring activity to this control measure, however.

   Various other management practices were identified as having local interest by individual NURP projects, but none of them was allocated the necessary resources to be pursued to a point which allowed an evaluation of their ability to control pollution from urban runoff. Management practices in this category included urban housekeeping (e.g., litter programs, catch basin cleaning, pet ordinances) and public information programs.

2. Detention basins are capable of providing very effective removal of pollutants in urban runoff. Both the design concept and the size of the basin in relation to the urban area served have a critical influence on performance capability.

   Wet basins (designs which maintain a permanent water pool) have the greatest performance capabilities. Observed pollutant reductions varied from excellent to very poor in the basins which were monitored. However, when basins are adequately sized, particulate removals in excess of 90 percent (TSS, lead) can be obtained. Pollutants with significant soluble fractions in urban runoff show lower reductions; on the order of 65 percent for total P and approximately 50 percent for BOD, COD, TKN, Copper, and Zinc. Results indicate that biological processes which are operative in the permanent pool produce significant reductions (50 percent or more) in soluble nutrients, nitrate and soluble phosphorus. These performance characteristics are indicated by both the NURP analysis results and conclusions reached by individual projects.

Dry basins, (conventional stormwater management basins), which are designed to attenuate peak runoff rates and hence only very briefly detain portions of flow from the larger storms, are indicated by NURP data to be essentially ineffective for reducing pollutant loads.

Dual-purpose basins (conventional dry basins with modified outlet structures which significantly extend detention time) are suggested by limited NURP data to provide effective reductions in urban runoff loads. Performance may approach that of wet ponds; however, the additional processes which reduce soluble nutrient forms do not appear to be operative in these basins. This design concept is particularly promising because it represents a cost effective approach to combining flood control and runoff quality control and because of the potential for converting existing conventional stormwater management ponds.

Approximate costs of wet pond designs are estimated to be in the order of \$500 to \$1500 per acre of urban area served, for on-site applications serving relatively small urban areas, and about \$100 to \$250 per acre of urban area for off-site applications serving relatively large urban areas. The costs reflect present value amounts which include both capital and operating costs. The difference is due to an economy of scale associated with large basin volumes. The range reflects differences in size required to produce particulate removals in the order of 50 percent or 90 percent. Annual costs per acre of urban area served are estimated at \$60 to \$175, and \$10 to \$25 respectively.

3. Recharge Devices are capable of providing very effective control of urban runoff pollutant discharges to surface waters. Although continued attention is warranted, present evidence does not indicate that significant groundwater contamination will result from this practice.

Both individual project results and NURP screening analyses indicate that adequately sized recharge devices are capable of providing high levels of reduction in direct discharges of urban runoff to surface waters. The level of performance will depend on both the size of the unit and the soil permeability.

Application will be restricted to areas where conditions are favorable. Soil type, depth to groundwater, land slopes, and proximity of water supply wells will all influence the appropriateness of this control technique.

Surface accumulations which result from the high efficiency of soils to retain pollutants, suggest further attention in applications where dual purpose recharge areas also serve as recreational fields or playground areas.

4. Street sweeping is generally ineffective as a technique for improving the quality of urban runoff.

Five NURP projects evaluated street sweeping as a management practice to control pollutants in urban runoff. Four of these projects concluded that street sweeping was not effective for this purpose. The fifth, which had pronounced wet and dry seasons, believed that sweeping just prior to the rainy season could produce some benefit in terms of reduced pollution in urban runoff.

A large data base on the quality of urban runoff from street sweeping test sites was obtained. At 10 study sites selected for detailed analysis, a total of 381 storm events were monitored under control conditions, and an additional 277 events during periods when street sweeping operations were in effect. Analysis of these data indicated that no significant reductions in pollutant concentrations in urban runoff were produced by street sweeping.

There may be special cases in which street cleaning applied at restricted locations or times of year could provide improvements in urban runoff quality. Some examples that have been suggested, though not demonstrated by the NURP program, include periods following snow melt or leaf fall, or urban neighborhoods where the general level of cleanliness could be significantly improved.

5. Grass swales can provide moderate improvements in urban runoff quality. Design conditions are important. Additional study could significantly enhance the performance capabilities of swales.

Concentration reductions of about 50 percent for heavy metals, and 25 percent for COD, nitrate, and ammonia were observed in one of the swales studied. However the swale was ineffective in reducing concentrations of organic nitrogen, phosphorus, or bacterial species. Two other swales studied failed to demonstrate any quality improvements in the urban runoff passing through them.

Evaluations by the NURP projects involved concluded, however, that this was an attractive control technique whose performance could be improved substantially by application of appropriate design considerations. Additional study to develop such information was recommended.

Design considerations cited included slope, vegetation type and maintenance, control of flow velocity and residence time, and enhancement of infiltration. The latter factor could produce load reductions greater than those inferred from concentration changes and effect reductions in those pollutant species which are not attenuated by flow through the swale.

6. Wetlands are considered to be a promising technique for control of urban runoff quality. However, neither performance characteristics nor design characteristics in relation to performance were developed by NURP.

   Although a number of projects indicated interest, only one assigned NURP monitoring activity to a wetland. This was a natural wetland, and flows passing though it were uncontrolled. Results suggest its potential to improve quality, but the investigation was not adequate to associate necessary design factors to performance capability. Additional attention to this control technique would be useful, and should include factors such as the need for maintenance harvesting to prevent constituent recycling.

ISSUES

A number of issues with respect to managing and controlling urban runoff emerge from the conclusions summarized above. In some instances they represent the need for additional data/information or for further study. In others they point to the need for follow-up activity by EPA, State, or local officials to assemble and disseminate what is already known regarding water quality problems caused by urban runoff and solutions.

Sediments

The nature and scope of the potential long-term threat posed by nutrient and toxic pollutant accumulation in the sediments of urban lakes and streams requires further study. A related issue is the safe and environmentally sound disposal of sediments collected in detention basins used to control urban runoff.

Priority Pollutants

NURP clearly demonstrated that many priority pollutants can be found in urban runoff and noted that a serious human health risk could exist when water supply intakes are in close proximity to urban stormwater discharges. However, questions related to the sources, fate, and transport mechanisms of priority pollutants borne by urban runoff and their frequencies of occurrence will require further study.

Rainfall pH Effects

The relationship between pH and heavy metal values in urban runoff has not been established and needs further study. Several NURP projects (mostly in the northeastern states) attributed high heavy metals concentrations in urban runoff to the effects of acid rain. Although it is quite plausible that acid rain increases the level of pollutants in urban runoff and may transform them to more toxic and more easily assimilated forms, further study is required to support this speculation.

Industrial Runoff

No truly industrial sites (as opposed to industrial parks) were included in any of the NURP projects. A very limited body of data suggests, however, that runoff from industrial sites may have significantly higher contaminant levels than runoff from other urban land use sites, and this issue should be investigated further.

Central Business Districts

Data on the characteristics of urban runoff from central business districts are quite limited as opposed to other land use categories investigated by NURP. The data do suggest, however, that some sites may produce pollutant concentrations in runoff that are significantly higher than those from other sites in a given urban area. When combined with their typically high degrees of imperviousness, the pollutant loads from central business districts can be quite high indeed. The opportunities for control in central business districts are quite limited, however.

Physical Effects

Several projects concluded that the physical impacts of urban runoff upon receiving waters have received too little attention and, in some cases, are more important determinants of beneficial use attainment than chemical pollutants. This contention requires much more detailed documentation.

Synergy

NURP did not evaluate the synergistic effects that might result from pollutant concentrations experienced in stormwater runoff, in association with pH and temperature ranges that occur in the receiving waters. This type of investigation might reveal that control of a specific parameter, such as pH, would adequately reduce an adverse synergistic effect caused by the presence of other pollutants in combination and be the most cost effective solution. Further investigations should include this issue.

Opportunities for Control

Based upon the results of NURP's evaluation of the performance of urban runoff controls, opportunities for significant control of urban runoff quality are much greater for newly developing areas. Institutional considerations and availability of space are the key factors. Guidance on this issue in a form useful to States and urban planning authorities should be prepared and issued.

Wet Weather Water Quality Standards

The NURP experience suggests that EPA should evaluate the possible need to develop "wet weather" standards, criteria, or modifications to ambient criteria to reflect differences in impact due to the intermittent, short duration exposures characteristic of urban runoff and other nonpoint source discharges.

Coliform Bacteria

The appropriateness of using coliform bacteria as indicator organisms for human health risk where the source is exclusively urban runoff warrants further investigation.

Wetlands

The use of wetlands as a control measure is of great interest in many areas, but the necessary information on design performance relationships required before cost effective applications can be considered has not been adequately documented. The environmental impacts of such use upon wetlands is a critical issue which, at present, has been addressed marginally, if at all.

Swales

The use of grass swales was suggested by two NURP projects to represent a very promising control opportunity. However, their performance is very dependent upon design features about which information is lacking. Further work to address this deficiency and appropriate maintenance practices appears warranted.

Illicit Connections

A number of the NURP projects identified what appeared to be illicit connections of sanitary discharges to stormwater sewer systems, resulting in high bacterial counts and dangers to public health. The costs and complications of locating and eliminating such connections may pose a substantial problem in urban areas, but the opportunities for dramatic improvement in the quality of urban stormwater discharges certainly exist where this can be accomplished. Although not emphasized in the NURP effort, other than to assure that the selected monitoring sites were free from sanitary sewage contamination, this BMP is clearly a desirable one to pursue.

Erosion Controls

NURP did not consider conventional erosion control measures because the information base concerning them was considered to be adequate. They are effective, and their use should be encouraged.

Combined Sewer Overflows

In order to address urban runoff from separate storm sewers, NURP avoided any sites where combined sewers existed. However, in view of their relative levels of contamination, priority should be given to control of combined sewer overflows.

Implementation Guidance

The NURP studies have greatly increased our knowledge of the characteristics of urban runoff, its effects upon designated uses, and of the performance efficiencies of selected control measures. They have also confirmed earlier impressions that some States and local communities have actually begun to develop and implement stormwater management programs incorporating water quality objectives. However, such management initiatives are, at present, scattered and localized. The experience gained from such efforts is both needed and sought after by many other States and localities. Documentation, evaluation, refinement and transfer of management and financing mechanisms/arrangements, of simple and reliable problem assessment methodologies, and of implementation guidance which can be used by planners and officials at the State and local level are urgently needed as is a forum for the sharing of experiences by those already involved, both among themselves and with those who are about to address nonpoint source issues.

*U.S. GOVERNMENT PRINTING OFFICE : 1984 0-421-082/520

MICHAEL S. TRACY (Bar No. 101456)
AMY G. NEFOUSE (Bar No. 159880)
MATTHEW B. DART (Bar No. 216429)
AMANDA C. FITZSIMMONS (Bar No. 258888)
Mike.tracy@dlapiper.com
Amy.nefouse@dlapiper.com
Matthew.dart@dlapiper.com
Amanda.fitzsimmons@dlapiper.com
DLA PIPER LLP (US)
401 B Street, Suite 1700
San Diego, CA 92101-4297
Tel: 619.699.3620
Fax: 619.699.2701

Attorneys for Designated Party
BAE Systems San Diego Ship Repair, Inc.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

SAN DIEGO REGION

IN RE TENTATIVE CLEANUP AND ABATEMENT ORDER NO. R9-2011-0001 (formerly No. R9-2010-0002)

DECLARATION OF SHAUN HALVAX IN SUPPORT OF BAE SYSTEMS SAN DIEGO SHIP REPAIR INC.'S REPLY TO ENVIRONMENTAL PARTIES' COMMENTS REGARDING TCAO/DTR NO. R9-2011-0001

Presiding Officer: Grant Destache

I, Shaun Halvax, declare:

1. I am the Manager Environmental Programs (West) for BAE Systems San Diego Ship Repair Inc. ("BAE Systems"). I make this declaration in support of BAE Systems' Reply to the comments submitted by San Diego Coastkeeper and Environmental Health Coalition (the "Environmental Parties" on May 26, 2011. I have personal knowledge of the matters set forth herein and, if called to testify, could and would competently testify thereto.

2. Among my responsibilities at BAE Systems is the financial and operational planning, management and oversight of dredge projects. The latest such dredge project was in December 2010, when BAE Systems undertook maintenance dredging in the sump located adjacent to its Pride of San Diego dry dock, dredging approximately 8,000 cubic yards.

3. The Environmental Parties, on pages 33-34 of their comments, assert that the "Proposed Remedial Footprint Should be Enlarged by Eight Polygons." As support for their assertion, the Environmental Parties argue "[r]emediating eight additional polygons is economically feasible" and calculate "the total additional dredging cost would be approximately $1.5 million." Based on my experience and personal knowledge with dredging at the Site, and the actual costs to perform the same, I submit this declaration to rebut the Environmental Parties' cost assertions and set forth my best estimate of the true costs to perform that work.

4. Attached as Exhibit 1 to my declaration is my cost estimate for the dredging associated with the eight additional polygons proposed by the Environmental Parties. This estimate utilizes the areas and volumes proposed by the Environmental Parties. The unit costs and assumptions are based on AnchorQEA Remedial Footprint cost estimate of $58.1 million dated July 12, 2010. In my assessment, the total estimated cost to dredge these additional eight polygons, inclusive of all additional costs associated with that dredging, would be approximately **$23.9 million.**

5. Based on my cost estimates, the total additional dredging costs associating with the proposed eight additional polygons would be 41% of the current estimated cleanup cost.

6. As stated above, having just conducted a dredge project at our site in December 2010, I am intimately familiar with the totality of costs associated with dredging within the site. In my assessment, based on first-hand experience, the Anchor 2010 cost estimates much more accurately capture actual dredge costs than does the Environmental Parties' stated costs in their comments. Moreover, based on my experience with recent dredge work at the Site, the Environmental Parties' stated cost estimates are highly inconsistent with the actual costs incurred in dredging in San Diego Bay.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 23rd day of June, 2011, at San Diego, California.

Halvax

Shaun Halvax

EXHIBIT 1

TO HALVAX DECLARATION

Cost Estimate[2] for 8 Additional Polygons[3]
San Diego Shipyards Sediment Site
6/21/2011

Item	Probable Quantity	Unit	Unit Cost	Probable Cost	Assumptions
DESIGN AND PERMITTING					
Additional Pre-Design Site Characterization	**0**	LUMP SUM	$348,000	$0	
Surveys and Engineering Design	**0**	LUMP SUM	$675,000	$0	
Permitting	**0**	LUMP SUM	$400,000	$0	See Note 1.
CEQA EIR - if required	**0**	LUMP SUM	$900,000	$0	Not an incremental increase.
CONSTRUCTION PREPARATION					
Mobilization(s) and Demobilization(s)	**0**	CONSTRUCTION SEASONS	$300,000	$0	Estimate assumes work is completed in 3 construction seasons.
Demolition	**0**	LUMP SUM	$500,000	$0	
DREDGING					
Unconstrained open-water dredging (outside of leasehold area)	**9,792**	CY	$7	$68,544	Unit costs are typical for unconstrained dredging outside of shipyard area.
Constrained dredging from inner shipyard (within leasehold area)	**110,129**	CY	$13	$1,431,677	Higher cost for dredging within leasehold line, near piers, in areas of ship traffic, etc.
Dredging Surface/Subsurface Debris	**5,996**	CY	$120	$719,526	Unknown quantity. Estimates assume 5% of total dredge volume. Pricing includes landfill disposal.
Engineering Controls (silt curtain, oil boom)	**0**	CONSTRUCTION SEASONS	$32,000	$0	Estimate assumes work is completed in 3 construction seasons.
Additional Dredging (as needed for 2nd pass)	**21,700**	CY	$13	$282,100	Two feet of dredging over one-half the remedial area. Same unit costs as for constrained dredging from inner shipyard.
MARINE STRUCTURES					
Placement of Quarry Run Rock for Protection of Marine Structures	**800**	TON	$45	$36,000	No structural retrofit of structures is assumed to be necessary. Estimated costs assume 4 foot setback of (150 ft at SW06, 200 ft at SW18, and 1000 ft at NA22) dredging from marine structures and revetments, and placement of quarry run blankets or berms to reinstate lateral resistance.
SEDIMENT OFFLOADING AND DISPOSAL					
Acquisition/Lease of Sediment Offloading Area	**0**	CONSTRUCTION SEASONS	$300,000	$0	An off-site sediment staging area will be needed in the vicinity of the project area. Location is unknown at this time. Costs assume a three-year construction period.
Preparation of Sediment Offloading Area	**0**	LUMP SUM	$300,000	$0	Preparation of sediment handling and dewatering area.
Rehandling and Dewatering	**141,621**	CY	$25	$3,540,525	Assumes stockpiling of sediments prior to transport to landfill and addition of lime or cement admixture to facilitate dewatering.
Transportation and Disposal at Landfill	**212,432**	TON	$75	$15,932,363	
UNDERPIER REMEDIATION					
Purchase and place 3 feet of clean sand/gravel beneath piers and overwater structures	**18,000**	SF	$30	$540,000	Assumes 3 foot thick layer of sand placed only under pier areas in the dredging footprint, quarry run rock assumed to be placed on the setback areas at BAE Pier 1 and Pier 3.
PLACEMENT OF CLEAN SAND COVER	**32,583**	CY	$40	$1,303,338	Assumes one half of dredged area receives 1-3 feet of sand.
SW04 cleanout, BMP Installation, Investigation	**0**	LS	$703,048	$0	
TOTAL DIRECT CONSTRUCTION COSTS				**$23,854,072**	

Item	Probable Quantity	Unit	Unit Cost	Probable Cost	Assumptions
BID MANAGEMENT AND SUPPORT	**0**	LUMP SUM	$25,000	$0	
CONSTRUCTION MANAGEMENT	**0**	CONSTRUCTION SEASONS	$450,000	$0	Estimate assumes work is completed in 3 construction seasons.
CONTINGENCY	**0%**	Percent		$0	Unquantifiable or identifiable unknowns
MONITORING COSTS					
Water Quality Monitoring during construction	**0**	WEEK	$18,000	$0	Not an incremental increase
Post-Dredging Confirmational Sampling	**8**	SAMPLES	$8,000	$64,000	Consistent with project approach per mediation discussions.
Long-Term Monitoring of Remediated Areas	**0**	LOCATIONS	$60,000	$0	Not an incremental increase
SW04 long term monitoring	**0**	LUMP SUM	$595,437	$0	Not an incremental increase
OTHER (NON-CONSTRUCTION) COSTS					
Eel Grass Habitat Mitigation (if needed) Construction and maintenance)	**0.00**	ACRES	$600,000	$0	No eelgras anticipated in water depth >15 ft.
Eel Grass land lease costs in perpetuity (LS)	**0.00**	ACRES	$1,500,000	$0	
Internal Shipyard Costs	**0**	LUMP SUM	$250,000	$0	
RWQCB Oversight Costs	**0**	YEARS	$45,000	$0	Duration covers periods of design, construction, and long-term monitoring oversight.
GRAND TOTAL				**$23,900,000**	

Note 1:
This is inclusive of all requried permits. Required permits will be identified with legal assistance. Implementation of the cleanup program requires resource agency permits and environmental review under state [California Environmental Quality Act (CEQA)] and possibly federal [National Environmental Policy Act (NEPA] guidelines.

Note 2:
Unit costs and assumptions based on AnchorQEA Remedial Footprint cost estimate of $58,100,000 dated July 12, 2010.

Note 3:
Includes polygons NA07, SW29, NA04, NA01, NA16, SW06, SW18, NA22.

Document No. 36730

Filed ______________

SD UNIFIED PORT DISTRICT Clerk's Office

AGREEMENT FOR AMENDMENT OF LEASE
AMENDMENT NO. 2

THIS AGREEMENT, made and entered into this 18TH day of NOVEMBER, 1997, by and between the SAN DIEGO UNIFIED PORT DISTRICT, a public corporation, hereinafter called "Lessor," and SOUTHWEST MARINE, INC., a California corporation, hereinafter called "Lessee," WITNESSETH:

WHEREAS, Lessor and Lessee, heretofore on the 17th day of September, 1979, entered into a Lease of certain tidelands in the city of San Diego, California, which Lease is on file in the Office of the Clerk of Lessor bearing Document No. 12223; and

WHEREAS, Lessor and Lessee heretofore on the 23rd day of April, 1985, entered into an Agreement for Amendment of Lease, Amendment No. 1, which amendment is on file in the Office of the Clerk of Lessor bearing Document No. 18106; and

WHEREAS, Lessor and Lessee are mutually desirous of amending said Lease;

NOW THEREFORE, for valuable consideration, said Lease is hereby amended in the following respects and no others, and except as expressly amended, all terms, covenants and conditions of said Lease shall remain in full force and effect:

A. Said Lease is hereby amended by deleting therefrom Paragraphs 2, 10, 21, 25 and 40 in their entirety and substituting in lieu thereof Paragraphs 2, 10, 21, 25, 40, 44, 45 and 46 as follows:

2. RENTAL: Lessee agrees to pay to Lessor rent in accordance with the following schedules and procedures:

(a) Commencing December 1, 1997 this Lease shall be divided into a series of rental periods, each consisting of one hundred twenty (120) months (the "rental periods"), the first such period to begin on December 1, 1997. Each successive rental period shall commence at the expiration of the immediately preceding rental period. The last rental period shall be reduced in term in order to coincide with the expiration of this Lease.

(b) The rental for the rental period commencing December 1, 1997 of this Lease shall be a sum per month calculated

DUPLICATE - ORIGINAL

on the basis of Eighty-One Cents ($.81) per square foot per year for Parcel No. 1 and Twenty Cents ($.20) per square foot per year for Parcel No. 2 subject to adjustment as provided below. Said rental sum shall be payable in advance on or before the tenth (10th) day of each month. For each successive rental period of this Lease and any extension thereof the rental shall be a sum agreed upon by Lessor and Lessee provided, however, during this and each successive rental period the rents shall be adjusted upward or downward after the expiration of the first sixty (60) months of each rental period (the adjustment date) according to the following computation: "The base figure for computing the adjustment is the arithmetic average of the thirty-six (36) monthly index figures for the fifth (5th) through fortieth (40th) months immediately preceding the existing rental period as shown in the Consumer Price Index for All Urban Consumers for Los Angeles/Anaheim/Riverside, CA/All Items based on the period 1982-84 = 100 as published by the United States Department of Labor's Bureau of Labor Statistics. The index figure for the adjustment date is the arithmetic average of the thirty-six (36) monthly index figures of said Consumer Price Index for All Urban Consumers for the fifth (5th) through fortieth (40th) months immediately preceding the adjustment date.

"The index for the adjustment date shall be computed as a percentage of the base figure. For example, assuming the base figure is 110 and the index figure for the adjustment date is 121, the percentage to be applied is 121/110 = 1.10 = 110%.

"That percentage of the base figure shall be applied to the initial rent in effect at the beginning of the then existing rental period and will continue for the remaining sixty (60) months of the rental period.

"In the event the Consumer Price Index for All Urban Consumers for Los Angeles/Anaheim/Riverside, CA/All Items is no longer published, the index for the adjustment date shall be the one reported in the U. S. Department of Labor's comprehensive official index most nearly answering the foregoing description of the index. If an index is calculated from a base different from the base period 1982-84 = 100, the base figure used for calculating the adjustment percentage shall first be converted under a formula supplied by the Bureau.

"If the above-described Department of Labor indices are no longer published, another index generally recognized as authoritative shall be substituted by agreement of the parties. If they are unable to agree within sixty

(60) days after demand by either party, a substitute index will be selected by the Chief Officer of the San Francisco Regional Office of the Bureau of Labor Statistics or its successor.

"Notwithstanding the publication dates of the index, the effective date of the rent adjustment is at the expiration of the first sixty (60) months of each rental period. Further, notwithstanding anything to the contrary contained here in this Paragraph 2(b), the rent adjustment shall not exceed seven (7) percent per annum or thirty-five percent (35%) per adjustment, nor shall the rental rate(s) resulting from the rent adjustment exceed the applicable rental rate(s) most recently adopted by the Board of Port Commissioners at the time of such rent adjustment. Until said rent adjustment can be reasonably determined by index publication, Lessee shall continue to make rental payments pursuant to this Lease at the same rent in effect at the then existing rental period. Because of this provision, overpayment of rents shall be credited to the Lessee's rental account and underpayments of rent shall be immediately paid to the Lessor."

(c) In the event the parties cannot agree to the rent for a rental period, the controversy as to rent for said period shall be determined by three arbitrators. After notice by either party to the other requesting arbitration, one arbitrator shall be appointed by each party. Notice of the appointment shall be given by each party to the other when made. The two arbitrators shall immediately choose a third arbitrator to act with them. If they fail to select a third arbitrator, on application by either party, the third arbitrator shall be promptly appointed by the then presiding judge of the Superior Court of the State of California, County of San Diego, acting in his individual capacity. The party making the application shall give the other party notice of his application. All of the arbitrators shall be qualified real estate appraisers. Each party shall bear the expense of its own appointed arbitrator and shall bear other expenses pursuant to Section 1284.2 of the Code of Civil Procedure of California. Hearings shall be held in the City of San Diego, California. The award shall be the decision of not less than two of the arbitrators. Said award shall be the rent which Lessor would derive from Lessor's property if it was vacant land, without any improvements thereon, and made available on the open market for new leasing purposes at the commencement of the rental period under arbitration. For the purpose of this arbitration procedure, the arbitrators shall assume that the Lessor has a fee simple absolute estate unburdened by any existing lease.

In determining what rent Lessor could derive from said property if it were made available on the open market for new leasing purposes, the arbitrators shall consider the benefits and burdens of all the provisions of this Lease to determine whether or not this Lease is more or less restrictive than private sector or other governmental leases; provided, however, no diminution in value shall be taken as a result of any existing Contaminants or improvements, or lack of improvements, on the subject property, and the property shall be considered as if it were available to be leased for general industrial uses. Said uses shall not be confined to those permitted Lessee herein nor to Lessee's actual use of the leased premises. In determining the rates, returns, rents and/or percentage rentals for said use and/or uses, the arbitrators shall use and analyze only the market data that is found in the open marketplace, such as is demanded and received by other Lessors for the same or similar uses as those referenced above. In all cases, the award shall be based upon recognized real estate appraisal principles and methods. The award determined by the arbitrators shall be effective and retroactive to the first day of the rental period under arbitration. The award shall be in writing in the form of a report that is in accordance with the powers of the arbitrators herein, supported by facts and analysis and in accordance with law. The arbitrators shall make copies of their report available to any ethical practice committee of any recognized professional real estate organization. The arbitration shall be conducted under and subject to Sections 1280 through 1294.2 of the Code of Civil Procedure of California.

(d) Lessee hereby acknowledges that late payment by Lessee to Lessor of rent and other sums due hereunder will cause Lessor to incur costs not contemplated by this Lease. Accordingly, in the event Lessee is delinquent in remitting the rent due in accordance with the rental provisions of this Lease, all rent not paid when due and payable shall bear interest from the date due until paid at the rate of ten percent (10) per annum. The parties hereby agree that said interest charges represent a fair and reasonable estimate of the costs Lessor will incur by reason of late payment by Lessee. Acceptance of such interest charges payment by Lessor shall in no event constitute a waiver of Lessee's default with respect to such overdue amount, nor prevent Lessor from exercising any of its other rights and remedies. The Executive Director of Lessor shall have the right to waive for good cause any interest charges upon written application of Lessee for any such delinquency period.

(e) All payments by Lessee to Lessor shall be by a good and sufficient check. No payment made by Lessee or receipt or acceptance by Lessor of a lesser amount than the correct amount of rent due under this Agreement shall be deemed to be other than a payment on account of the earliest rent due hereunder, nor shall any endorsement or statement on any check or any letter accompanying any check or payment be deemed an accord and satisfaction, and Lessor may accept such check or payment without prejudice to Lessor's right to recover the balance or pursue any other available remedy.

Notwithstanding the foregoing, in the event that Section 7 of Lessor's Board of Port Commissioners' Policy No. 352, adopted by Resolution No. 92-47 on February 18, 1992, is revised, superseded, or rescinded within twelve (12) months after the effective date of this Amendment, then 2(a) and 2(b)shall be automatically superseded by an amendment to this Lease to be signed by Lessor and Lessee, which shall reflect any changes to said Section 7 of Lessor's Board of Port Commissioners' Policy No. 352. In the event there is any dispute between Lessor and Lessee regarding the wording of said amendment, the decision of Lessor's Board of Port Commissioners regarding the wording of said amendment shall be final.

10. DEFAULTS AND REMEDIES:

a. Defaults. The occurrence of any one (1) or more of the following events shall constitute a default hereunder:

(1) Abandonment of the leased premises. Abandonment is herein defined to include, but is not limited to, any absence by Lessee from the leased premises for ten (10) consecutive days or longer.

(2) Failure by Lessee to make any payment of rent or other payment or charge required to be made by Lessee hereunder as and when due, where such failure shall continue for a period of ten (10) days after written notice thereof; provided, however, any such notice provided above or in (3) below shall be in lieu of, and not in addition to, any notice required under California Code of Civil Procedure Section 1161, as amended.

(3) Failure by Lessee to perform any other express or implied covenants or provisions herein contained (other than any breach under Paragraph 9 for which immediate notice of termination may be given) should such failure continue for thirty (30) days after written notice thereof from Lessor to Lessee specifying the particulars of such default; provided, further, that if the nature of Lessee's

default is such that more than thirty (30) days are reasonably required for its cure, then Lessee shall not be deemed to be in default if Lessee shall commence such cure within said thirty- (30) day period and thereafter diligently prosecute such cure to completion.

(4) Subject to any restrictions or limitations placed on Lessor by applicable laws governing bankruptcy, Lessee's (a) application for, consent to, or suffering of the appointment of a receiver, trustee or liquidator for all or for a substantial portion of its assets; (b) making a general assignment for the benefit of creditors; (c) admitting in writing its inability to pay its debts or its willingness to be adjudged a bankrupt; (d) becoming unable to or failing to pay its debts as they mature; (e) being adjudged a bankrupt; (f) filing a voluntary petition or suffering an involuntary petition under any bankruptcy, arrangement, reorganization or insolvency law (unless in the case of an involuntary petition, the same is dismissed within thirty (30) days of such filing); (g) convening a meeting of its creditors or any class thereof for purposes of effecting a moratorium, extension or composition of its debts; or (h) suffering or permitting to continue unstayed and in effect for ten (10) consecutive days any attachment, levy, execution or seizure of all or a substantial portion of Lessee's assets or of Lessee's interest in this Lease.

The conditions of this Paragraph 10a(4) shall not be applicable or binding on the beneficiary in any deed of trust, mortgage, or other security instrument on the leased premises which is of record with Lessor and has been consented to by resolution of Lessor, or to said beneficiary's successors in interest consented to by resolution of Lessor, as long as there remains any monies to be paid by Lessee to such beneficiary under the terms of such deed of trust; provided that such beneficiary or its successors in interest, continuously pays to the Lessor all rent due or coming due under the provisions of this Lease and the leased premises are continuously and actively used in accordance with Paragraph 14 of this Lease, and provided that said beneficiary agrees in writing to assume each and every obligation under the Lease and perform all obligations under the Lease.

(5) Failure by Lessee to timely comply with, but not

limited to, the provisions of Paragraphs 7, 8 and 23 of this Lease.

b. Remedies. In any of such events of default and in addition to any or all other rights or remedies of Lessor hereunder or by law provided, Lessor may exercise the following remedies at its sole option:

(1) Termination: Terminate Lessee's right to possession of the leased premises by any lawful means, in which case this Lease shall terminate and Lessee shall immediately surrender possession of the leased premises to Lessor. In such event Lessor shall be entitled to recover from Lessee:

(a) The worth at the time of award of the unpaid rent which had been earned at the time of termination;

(b) The worth at the time of award of the amount by which the unpaid rent which would have been earned after termination until the time of award exceeds the amount of such loss that Lessee proves could have been reasonably avoided;

(c) The worth at the time of award of the amount by which the unpaid rent for the balance of the term of this Lease after the time of award exceeds the amount of such loss that Lessee proves could have been reasonably avoided; and

(d) Any other amount necessary to compensate Lessor for all the detriment proximately caused by Lessee's failure to perform its obligations under this Lease or which in the ordinary course of things would be likely to result therefrom including, but not limited to, the cost of recovering possession of the leased premises; expenses of reletting (including necessary repair, renovation and alteration of the leased premises), reasonable attorneys' fees and any other reasonable costs.

The "worth at the time of award" of the amounts referred to in subparagraphs (a) and (b) shall be computed by allowing interest at ten percent (10%) per annum from the dates such amounts accrued to Lessor. The worth at the time of award of the amount referred to in subparagraph (c) shall be computed by discounting such amount at one (1) percentage point above the discount rate of the Federal Reserve Bank of San Francisco at the time of the award.

(2) Reletting. Without terminating or effecting a forfeiture of the Lease or otherwise relieving Lessee of any obligation hereunder, Lessor may, but need not, relet the leased premises or any portion thereof at any time or from time to time and for such terms and upon such conditions and rental as Lessor, in its sole discretion, may deem proper. Whether or not the leased premises are relet, Lessee shall pay to Lessor all amounts required by Lessee hereunder up to the date that Lessor terminates Lessee's right to possession of the leased premises; provided, however, that following a default, Lessor shall not unreasonably withhold its consent to an assignment of this Lease or a subletting of the leased premises requested by Lessee unless Lessor shall also elect to terminate this Lease and Lessee's right to possession of the leased premises, as provided in Paragraph 10(b)(1). Such payments by Lessee shall be due at the times provided in the Lease and Lessor need not wait until the termination of the Lease to recover them by legal action or in any other manner. If Lessor relets the leased premises or any portion thereof, such reletting shall not relieve Lessee of any obligation hereunder, except that Lessor shall apply the rent or other proceeds actually collected by it for such reletting against amounts due from Lessee hereunder to the extent such proceeds compensate Lessor for nonperformance of any obligation of Lessee hereunder. Lessor may execute any lease made pursuant hereto in its own name and the Lessee thereunder shall be under no obligation to see the application by Lessor of any proceeds to Lessee nor shall Lessee have any right to collect any such proceeds. Lessor shall not by any reentry or other act be deemed to have accepted any surrender by Lessee of the leased premises or Lessee's interest therein or be deemed to have terminated this Lease or to have relieved Lessee of any obligation hereunder unless Lessor shall have given Lessee express written notice of Lessor's election to do so, as set forth herein.

In the event Lessor consents to an encumbrance of this Lease for security purposes in accordance with Paragraph 8 of this Lease, it is understood and agreed that Lessor shall furnish copies of all notices of defaults to the beneficiary or mortgagee under said encumbrance by certified mail (provided Lessee has delivered to Lessor written request therefore, together with the name and address of any such beneficiary or mortgagee) contemporaneously with the furnishing of such notices to Lessee, and in the event Lessee shall fail to cure such default or defaults within the time allowed above, said beneficiary or mortgagee shall be afforded the right to cure such default at any time within fifteen (15) days following the expiration of the period within which Lessee may cure such default, provided, however, Lessor shall not be required to furnish any further notice of default to said beneficiary or mortgagee.

In the event of the termination of this Lease pursuant to the provisions of this Paragraph, Lessor shall have any rights to which it would be entitled in the event of the expiration or sooner termination of this Lease under the provisions of Paragraph 6.

Notwithstanding the foregoing, should a default not be cured within the grace periods referred to above, said Lease shall nevertheless not be terminated as to said beneficiary or mortgagee unless the Lessor first legally offers in writing to enter into a valid Lease with said offer in writing within (30) days after it is made, and such new Lease is entered into as a condition concurrent to such termination, for the then balance of the term of this Lease and otherwise with the same terms, conditions and priority as this Lease, provided the mortgagee or beneficiary promptly cures all then existing defaults under this Lease when and to the extent it is able to cure them. Such new Lease may be entered into even though possession of the leased premises has not been surrendered by the defaulting lessee, and, in such event, the Lessor shall proceed, unless legally restrained, promptly to obtain possession of the leased premises and to deliver possession to said mortgagee or beneficiary as soon as the same is obtained. Should the mortgagee or beneficiary fail to accept said offer in writing within said thirty- (30) day period, or having so accepted said offer should it fail promptly to cure all existing defaults under this Lease when and to the extent it is able to cure them, then such termination shall also be effective as to said mortgagee or beneficiary.

21. HOLD HARMLESS: Lessor, and its agents, officers, and employees shall, to the full extent allowed by law, be held by Lessee free and harmless from and indemnified against any liability pertaining to or arising out of the use and operation of the premises by Lessee and any costs or expenses incurred on account of any claim or claims therefor, including reasonable attorney's fees. Nothing herein is intended to exculpate Lessor from its sole active negligence or willful misconduct.

25. INSURANCE: Lessee shall maintain insurance acceptable to Lessor in full force and effect throughout the term of this Lease. The policies for said insurance shall, as a minimum, provide the following:

(a) Forms of Coverage

(1) "OCCURRENCE" form Commercial General Liability covering the leased premises, operations and contractual liability assumed by Lessee in this Lease in the amount of not less than Two Million Dollars ($2,000,000) combined single limit per occurrence for bodily injury, personal injury and property damage. Either the general aggregate limit shall apply separately to this location or the general aggregate limit shall be twice the required occurrence limit.

If alcoholic beverages are served or sold on the leased premises, Liquor Liability coverage in the amount of not less than One Million Dollars ($1,000,000) shall be obtained.

(2) Fire and Extended Coverage, including water damage and debris cleanup provisions in an amount not less than ninety percent (90%) of full replacement value of all improvements located within the leased premises. The fire and extended coverage policies shall be endorsed to state that any insurance proceeds in excess of Twenty-Five Thousand Dollars ($25,000) resulting from a loss under said policies shall be payable jointly to Lessor and Lessee in order that said proceeds will be reinvested in rebuilding and/or repairing the damaged portions of the leased premises; provided, however, that within the period during which there is in existence a mortgage or deed of trust upon the leasehold given by Lessee with the prior consent of Lessor, then and for that period all fire and extended coverage policies shall be made payable jointly to the mortgagee or beneficiary and Lessee, and any proceeds collected therefrom shall be held by said mortgagee or beneficiary for the following purposes:

(i) As a trust fund to pay for the reconstruction, repair, or replacement of the damaged or destroyed improvements in kind and scope in progress payments as the work is performed with any excess remaining after completion of said work to be retained by said mortgagee or beneficiary and applied to reduction of the debt secured by such mortgage or deed of trust and with any excess remaining after full payment of said debt to be paid over to Lessee; or

(ii) In the event that this Lease is terminated with consent of both Lessor and mortgagee or beneficiary and said improvements are not reconstructed, repaired, or replaced, the insurance proceeds shall be retained, without liability, by said mortgagee or beneficiary to the extent necessary to fully discharge the debt secured by said mortgage or deed of trust and said mortgagee or beneficiary shall hold the balance thereof to restore the leased premises to a neat and clean condition and then for Lessor and Lessee as their interests may appear.

(3) Pollution Liability for Underground Storage Tanks

Due to operation of underground storage tanks, Lessee is required to comply with Subpart H of 40 CFR (Code of Federal Regulations) or Title 23, Division 3, Chapter 18 of California Code of Regulations (collectively, "applicable UST law"). At the time Lessee is required to comply with any provisions of applicable UST law requiring financial assurance mechanisms, Lessee shall provide Lessor with a certified copy of its Certification of Financial Responsibility. If Lessee's program for financial responsibility includes insurance, then Lessee's policy(ies) shall name Lessor, its officers, officials and employees as additional insureds, and, all other terms of Section (b), below, shall apply. Any time Lessee changes its financial assurance mechanisms, Lessee shall provide Lessor with a certified copy of its revised Certification of Financial Responsibility.

(b) General Requirements

(1) All required insurance shall be in force the first day of the term of this Lease. The cost of all required insurance shall be borne by Lessee. Certificates in a form acceptable to Lessor evidencing the existence of the necessary insurance policies, and original endorsements effecting coverage required by this clause, shall be kept on file with Lessor during the entire term of this Lease. The certificates and endorsements for each insurance policy are to be signed by a person authorized by that insurer to bind coverage on its behalf. The Lessor reserves the right to require complete, certified copies of all required policies at any time.

(2) All liability insurance policies will name, or be endorsed to name, Lessor, its officers, officials and employees as additional insureds and protect Lessor, its officers, officials and employees against any legal costs in defending claims. All insurance policies will be endorsed to state that coverage will not be suspended, voided, cancelled, reduced in coverage or in limits except after thirty (30) days' prior written notice by certified mail, return receipt requested has

been given to the Lessor. All insurance policies will be endorsed to state that Lessee's insurance is primary and not excess or contributory to any insurance issued in the name of Lessor. And, all insurance companies must be satisfactory to Lessor.

(3) Any deductibles or self-insured retentions must be declared and acceptable to the Lessor. If the deductibles or self-insured retentions are unacceptable to the Lessor, the Lessee shall have the option of either: reducing or eliminating such deductibles or self-insured retentions as respects the Lessor, its officers, officials, and employees; or, procuring a bond guaranteeing payment of losses and related investigations, claim administration and defense expenses.

(4) Lessor shall retain the right at any time to review the coverage, form, and amount of the insurance required hereby. If, in the opinion of Lessor, the insurance provisions in this Lease do not provide adequate protection for Lessor and/or for members of the public using the leased premises, Lessor may require Lessee to obtain insurance sufficient in coverage, form and amount to provide adequate protection. Lessor's requirements shall be reasonable but shall be designed to assure protection from and against the kind and extent of risk which exist at the time a change in insurance is required.

(5) Lessor shall notify Lessee in writing of changes in the insurance requirements. With respect to changes in insurance requirements that are available from Lessee's then existing insurance carrier, Lessee shall deposit certificates evidencing acceptable insurance policies with Lessor incorporating such changes within sixty (60) days of receipt of such notice. With respect to changes in insurance requirements that are not available from Lessee's then existing insurance carrier, Lessee shall deposit certificates evidencing acceptable insurance policies with Lessor, incorporating such changes within one hundred twenty (120) days of receipt of such notice. In the event Lessee fails to deposit insurance certificates as required herein, this Lease shall be in default without further notice to Lessee, and Lessor shall be entitled to all legal remedies.

(6) If Lessee fails or refuses to maintain insurance as required in this Lease, or fails to provide proof of insurance, Lessor has the right to declare this Lease in default without further notice to Lessee and Lessor shall be entitled to exercise all legal remedies.

(7) The procuring of such required policies of insurance shall not be construed to limit Lessee's liability hereunder, nor to fulfill the indemnification provisions and requirements of this Lease. Notwithstanding said policies of insurance, Lessee shall be obligated for the full and total amount of any damage, injury, or loss caused by negligence or neglect connected with this Lease or with the use or occupancy of the leased premises.

(8) Lessee agrees not to use the leased premises in any manner, even if use is for purposes stated herein, that will result in the cancellation of any insurance Lessor may have on the leased premises or on adjacent premises, or that will cause cancellation of any other insurance coverage for the leased premises or adjoining premises. Lessee further agrees not to keep on the leased premises or permit to be kept, used, or sold thereon, anything prohibited by any fire or other insurance policy covering the leased premises. Lessee shall, at its sole expense, comply with any and all requirements, in regard to the leased premises, of any insurance organization necessary for maintaining fire and other insurance coverage at reasonable cost.

40. EQUAL EMPLOYMENT OPPORTUNITY AND NON-DISCRIMINATION: Lessee agrees to comply with Title VII of the Civil Rights Act of 1964, as amended, the California Constitution, the California Fair Employment and Housing Act and any other applicable Federal, State or local laws and regulations now existing or hereinafter enacted, requiring equal employment opportunities or prohibiting discrimination, including without limitation, laws and regulations prohibiting discrimination because of race, color, ancestry or national origin, religion, age, sex or disability. Upon reasonable notice, Lessee shall make available for inspection and copying all of its records relevant to compliance with this provision.

Lessee's compliance with the equal employment opportunity provisions of this Lease is an express condition hereof and any failure by Lessee to so comply and perform shall be a default as provided in said Lease and Lessor may exercise any right as provided therein and as otherwise provided by law.

44. HAZARDOUS MATERIALS: Lessee shall comply with all laws regarding hazardous substances, materials or wastes, or petroleum products or fraction thereof (herein collectively referred to as "Contaminants") relative to occupancy and use of the leased premises. Lessee shall be liable and responsible for any Contaminants arising out of the occupancy or use of the leased premises by Lessee. Such liability and responsibility shall include, but not be limited to, (i)

removal from the leased premises any such Contaminants; (ii) removal from any area outside the leased premises, including but not limited to surface and groundwater, any such Contaminants generated as part of the operations on the leased premises; (iii) damages to persons, property and the leased premises; (iv) all claims resulting from those damages; (v) fines imposed by any governmental agency, and (vi) any other liability as provided by law. Lessee shall defend, indemnify and hold harmless the Lessor, its officials, officers, agents, and employees from any and all such responsibilities, damages, claims, fines, liabilities, including without limitation any costs, expenses and attorney's fees therefor. Lessor shall have a direct right of action against Lessee even if no third party has asserted a claim. Furthermore, Lessor shall have the right to assign said indemnity.

If Lessee has in the past or continues to use, dispose, generate, or store Contaminants on the leased premises, Lessor, or its designated representatives, at Lessor's sole discretion, may at any time during the term of this Lease, enter upon the leased premises and make any inspections, tests or measurements Lessor deems necessary in order to determine if a release of Contaminants has occurred. Lessor shall give Lessee a minimum of twenty-four (24) hours' notice in writing prior to conducting any inspections or tests, unless, in Lessor's sole judgment, circumstances require otherwise, and such tests shall be conducted in a manner so as to attempt to minimize any inconvenience and disruption to Lessee's operations. If such tests indicate a release of Contaminants, then Lessor, at Lessor's sole discretion, may require Lessee, at Lessee's sole expense, and at any time during the term of this Lease, to have tests for such Contaminants conducted by a qualified party or parties on the leased premises. If Lessor has reason to believe that any Contaminants that originated from a release on the leased premises have contaminated any area outside the leased premises, including but not limited to surface and groundwater, then Lessor, at Lessor's sole discretion, may require Lessee, at Lessee's sole expense, and at any time during the term of this Lease, to have tests for such Contaminants conducted by a qualified party or parties on said area outside the leased premises.

The tests conducted by Lessee's qualified party shall include, but not be limited to, applicable comprehensive soil, emission, or groundwater sampling test or other procedures to determine any actual or possible contamination. Lessee shall expeditiously, but no longer than thirty (30) days after Lessor's request for such release. Lessee will be responsible for all fees and costs related to the unauthorized release of Contaminants including but not limited to investigative, surface and groundwater cleanup, and expert and agency fees. Lessee shall maintain evidence of financial responsibility for taking corrective action and for compensating third parties for bodily injury and property damage caused by a release from the underground tank system. Lessee further agrees to be responsible for maintenance and repair of the storage tanks, obtaining tank permits, filing a business plan with HMMD or other responsible agency and for paying underground storage tank fees, permit fees, and other regulatory agency fees relating to underground storage tanks.

Lessee agrees to keep complete and accurate records on the leased premises for a period of not less than thirty-six (36) months from the applicable events, including, but not limited to permit applications, monitoring, testing, equipment installation, repairing and closure of the underground storage tanks, and any unauthorized releases of Contaminants and make such records available for Lessor or responsible agency inspection. Lessee further agrees to include a copy of Health and Safety Code, Chapter 6.7, Section 25299, as part of any agreement between Lessee and any Operator of such underground storage tanks.

Furthermore, Lessee shall be responsible for compliance with all other laws and regulations presently existing or hereinafter enacted applicable to underground storage tanks, including without limitation any such laws and regulations which alter any of the above requirements.

45. UNDERGROUND STORAGE TANKS: In the event any underground storage tanks are located on the leased premises or hereinafter placed on the leased premises by any party during the term or extension of this Lease, Lessee shall be responsible for tank monitoring of all such underground storage tanks as required by the County of San Diego Hazardous Material Management Division (HMMD) or any other responsible agency. Lessee further agrees to take responsibility for reporting unauthorized releases to HMMD and the Lessor within twenty-four (24) hours of such unauthorized including but not limited to, investigative, surface and groundwater cleanup, expert and agency fees.

46. ABOVEGROUND STORAGE TANKS: Lessee shall be responsible for any aboveground storage tanks on the leased premises. Lessee shall, in accordance with this Lease and applicable laws and regulations, secure and pay for all necessary permits and approvals, prepare a spill prevention control counter measure plan and conduct periodic inspections to ensure compliance therewith, including conformance with the latest version of said laws and regulations. In addition, Lessee shall maintain and repair said tanks and conform and comply with all other applicable laws and regulations for aboveground storage tanks, including without limitation all of the requirements of Health & Safety Code, Sections 25270

through 25170.13 as presently existing or as hereinafter amended, including without limitation conducting daily visual inspection of said tanks, allowing the San Diego Regional Water Quality Control Board, the Lessor, or responsible agency, to conduct periodic inspections and complying with valid orders of said Board, filing the required storage tank statement and payment of the fee therefor, establishing and maintaining the required monitoring program and systems, reporting spills as required, and payment of lawfully imposed penalties as provided therein and as otherwise provided by law. The Lessee shall be responsible for all costs associated with an unauthorized release from such tanks, tests, furnish to Lessor the results of said tests, sampling plans, and analysis thereof identifying any Contaminants which exceed then applicable levels permitted by federal, state, or local laws. Lessee shall report such contamination to the Lessor within seventy-two (72) hours and shall diligently proceed to identify the extent of contamination, how it will be remediated, when it will be remediated, by whom, and the cost of such remediation.

ABSTRACT OF LEASE AMENDMENT

B. ABSTRACT OF LEASE AMENDMENT NO. 2: This is the final paragraph and abstract of Lease Amendment No. 2, dated NOVEMBER 18TH, 1997, between SAN DIEGO UNIFIED PORT DISTRICT, Lessor, and SOUTHWEST MARINE, INC., Lessee, concerning the premises described in Exhibits "A" and "B", attached hereto and by this reference made a part hereof.

For good and adequate consideration, Lessor leases the premises to Lessee, and Lessee hires them from Lessor, for the term and on the provisions contained in Lease dated September 17, 1979, Lease * Amendment No. 1 dated April 23, 1985, and this Lease Amendment No. 2, including, without limitation, provisions prohibiting assignment, subleasing, and encumbering the leasehold without the express written consent of Lessor in each instance, all as more specifically set forth in said Lease and said Amendments, which are incorporated in this abstract by this reference.

The term is fifty (50) years beginning September 1, 1984, and ending on August 31, 2034. This Lease Amendment No. 2 shall become effective as of December 1, 1997.

This abstract is not a complete summary of the Lease Amendment. Provisions in the abstract shall not be used in interpreting the Lease Amendment provisions. In the event of conflict between the abstract and other parts of the Lease Amendment, the other parts shall control. Execution hereof constitutes execution of the Lease Amendment itself.

DATED: NOVEMBER 24TH, 1997

Port Attorney

By S Mason

APPROVED
GENERAL
COUNSEL

SAN DIEGO UNIFIED PORT DISTRICT

By Wayne Lindquist
Deputy Executive Director

SOUTHWEST MARINE, INC.

By
Title: CHIEF EXECUTIVE OFFICER

---

*Please Note: Original Lease was recorded as Document #79-390699.

(FOR USE BY SAN DIEGO UNIFIED PORT DISTRICT)

STATE OF CALIFORNIA)

COUNTY OF SAN DIEGO)

On November 24th, 1997 before me, Timothy A. Deuel, Notary Public, personally appeared Wayne Lindquist, personally known to me ~~(or proved to me on the basis of satisfactory evidence)~~ to be the person~~(s)~~ whose name~~(s)~~ is~~/are~~ subscribed to the within instrument and acknowledged to me that he~~/she/they~~ executed the same in his~~/her/their~~ authorized capacity~~(ies)~~, and that by his~~/her/their~~ signature~~(s)~~ on the instrument ~~the person(s), or~~ the entity upon behalf of which the person~~(s)~~ acted, executed the instrument.

WITNESS my hand and official seal.

TIMOTHY A. DEUEL
COMM. # 1038251
Notary Public — California
SAN DIEGO COUNTY
My Comm. Expires SEP 8, 1998

Signature Timothy A. Deuel

PARCEL NO. 1 (Land Area)

Commencing at Harbor Line Station No. 468 on the U.S. Bulkhead Line, as said U.S. Harbor Lines are now established for the Bay of San Diego and delineated on map entitled "Harbor Lines, San Diego Bay, California, File No. (D.O. Series) 426", approved by the Secretary of the Army, April 29, 1963, and filed in the Office of the District Engineer, Los Angeles, California; thence along said U.S. Bulkhead Line North 56°20'08" West a distance of 71.94 feet to the TRUE POINT OF BEGINNING of Parcel No. 1, said point also being the True Point of Beginning of the hereinafter described Parcel No. 2; thence continuing along said U.S. Bulkhead Line North 56°20'08" West a distance of 872.31 feet to a point on the Easterly line of an area now under lease to the San Diego Gas & Electric Company, said point lies South 56°20'08" East and distant 1,097.06 feet from Harbor Line Station No. 464; thence leaving said U.S. Bulkhead Line and along the said Easterly property line of the San Diego Gas & Electric Company leasehold North 33°39'52" East a distance of 408.86 feet ; thence North 66°05'47" East a distance of 83.85 feet to a point on a line which lies parallel to and distant 110.00 feet Southwesterly from the center line of the main track and the center line of a 100.00 foot wide right of way of the Atchison, Topeka and Santa Fe Railway Company; thence leaving the said Easterly property line of the San Diego Gas & Electric Company leasehold and along the said 110.00 foot parallel line South 50°09'35" East a distance of 163.24 feet to the True Point of Beginning of the hereinafter described Parcel No. 3; thence continuing South 50°09'35" East a distance of 32.75 feet; thence North 49°28'51" East a distance of 1.43 feet; thence South 40°31'09" East a distance of 8.00 feet; thence North 49°28'51" East a distance of 5.00 feet; thence South 40°31'09" East a distance of 89.20 feet to a point on a curve concave to the Northeast having a radius of 2,030.08 feet the center of which bears North 39°24'23" East, said curve also being concentric to and distant 120.00 feet Southwesterly from the center line of the said 100.00 foot wide Atchison, Topeka and Santa Fe Railway Company right of way; thence Southeasterly along said curve through a central angle of 9°05'45" an arc distance of 322.28 feet to a point which bears South 30°18'38" West from the center of said 2,030.08 foot radius curve, said point also being on the Westerly property line of an area now under lease to National Steel and Shipbuilding Company; thence along the said National Steel and Shipbuilding Company leasehold South 34°57'12" West a distance of 312.70 feet; thence South 55°02'48" East a distance of 225.00 feet; thence North 34°57'12" East a distance of 127.21 feet; thence leaving said National Steel and Shipbuilding Company leasehold South 56°20'08" East a distance of 170.15 feet to the beginning of a tangent curve concave to the West having a radius of 28.00 feet; thence Southerly along the arc of said curve through a central angle of 90°00'00" an arc

REVISED:

Sheet 1 of 3

DRAWN RVB
CHECKED RWJ
EVIEWED D. [illegible]
APPROVED
CHIEF ENGINEER

SAN DIEGO UNIFIED PORT DISTRICT

TIDELAND LEASE
Within Corporate Limits of San Diego
SOUTHWEST MARINE, INC.

DATE Jan. 25, 1985
SCALE
REF.
DRAWING NO.
2646-B

EXHIBIT "A"

distance of 43.98 feet to a point which bears South 56°20'08" East from the center of said 28.00 foot radius curve; thence South 33°39'52" West a distance of 116.65 feet to the beginning of a tangent curve concave to the East having a radius of 48.00 feet; thence Southerly along the arc of said curve through a central angle of 35°20'04" an arc distance of 29.60 feet to a point of reverse curve the common radial of which bears South 88°19'48" West from the center of said 48.00 foot radius curve; thence Southerly along the arc of a 28.00 foot radius curve concave to the West through a central angle of 35°20'04" an arc distance of 17.27 feet to a point which bears South 56°20'08" East from the center of said 28.00 foot radius curve; thence South 33°39'52" West a distance of 325.00 feet; thence North 56°20'08" West a distance of 4.00 feet; thence South 33°39'52" West a distance of 1.89 feet; thence North 56°20'08" West a distance of 150.00 feet to a point on a curve concave to the East having a radius of 80.00 feet the center of which bears North 48°14'45" East; thence Northerly along said curve through a central angle of 62°24'19" an arc distance of 87.13 feet to a point which bears North 69°20'56" West from the center of said 80.00 foot radius curve; thence North 56°20'08" West a distance of 5.77 feet; thence North 33°39'52" East a distance of 215.06 feet to the TRUE POINT OF BEGINNING of Parcel No. 1, containing 424,627 square feet or 9.75 acres of tideland area.

PARCEL NO. 2 (Water Area)

BEGINNING at the TRUE POINT OF BEGINNING of Parcel No. 2 as described in the above Parcel No. 1, said point also being on the Southwesterly line of said Parcel No. 1, thence along said Southwesterly line of Parcel No. 1 South 33°39'52" West a distance of 215.06 feet; thence South 56°20'08" East a distance of 5.77 feet to a point on a curve concave to the East having a radius of 80.00 feet the center of which bears South 69°20'56" East; thence Southerly along said curve through a central angle of 62°24'19" an arc distance of 87.13 feet to a point which bears South 48°14'45" West from the center of said 80.00 foot radius curve; thence South 56°20'08" East a distance of 150.00 feet; thence North 33°39'52" East a distance of 1.89 feet; thence continuing along said Southwesterly line of Parcel No. 1 and its Southeasterly prolongation South 56°20'08" East a distance of 51.50 feet to a point of intersection with the Westerly property line of an area now under lease to National Steel and Shipbuilding Company; thence along said Westerly property line of National Steel and Shipbuilding Company leasehold South 33°39'52" West a distance of 427.42 feet to a point of intersection with the U.S. Pierhead Line, as said U.S. Pierhead Line is now established and delineated on the above described Harbor Lines Map; thence leaving said Westerly property line of National Steel and Shipbuilding Company leasehold and along said U.S. Pierhead Line North 56°20'08" West a

REVISED:

DRAWN RVB
CHECKED RWJ
REVIEWED L. C. F. [illegible]
APPROVED
CHIEF ENGINEER

SAN DIEGO UNIFIED PORT DISTRICT
TIDELAND LEASE
Within Corporate Limits of San Diego
SOUTHWEST MARINE, INC.

DATE Jan 25, 1985
SCALE
REF.
DRAWING NO.
2646-B

distance of 1,137.39 feet to a point on the Easterly property line of the above described San Diego Gas & Electric Company leasehold; thence leaving said U.S. Pierhead Line and along the Easterly property line of the San Diego Gas & Electric Company leasehold North 33°39'52" East a distance of 700.00 feet to a point on the above described U.S. Bulkhead Line; thence leaving the said Easterly property line of the San Diego Gas & Electric Company leasehold and along the U.S. Bulkhead Line South 56°20'08" East a distance of 872.31 feet to the TRUE POINT OF BEGINNING of Parcel No. 2, containing 724,923 square feet or 16.64 acres of water covered area.

PARCEL NO. 3 (Land Area - Belt Street)

BEGINNING at the TRUE POINT OF BEGINNING of Parcel No. 3 as described in the above Parcel No. 1, said point being the beginning of a curve concave to the North having a radius of 55.00 feet the center of which bears North 39°50'25" East; thence Easterly along said curve through a central angle of 90°02'23" an arc distance of 86.43 feet; thence tangent to said 55.00 foot radius curve North 39°48'02" East a distance of 4.96 feet to a point on the Southwesterly line of the above described 100.00 foot wide Atchison, Topeka, and Santa Fe Railway Company right of way; thence along said Southwesterly right of way line South 50°09'35" East a distance of 59.28 feet to the beginning of a tangent curve concave to the Northeast having a radius of 1,960.08 feet; thence Southeasterly along said curve through a central angle of 9°41'46" an arc distance of 331.70 feet to a point which bears South 30°08'39" West from the center of said 1,960.08 foot radius curve; thence leaving said Southwesterly line of the Atchison, Topeka, and Santa Fe Railway Company right of way South 34°57'12" West a distance of 70.24 feet to a point on a concentric curve concave to the Northeast having a radius of 2,030.08 feet the center of which bears North 30°18'38" East, said point also being on the Northeasterly line of the above described Parcel No. 1; thence Northwesterly along said Northeasterly line and the arc of said curve through a central angle of 9°05'45" an arc distance of 322.28 feet to a point which bears South 39°24'23" West from the center of said 2,030.08 foot radius curve; thence North 40°31'09" West a distance of 89.20 feet; thence South 49°28'51" West a distance of 5.00 feet; thence North 40°31'09" West a distance of 8.00 feet; thence South 49°28'51" West a distance of 1.43 feet; thence North 50°09'35" West a distance of 32.75 feet to the TRUE POINT OF BEGINNING of Parcel No. 3, containing 27,689 square feet or 0.64 acre of tideland area.

The above described areas are those delineated on Drawing No. 2646-B, Sheets 1 and 2, dated January 25, 1985, as revised, and made a part of this agreement.

REVISED:

Sheet 3 of 3

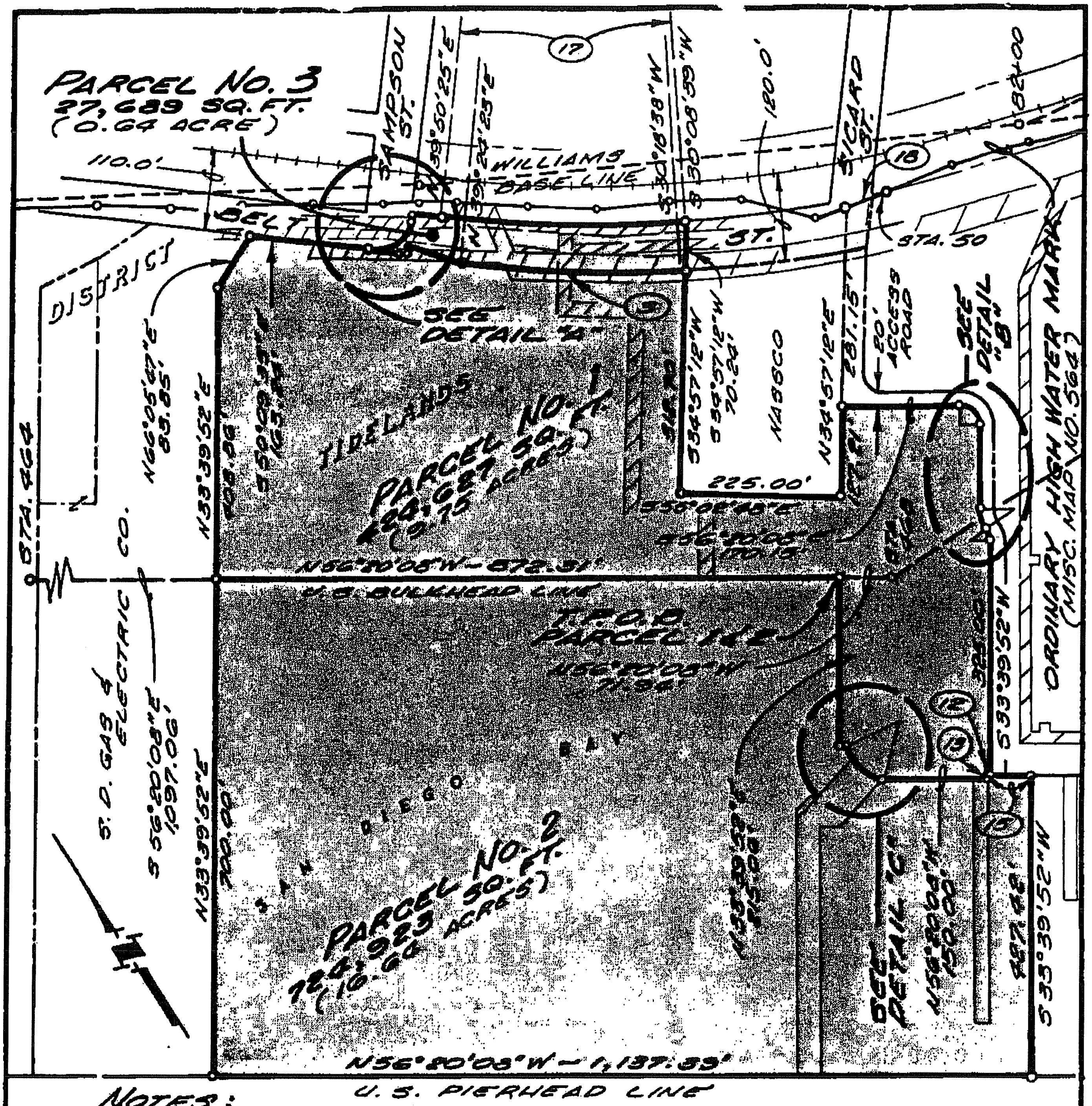
DRAWN RVB
CHECKED RWJ
REVIEWED L.O. Pierce
APPROVED
CHIEF ENGINEER

SAN DIEGO UNIFIED PORT DISTRICT

TIDELAND LEASE
Within Corporate Limits of San Diego
SOUTHWEST MARINE, INC.

DATE Jan. 25, 1985
SCALE
REF.

DRAWING NO.
2646-B



NOTES:

LEASE AREAS SHOWN SHADED.

BEARINGS & DISTANCES ARE BASED ON THE CALIFORNIA COORDINATE SYSTEM, ZONE 6.

CITY OF SAN DIEGO UTILITY EASEMENTS SHOWN HATCHED.

REVISED: FROM 2618-B, JAN. 25,'85, BY B.B.; APPROVED BY CHIEF ENGR. John E B Wilbur

DRAWN BOURKE
CHECKED R. JOHNSON
REVIEWED M. J. Gerst

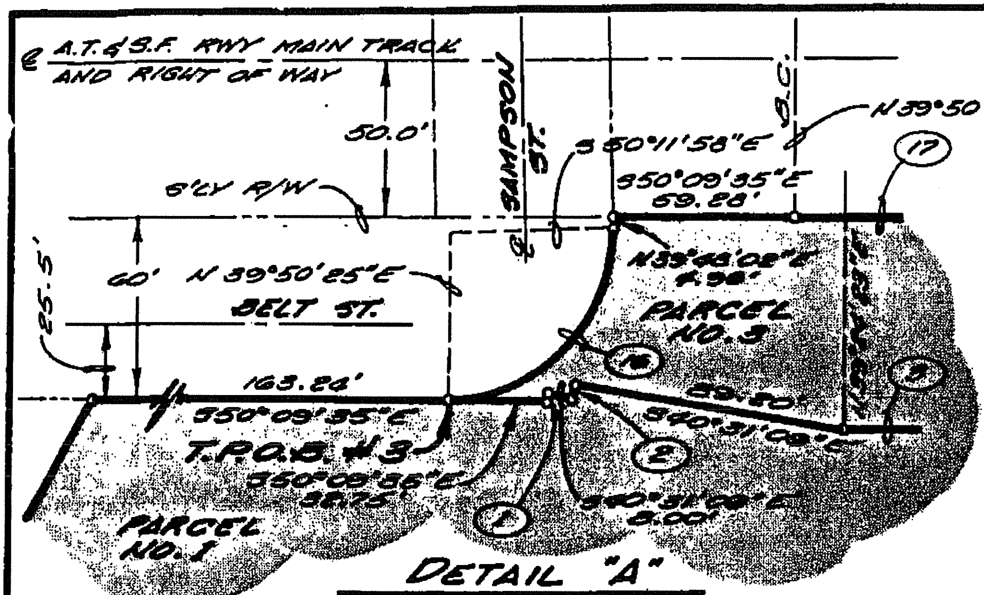
APPROVED John E B Wilbur
CHIEF ENGINEER

SAN DIEGO UNIFIED PORT DISTRICT
TIDELAND LEASE
WITHIN CORPORATE LIMITS OF SAN DIEGO
SOUTHWEST MARINE, INC.

DATE OCT. 12, 1984
SCALE 1" = 200'±
REF. 2087-B, 2E-21

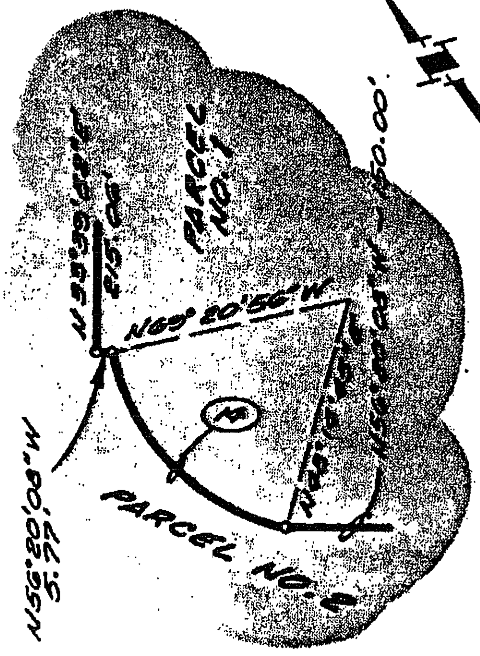
DRAWING NO.
2646-B
SHEET 1 OF 2

EXHIBIT "B"



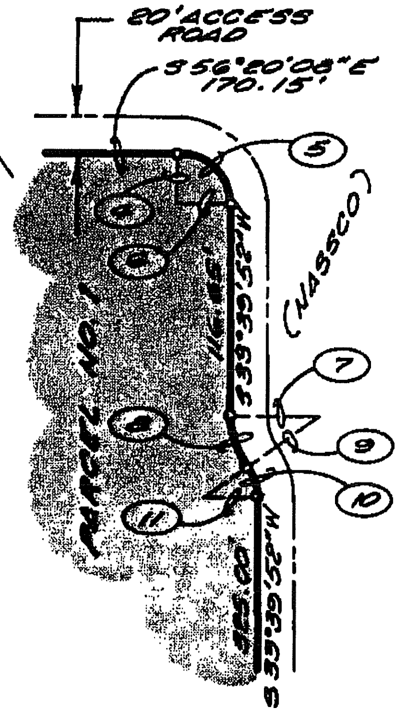
DETAIL "A"

SCALE – 1" = 60' ±



DETAIL "C"

SCALE – 1" = 60' ±



DETAIL "B"

SCALE – 1" = 100' ±

— TRAVERSE DATA —

①	N 49°28'51"E 1.43'
②	N 49°28'51"E 5.00'
③	Δ = 9°05'45" R = 2,030.08' T = 161.48' L = 322.28'
④	S 33°39'52"W RADIAL
⑤	Δ = 90°00'00" R = 28.00' T = 28.00' L = 43.98'
⑥	S 56°20'08"E RADIAL
⑦	S 56°20'08"E RADIAL
⑧	Δ = 35°20'04" R = 48.00' T = 15.29' L = 29.60'
⑨	S 88°19'48"W RADIAL
⑩	Δ = 35°20'04" R = 28.00' T = 8.92' L = 17.27'
⑪	S 56°20'08"E RADIAL
⑫	N 56°20'08"W 4.00'
⑬	S 33°39'52"W 1.89'
⑭	Δ = 62°24'19" R = 80.00' T = 48.46' L = 87.13'
⑮	S 56°20'08"E 51.50'
⑯	Δ = 90°02'23" R = 55.00' T = 55.04' L = 86.43'
⑰	Δ = 9°41'46" R = 1,960.08' T = 166.25' L = 331.70'
⑱	N 74°31'22"W 50.66'

REVISED:

DRAWN BOURKE
CHECKED R. JOHNSON
REVIEWED L. O. PIERCE

APPROVED
John E. S. Wright
CHIEF ENGINEER

SAN DIEGO UNIFIED PORT DISTRICT
TIDELAND LEASE
WITHIN CORPORATE LIMITS OF SAN DIEGO
SOUTHWEST MARINE, INC.

DATE JAN. 25, 1985
SCALE AS SHOWN
REF. 2618-B, 2E-21

DRAWING NO.
2646-B
SHEET 2 OF 2

mBD

Recording Requested by
d mail to:

District Clerk
San Diego Unified Port District
P.O. Box 120488
San Diego, CA 92112

No Document Fee
Recordation for Benefit of District

THE ORIGINAL OF THIS DOCUMENT
WAS RECORDED ON OCT 11 2004
DOCUMENT NUMBER 2004-0964217
GREGORY J. SMITH, COUNTY RECORDER
SAN DIEGO COUNTY RECORDER'S OFFICE
TIME: 2 56 PM

AMENDMENT NO. 3
TO LEASE # 12223

BETWEEN
SAN DIEGO UNIFIED PORT DISTRICT
AND
SOUTHWEST MARINE INCORPORATED

San Diego Unified Port District
Document No. 46843
Filed NOV 05 2004
Office of the District Clerk

AGREEMENT FOR AMENDMENT OF LEASE
AMENDMENT NO. 3

THIS AGREEMENT, made and entered into this 6th day of January, 2004, by and between the SAN DIEGO UNIFIED PORT DISTRICT, a public corporation, hereinafter called "Lessor," and SOUTHWEST MARINE, INC., a California corporation, hereinafter called "Lessee," WITNESSETH:

WHEREAS, Lessor and Lessee, heretofore on the 17th day of September, 1979, entered into a Lease of certain tidelands in the city of San Diego, California, which are more fully set forth on Exhibits "A" and "B" attached hereto and made a part hereof. Said Lease is on file in the Office of the Clerk of Lessor bearing Document No. 12223; and

WHEREAS, Lessor and Lessee heretofore on the 23rd day of April, 1985, entered into an Agreement for Amendment of Lease, Amendment No. 1, which amendment is on file in the Office of the Clerk of Lessor bearing Document No. 18106; and

WHEREAS, Lessor and Lessee heretofore on the 18th day of November, 1997, entered into an Agreement for Amendment of Lease, Amendment No. 2, which amendment is on file in the Office of the Clerk of Lessor bearing Document No. 36730; and

WHEREAS, Lessor and Lessee are mutually desirous of amending said Lease;

NOW THEREFORE, for valuable consideration, said Lease is hereby amended in the following respects and no others, and except as expressly amended, all terms, covenants and conditions of said Lease shall remain in full force and effect:

A. Said Lease is hereby amended by adding Paragraph 47 as follows:

> 47. LESSEE'S OFF-SITE MITIGATION RESPONSIBILITIES: By no later than July 31, 2006, Lessee, pursuant to plans approved in writing by Lessor, shall construct on the Leased Premises a 200-linear-foot-long bulkhead wall and will fill behind it with appropriate fill materials which will result in the creation of approximately Seventy-Seven Hundreds (0.77) of an acre of additional land ("Lessee's Bulkhead Extension Project") which land shall be part of the Leased Premises. The parties understand Lessee must obtain an Army Corps of Engineer's (Corps) Permit to construct Lessee's Bulkhead Extension Project. To obtain such permit, Lessee must take such environmental mitigation measures as may be required by the Corps or other regulatory agency.

DUPLICATE - ORIGINAL

Lessor intends to use its reasonable best efforts to create, maintain and preserve in a natural condition for the preservation and enhancement of native species an approximately Six and Forty-Nine Hundredths (6.49) of an acre site that is located on Lessor's tidelands at the prolongation of "D" Street in Chula Vista, California ("Lessor's Mitigation Site") which is more particularly described and delineated on Exhibits "C" and "D," attached hereto and made a part hereof. Lessor and Lessee hereby agree that Lessee shall pay for the creation, maintenance and preservation of a Seventy-Seven Hundreds (0.77) of an acre portion of Lessor's Mitigation Site as the means of providing mitigation for Lessee's Bulkhead Extension Project.

On or before the date of this Agreement, Lessee shall pay to Lessor the Lessee's Pro Rata Share of Projected Cost, as exhibited on attached Exhibit E "PROJECTED PRO RATA SHARE OF MITIGATION SITE CONSTRUCTION COST". Said costs shall include CEQA processing expenses, design and monitoring, raw land value, mitigation construction, including necessary change orders, and permits and processing expense.

Lessee shall pay Lessor the Lessee's pro rata share of the actual cost to construct Lessor's Mitigation Site. Lessor shall provide to Lessee an accounting of the actual total cost to construct the Lessor's Mitigation Site within one hundred eight (180) days following completion of construction of such. If the total actual cost exceeds the Total Projected Cost identified on attached Exhibit E, Lessee shall pay to Lessor within ninety (90) days the amount by which Lessee's pro rata share of the total actual costs exceed the Lessee's Pro Rata Share of Total Projected Costs. If the total actual costs are less than the total projected costs, Lessor shall refund to Lessee within ninety (90 days) the amount by which Lessee's pro rata share of the total actual costs are less than the Lessee's Pro Rata Share of Total Projected Costs paid to Lessor on or before the date of this agreement. Lessee also agrees during the entire term of the Lease, including any extensions or renewals thereof, to annually reimburse Lessor for its pro rata share based on Lessee's use of Seventy-Seven Hundreds (0.77) of an acre of Lessor's annual cost to maintain and preserve Lessor's Mitigation Site. Lessee shall pay Lessor within thirty (30) days from receipt of Lessor's annual maintenance and preservation invoice.

Lessee's obligations pursuant to this Paragraph 47 are contingent upon Lessee's Bulkhead Extension Project receiving all necessary permits and approvals including, as required, its inclusion under the Army Corps of Engineer's Permit for the Lessor's Mitigation Site. In the event Lessee does not receive all necessary permits and approvals to construct Lessor's Bulkhead Extension Project by no later than December 31, 2005, then Lessor shall return to Lessee the above described Lessee's Pro Rata Share of Total Projected Costs and this Paragraph 47 shall be of no further force and effect.

ABSTRACT OF LEASE AMENDMENT

B. ABSTRACT OF LEASE AMENDMENT NO. 3: This is the final paragraph and abstract of Lease Amendment No. 3, dated January 6 2004, between SAN DIEGO UNIFIED PORT DISTRICT, Lessor, and SOUTHWEST MARINE, INC., Lessee, concerning the premises described in Exhibits "A", "B", "C", "D", and "E" attached hereto and by this reference made a part hereof.

For good and adequate consideration, Lessor leases the premises to Lessee, and Lessee hires them from Lessor, for the term and on the provisions contained in Lease*dated September 17, 1979, Lease Amendment No. 1 dated April 23, 1985, Lease Amendment No. 2 dated November 18, 1997 and this Lease Amendment No. 3, including, without limitation, provisions prohibiting assignment, subleasing, and encumbering the leasehold without the express written consent of Lessor in each instance, all as more specifically set forth in said Lease and said Amendments, which are incorporated in this abstract by this reference.

The term is fifty (50) years beginning September 1, 1984, and ending on August 31, 2034. This Lease Amendment No. 3 shall become effective as of January 6, 2004.

This abstract is not a complete summary of the Lease Amendment. Provisions in the abstract shall not be used in interpreting the Lease Amendment provisions. In the event of conflict between the abstract and other parts of the Lease Amendment, the other parts shall control. Execution hereof constitutes execution of the Lease Amendment itself.

DATED: October 6, 2004

Port Attorney

By
Deputy Port attorney

*Clerk Note: Original Lease was Recorded on 9/18/1979 as Document No. 1979-390699

APPROVED AS TO FORM
GENERAL COUNSEL

SAN DIEGO UNIFIED PORT DISTRICT

By
Signature

SOUTHWEST MARINE, INC.

By
Signature

Title: ROBERT A. KILPATRICK
President

(FOR USE BY SAN DIEGO UNIFIED PORT DISTRICT)

STATE OF CALIFORNIA)

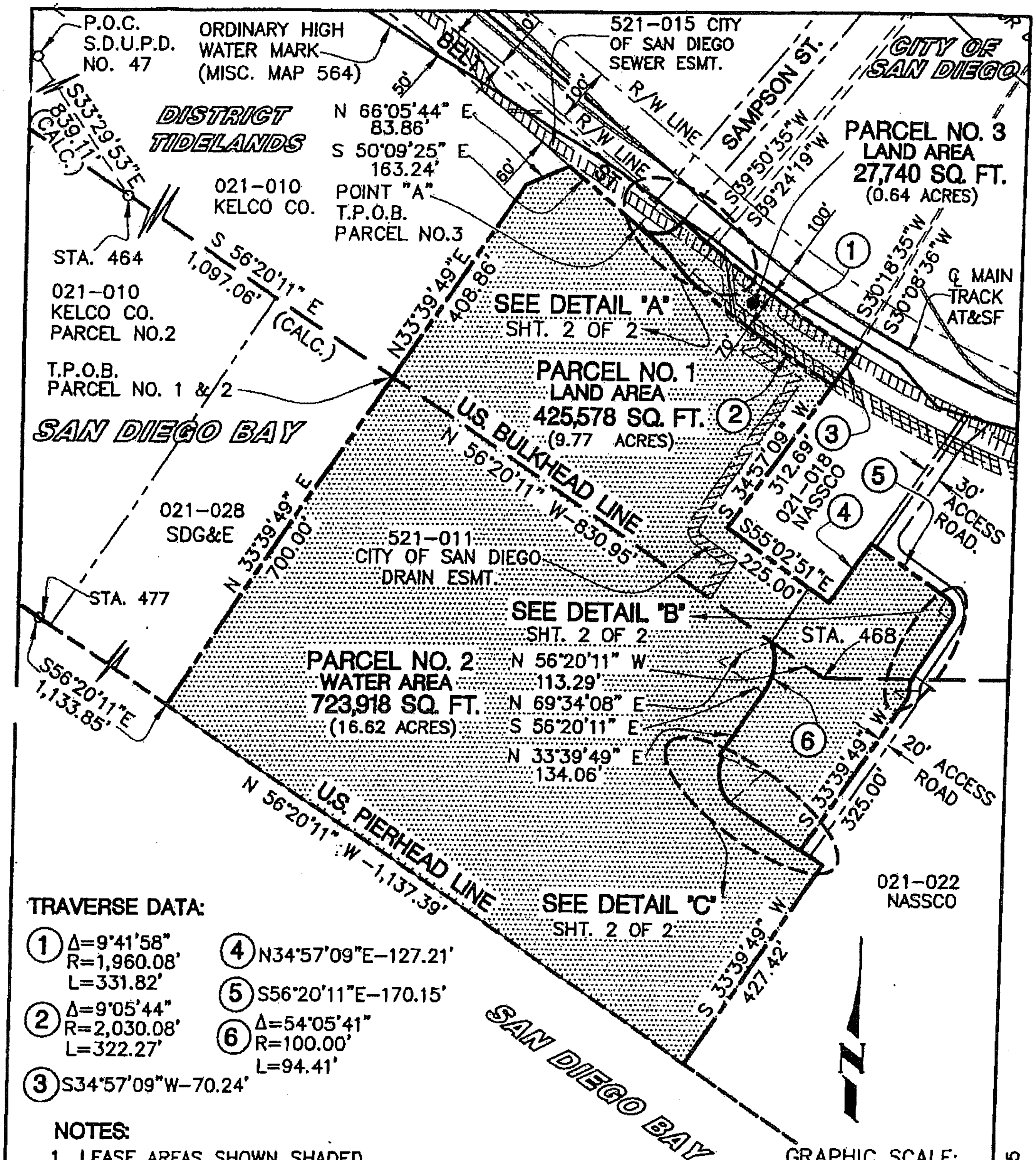
COUNTY OF SAN DIEGO)

On OCTOBER 6TH, 2004 before me, TIMOTHY A. DEUEL, personally appeared DIRK MATHIASEN, personally known to me ~~(or proved to me on the basis of satisfactory evidence)~~ to be the person~~(s)~~ whose name~~(s)~~ is/~~are~~ subscribed to the within instrument and acknowledged to me that he/~~she/they~~ executed the same in his/~~her/their~~ authorized capacity~~(ies),~~ and that by his/~~her/their~~ signature~~(s)~~ on the instrument the person(s), or the entity upon behalf of which the person~~(s)~~ acted, executed the instrument.

WITNESS my hand and official seal.

Signature Timothy A. Deuel

TIMOTHY A. DEUEL
Commission # 1384852
Notary Public - California
San Diego County
My Comm. Expires Nov 17, 2006



TRAVERSE DATA:

① Δ=9°41'58" R=1,960.08' L=331.82'

② Δ=9°05'44" R=2,030.08' L=322.27'

③ S34°57'09"W-70.24'

④ N34°57'09"E-127.21'

⑤ S56°20'11"E-170.15'

⑥ Δ=54°05'41" R=100.00' L=94.41'

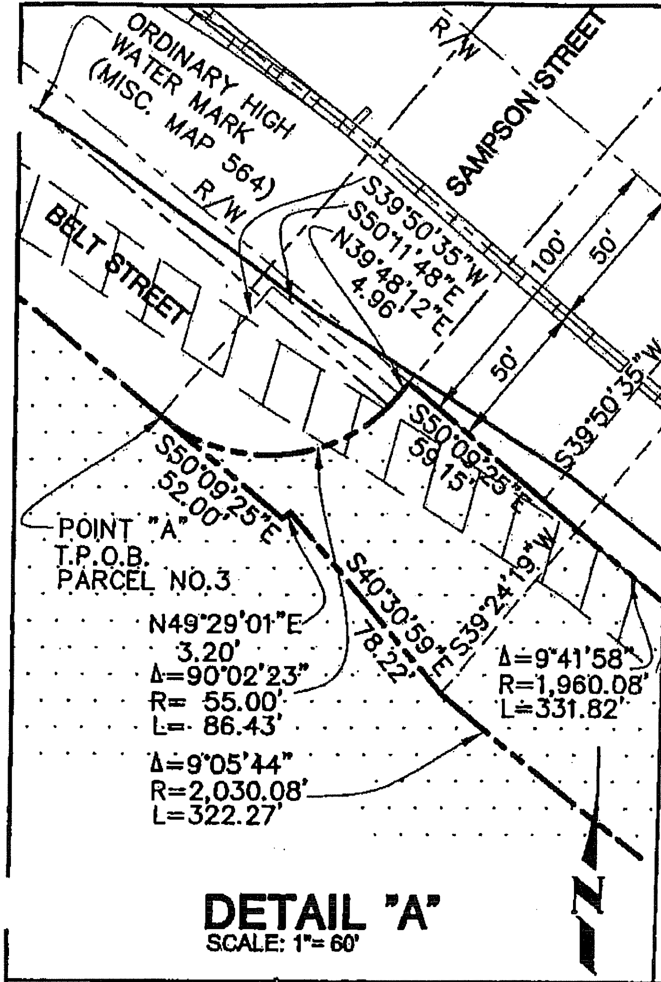
NOTES:

1. LEASE AREAS SHOWN SHADED.
2. EASEMENT AREAS SHOWN HATCHED.
3. BEARINGS AND DISTANCES ARE GRID AND BASED UPON THE CALIFORNIA COORDINATE SYSTEM ZONE 6, NAD 83, EPOCH 1991.35.

RAWN ASNOR SANTONIL HECKED Sochoa REVIEWED APPROVED Charles G. Sykes LAND SURVEYOR, S.D.U.P.D.	**SAN DIEGO UNIFIED PORT DISTRICT** TIDELAND LEASE WITHIN CORPORATE LIMITS OF SAN DIEGO **SOUTHWEST MARINE, INC.**	DATE FEB. 12, 2004 SCALE 1"=250' REF. FIELD SURVEY, 2846-B DRAWING NO. SHEET 1 OF 2 021-015

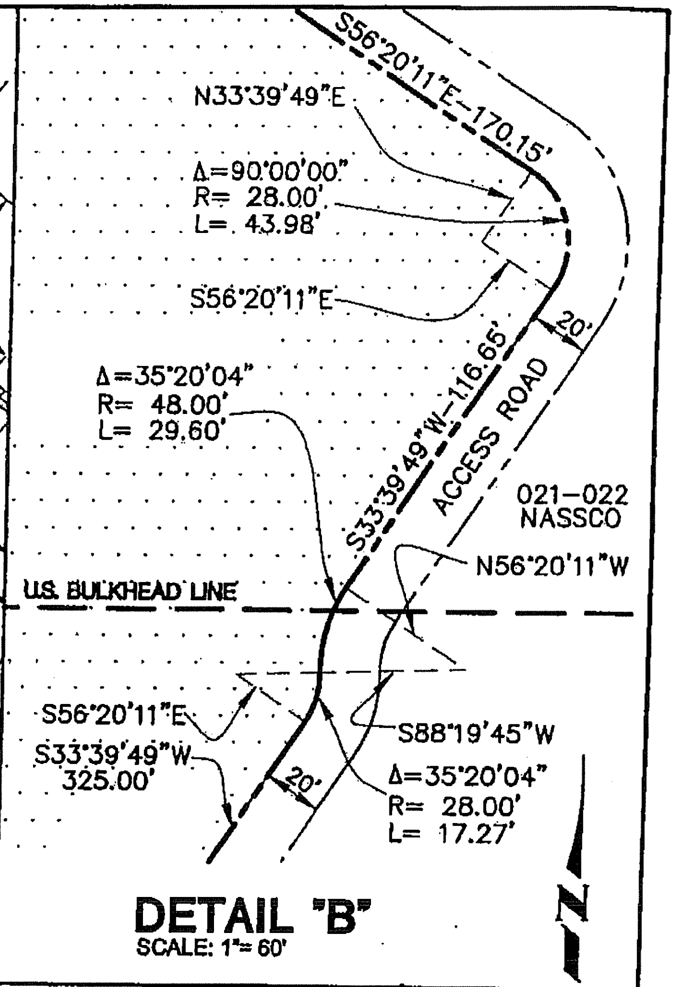
DEVSERV\REMI\E21\021-015

EXHIBIT "A"



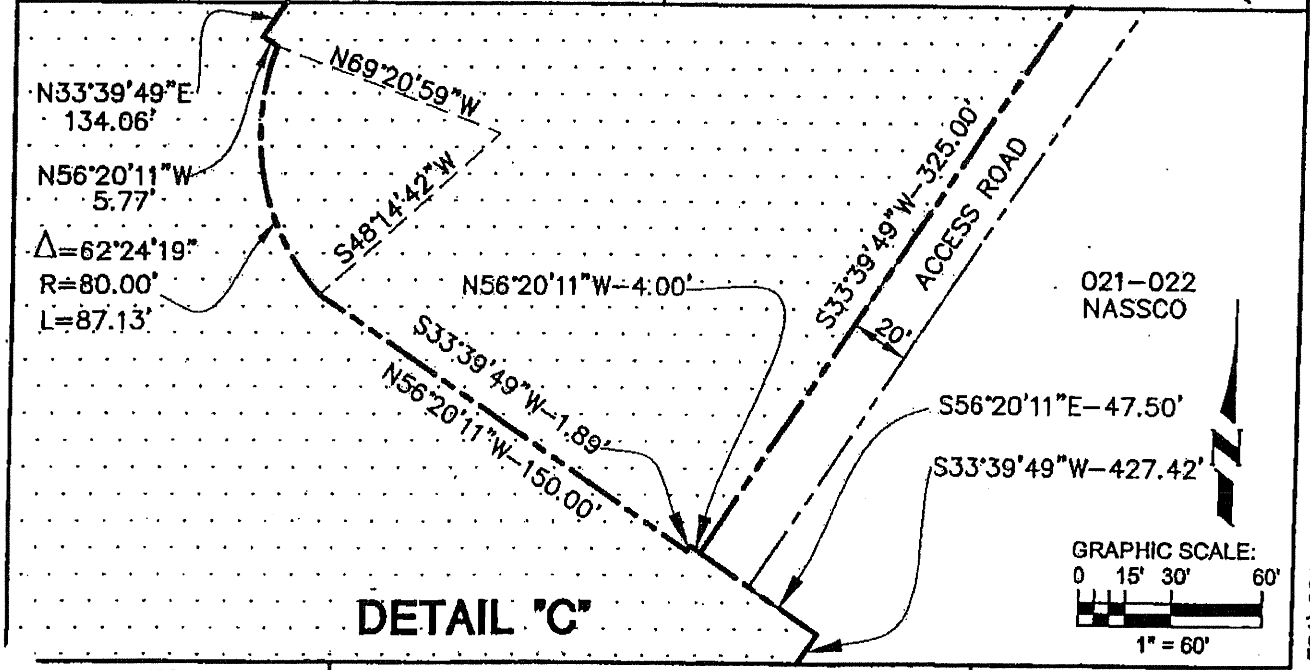
DETAIL "A"

SCALE: 1"= 60'



DETAIL "B"

SCALE: 1"= 60'



DETAIL "C"

RAWN ASNOR SANTONIL
HECKED
REVIEWED
APPROVED
LAND SURVEYOR, S.D.U.P.D.

SAN DIEGO UNIFIED PORT DISTRICT

TIDELAND LEASE
WITHIN CORPORATE LIMITS OF SAN DIEGO

SOUTHWEST MARINE, INC.

DATE FEB. 12, 2004
SCALE 1"=60'
REF. FIELD SURVEY
DRAWING NO.
SHEET 2 OF 2
021-015

DEVSERV\REMI\E21\021-015

Legal Description for
SOUTHWEST MARINE, INC.
TIDELAND LEASE
Parcel / Drawing No 021-015
Within Corporate Limits of San Diego

All that certain portion of land conveyed to the San Diego Unified Port District by that certain Act of Legislature of the State of California pursuant to Chapter 67, Statutes of 1962, First Extraordinary Session, as amended, and delineated on that certain Miscellaneous Map No. 564, filed in the Office of the San Diego County Recorder on May 28, 1976, File No. 76-164686, in the City of San Diego, County of San Diego, State of California, and more particularly described as follows:

PARCEL NO. 1 LAND AREA

Commencing at a 3" diameter brass disk monument stamped S.D.U.P.D. No. 47 as shown on Record Of Survey Map No. 17055, filed in the Office of the San Diego County Recorder on June 29, 2001; thence leaving said monument South 33°29'53" East a distance of 839.11 feet (calculated) to Harbor Line Station 464 on the U.S. Bulkhead line, as said U.S. Harbor Line is now established for the bay of San Diego and delineated on map entitled "Harbor Lines, San Diego Bay, California, File No. (D.O. Series) 426", approved by the Secretary of the Army, April 29, 1963, and filed in the Office of the District Engineer, Los Angeles, California; thence along said U.S. Bulkhead Line South 56°20'11" East a distance of 1,097.06 feet to the TRUE POINT OF BEGINNING of Parcel No. 1; thence leaving said U.S. Bulkhead Line North 33°39'49" East a distance of 408.86 feet; thence North 66°05'44" East a distance of 83.86 feet to a point on a line which lies parallel to and 110.00 feet southwesterly from the centerline of the 100.00 foot wide Atchison, Topeka and Santa Fe Railway Company right of way; thence along said parallel line South 50°09'25" East a distance of 163.24 feet to a point hereinafter known as Point "A"; thence continuing South 50°09'25" East a distance of 52.00 feet; thence North 49°29'01" East a distance of 3.20 feet; thence South 40°30'59" East a distance of 78.22 feet to the beginning of a non-tangent 2,030.08 feet radius curve, concave to the north to which a radial bears South 39°24'19" West, said curve also being concentric to and 120.00 feet southwesterly from the centerline of said 100.00 foot wide Atchison, Topeka and Santa Fe Railway Company right of way; thence southeasterly along the arc of said curve through a central angle of 9°05'44" an arc distance of 322.27 feet to a point which bears South 30°18'35" West from the center of said curve; thence South 34°57'09" West a distance of 312.69 feet; thence South 55°02'51" East a distance of 225.00 feet; thence North 34°57'09" East a distance of 127.21 feet; thence South 56°20'11" East a distance of 170.15 feet to the beginning of a tangent 28.00 feet radius curve, concave to the west; thence southerly along the arc of said curve through a central angle of 90°00'00" an arc distance of 43.98 feet to a point of tangency; thence South 33°39'49" West a distance of 116.65 feet to the beginning of a tangent 48.00 feet radius curve, concave to the east; thence southerly along the arc of said curve through a central angle of 35°20'04" an arc distance of 29.60 feet to the beginning of a 28.00 feet radius reverse curve, concave to the west, to which a radial bears South 88°19'45" West; thence southerly along the arc of said curve through a central angle of 35°20'04" an arc distance of 17.27 feet to a point of tangency; thence South 33°39'49" West a distance of 325.00 feet; thence North 56°20'11" West a distance of 4.00 feet; thence South 33°39'49" West a distance of 1.89 feet; thence North 56°20'11" West a distance of 150.00 feet to the beginning of a non-tangent 80.00 feet radius curve, concave to the east to which a radial bears South 48°14'42" West; thence northerly along the arc of said curve through a central angle of 62°24'19" an arc distance of 87.13 feet to a point of non-tangency which bears North 69°20'59" West from the center of said curve; thence North 56°20'11" West a distance of 5.77 feet; thence North 33°39'49" East a distance of 134.06 feet to the beginning of a tangent 100.00 feet radius curve, concave to the west; thence northerly along the arc of said curve through a central angle of 54°05'41" an arc distance of 94.41 feet to a point of non tangency which bears North 69°34'08" East from the center of said curve, said point also lies on said U.S. Bulkhead Line and bears North 56°20'11" West a distance of 113.29 feet from U.S. Bulkhead Station 468; thence along said U.S. Bulkhead Line North 56°20'11" West a distance of 830.95 feet to the TRUE POINT OF BEGINNING of Parcel No.1, containing 425,578 square feet or 9.77 acres of tidelands area.

PARCEL NO. 2 WATER AREA

Commencing at the true point of beginning of the above described Parcel No.1, said point also being the TRUE POINT OF BEGINNING of Parcel No.2; thence along said U.S. Bulkhead Line South 56°20'11"East a distance of 830.95 feet to the beginning of a non-tangent 100.00 feet radius curve, concave to the west to which a radial bears North 69°34'08" East; thence leaving said U.S. Bulkhead Line southerly along the arc of said curve through a central angle of 54°05'41" an arc distance of 94.41 feet to a point of tangency; thence South 33°39'49" West a distance of 134.06 feet; thence South 56°20'11" East a distance of 5.77 feet; to the beginning of a non-tangent 80.00 feet radius curve, concave to the east to which a radial bears North 69°20'59" West ; thence southerly along the arc of said curve through a central angle of 62°24'19" an arc distance of 87.13 feet to a point of non-tangency to which a radial bears South 48°14'42" West from the center of said curve; thence South 56°20'11" East a distance of 150.00 feet; thence North 33°39'49" East a distance of 1.89 feet; thence South 56°20'11"East a distance of 4.00 feet to a point of intersection with the southeasterly line of Parcel No.1; thence continuing South 56°20'11"East a distance of 47.50 feet; thence South 33°39'49" West a distance of 427.42 feet to a point of intersection with the U.S. Pierhead Line, as said U.S. Pierhead Line is now established for the Bay of San Diego; thence along said U.S. Pierhead Line North 56°20'11" West a distance of 1,137.39 feet to a point which bears South 56°20'11" East a distance of 1,133.85 feet from U.S. Pierhead Station 477; thence leaving said U.S. Pierhead Line North 33°39'49" East a distance of 700.00 feet to a point of intersection with the above described U.S. Bulkhead Line, said point also being the TRUE POINT OF BEGINNING of Parcel No. 2, containing 723,918 square feet or 16.62 acres of water covered area.

PARCEL NO. 3 LAND AREA –BELT STREET

Commencing at the above described Point "A", said point also being the TRUE POINT OF BEGINNING of Parcel No.3, said point also being the beginning of a 55.00 feet radius curve concave to the north, to which a radial bears South 39°50'35" West; thence easterly along the arc of said curve through a central angle of 90°02'23" an arc distance of 86.43 feet to a point of tangency; thence North 39°48'12" East a distance of 4.96 feet to a point on the southwesterly line of the above described 100.00 foot wide Atchison, Topeka and Santa Fe Railway Company right of way; thence along said southwesterly right of way line South 50°09'25" East a distance of 59.15 feet to the beginning of a tangent 1,960.08 feet radius curve, concave to the northeast; thence southeasterly along the arc of said curve through a central angle of 9°41'58" an arc distance of 331.82 feet to a point of non-tangency; thence leaving said southwesterly right of way line South 34°57'09" West a distance of 70.24 feet to a point of non-tangency at the beginning of a concentric 2,030.08 radius curve, concave to the northeast; thence northwesterly along the arc of said curve through a central angle of 9°05'44" an arc distance of 322.27 feet to a point of non-tangency; thence North 40°30'59" West a distance of 78.22 feet; thence South 49°29'01"West a distance of 3.20 feet; thence North 50°09'25" West a distance of 52.00 feet to the TRUE POINT OF BEGINNING of Parcel No. 3, containing 27,740 square feet or 0.64 acre of tidelands area.

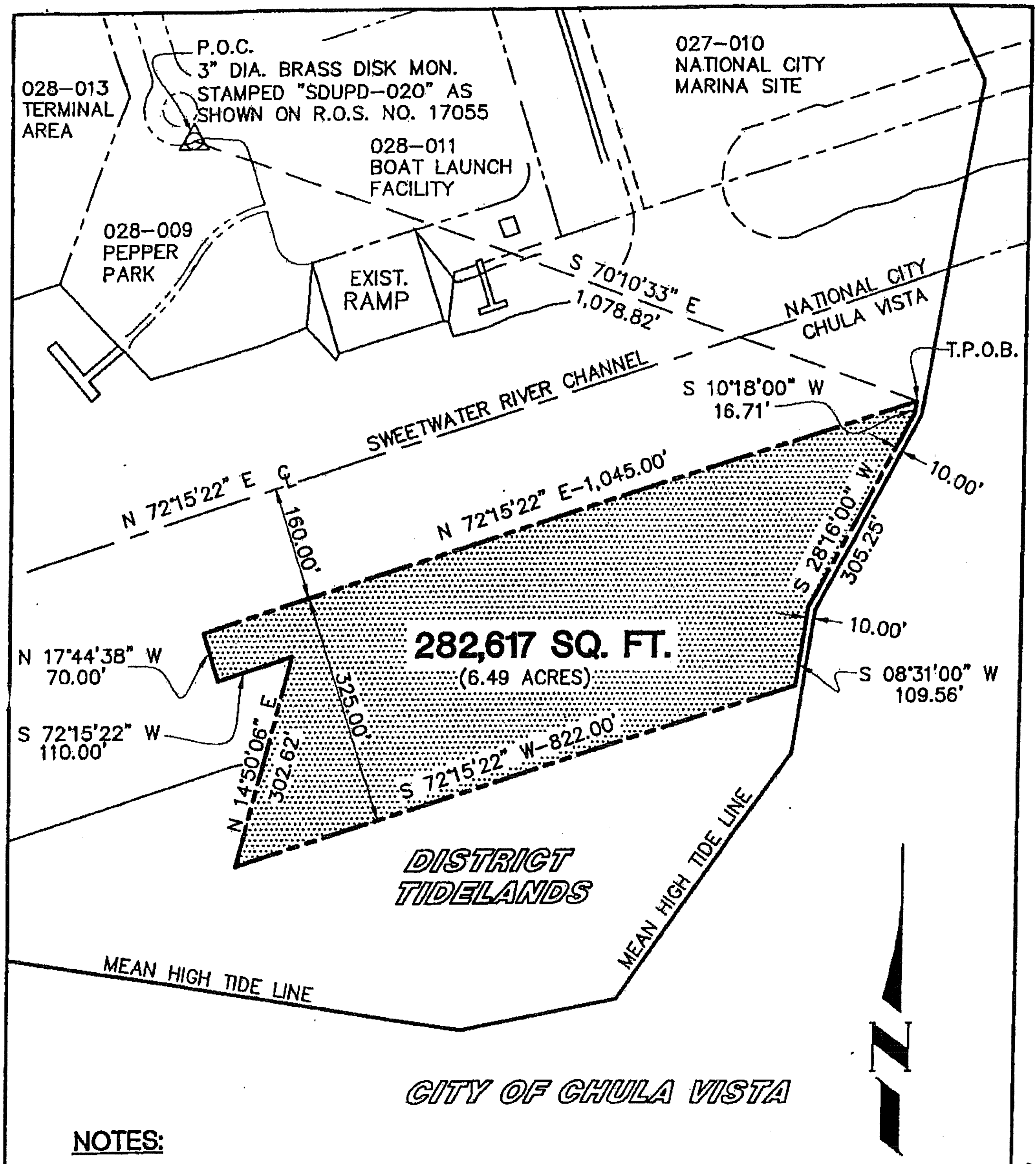
The above described land and water areas are delineated on the San Diego Unified Port District Drawing No. 021-015, dated 12 February 2004 and made a part of this agreement.

EXHIBIT "B"

All bearings and distances in the above legal description are grid, and based upon the California Coordinate System, Zone 6, N.A.D. 83, Epoch 1991.35.

3/8/04
Charles J. Sefkow Date
L.S. 7876 Expires 31 Dec. 2006
Land Surveyor
San Diego Unified Port District

CHARLES J. SEFKOW
PLS NO. 7876
EXP 12/31/06



NOTES:

1. LEASE AREAS SHOWN SHADED.
2. BEARINGS AND DISTANCES ARE GRID AND BASED UPON THE CALIFORNIA COORDINATE SYSTEM ZONE 6, N.A.D.83, EPOCH 1991.35.

GRAPHIC SCALE:
0 50' 100' 200'

DRAWN ASNOR SANTONIL
CHECKED
REVIEWED
APPROVED
LAND SURVEYOR, S.D.U.P.D.

SAN DIEGO UNIFIED PORT DISTRICT
MITIGATION SITE
WITHIN CORPORATE LIMITS OF CHULA VISTA
SAN DIEGO UNIFIED
PORT DISTRICT

DATE APRIL 8, 2004
SCALE 1"=200'
REF. 1876, FIELD SURVEY
DRAWING NO.
SHEET 1 OF 1
028-022

DEVSERV\REMI\E28\028-022

Legal Description for
SAN DIEGO UNIFIED PORT DISTRICT
MITIGATION SITE
Parcel / Drawing No 028-022
Within Corporate Limits of Chula Vista

All that certain portion of land conveyed to the San Diego Unified Port District by that certain Act of Legislature of the State of California pursuant to Chapter 67, Statutes of 1962, First Extraordinary Session, as amended, and delineated on that certain Miscellaneous Map No. 564, filed in the Office of the San Diego County Recorder on May 28, 1976, File No. 76-164686, in the City of San Diego, County of San Diego, State of California, and more particularly described as follows:

Commencing at a 3" diameter brass disk monument stamped "SDUPD–020" as shown on Record Of Survey Map No. 17055, filed in the Office of the San Diego County Recorder on June 29, 2001; thence leaving said monument South 70°10'33" East a distance of 1,078.82 feet (calculated) to a point on a line parallel with and 10.00 feet northwesterly from the Mean High Tide Line, as said Mean High Tide Line is shown on the above described Miscellaneous Map No. 564; said point also being on a line parallel with and 160.00 feet southeasterly from the boundary line between the City of National City and the City of Chula Vista, as said boundary line is shown on the above described Miscellaneous Map No. 564; said point also being the TRUE POINT OF BEGINNING; thence along said line parallel with and 10.00 feet northwesterly from the Mean High Tide Line South 10°18'00" West a distance of 16.71 feet; thence South 28°16'00" West a distance of 305.25 feet; thence South 08°31'00" West a distance of 109.56 feet; thence along a line parallel with and 485.00 feet southeasterly from said boundary line between the City of National City and the City of Chula Vista, South 72°15'22" West a distance of 822.00 feet; thence North 14°50'06" East a distance of 302.62 feet; thence South 72°15'22" West a distance of 110.00 feet; thence North 17°44'38" West a distance of 70.00 feet to a point on a line parallel with and 160.00 feet southeasterly from the boundary line between the City of National City and the City of Chula Vista; thence along said parallel line North 72°15'22" East a distance of 1,045.00 feet to the TRUE POINT OF BEGINNING containing 282,617 square feet or 6.49 acres of tidelands area.

The above described tidelands area is delineated on the San Diego Unified Port District Drawing No. 028-022, dated 8 April 2004 and made a part of this agreement.

All bearings and distances in the above legal description are grid, and based upon the California Coordinate System, Zone 6, N.A.D. 83, Epoch 1991.35.

Charles J Sefkow 4-8-04

Charles J. Sefkow Date
L.S. 7876 Expires 31 Dec. 2006
Land Surveyor
San Diego Unified Port District

LICENSED LAND SURVEYOR
CHARLES J. SEFKOW
PLS NO. 7876
EXP. 12-31-06
STATE OF CALIFORNIA

EXHIBIT "D"

EXHIBIT E

PROJECTED PRO RATA SHARE OF MITIGATION SITE CONSTRUCTION COST

Item	*Cost*
CEQA	$ 151,851.00
Salt Marsh Design and Long Term Monitoring	$ 120,000.00
Total Land Value (estimated at 6.34 acres)	$ 158,500.00
Marsh Restoration Contract Price	$ 1,285,000.00
Permits and Processing	$ 80,000.00
Total Projected Cost	**$ 1,795,351.00**
Lessee's Mitigation Requirement (A)	0.77 acre
Estimated Mitigation Site Total (B)	6.49 acre
Lessee's Estimated Pro Rata Share of Mitigation Site (A/B)	11.86%
Lessee's Pro Rata Share of Total Projected Cost *	**$ 212,928.63**
(due on or before date of Agreement)	

*Not including necessary change orders, if any, which shall be documented by Lessor to Lessee.