CHARACTERIZATION OF STORMWATER CONTAMINATED SEDIMENT AND DEBRIS FOR DETERMINING PROPER DISPOSAL METHODS

FINAL REPORT

Prepared by:
Florida Department of Environmental Protection
Division of Water Facilities
2600 Blairstone Road
Tallahassee, Florida 32399-2400

By:
John H. Cox, Environmental Specialist III
Ms. Sherry Allick, Engineer II
Ms. Emila Be, Engineer IV
Industrial Waste Section

Revised August 13, 1998

This project and preparation of this report was funded in part by a Section 319 Nonpoint Source Management Program grant from the U. S. Environmental Protection Agency (USEPA) through the Stormwater/Nonpoint Source Management Section of the Florida Department of Environmental Protection. The total cost of the project was $167,000.00 of which $100,000.00, or 60% was provided by the USEPA.

Executive Summary

Increasing attention to the maintenance of structural stormwater controls and how the residuals or sediment that accumulates in these systems should be utilized or disposed is an emerging issue in Florida. Existing data on the characteristics of stormwater sediments deposited in stormwater systems throughout Florida is sparse and not easily correlated due to differences in sampling methods used by the various investigators. The primary goal of the current research was to better characterize the stormwater residuals that local governments and stormwater utilities associations are having to deal with. Sediment and debris from a wide array of treatment systems and background samples of native soils were collected by each of 14 participating entities.

The sampling sites for this project (87 total) were associated with the most common stormwater BMPs currently in use throughout the state of Florida. Samples of native soil were also collected at (15) control sites to determine background levels of metals and organic compounds associated with open land areas in each municipality. Sample collection was a cooperative effort between FDEP and personnel from local government stormwater programs around the state.

Samples were tested for a total of one hundred and sixty eight (168) pollutants. Each sample was also examined for its physical characteristics relative to percentage particle size distribution in six (6) fractions ranging from fine silt and clay to coarse sands. In addition the organic matter content of samples was evaluated via the total organic carbon (TOC) concentration.

Results proved similar to previous studies. From a total of approximately 15,000 records, 10% of the analytical results exceeded the minimum detection limits (MDL's). Fifty three (53) pollutants were found in detectable concentrations. Similar to previous studies, traffic related metals (i.e., Cr., Pb., and Zn.) were found at virtually all sites. Total recoverable petroleum hydrocarbon (TRPH) levels exceeded MDL's at 90% of the test sites followed by the pesticide Chlordane which was detected at an 82% frequency. A total of 13 PAH's, 2 pesticides plus DDT and it's derivatives, 2 phthalate compounds and PCB 1260 were detected in 10 percent or more of samples. As expected, the background sites contained lower levels and substantially fewer contaminants than found in stormwater sediments.

In contrast to the results of our previous literature study, traffic related PAH's exceeded the various screening level criteria more often than the seven heavy metals that were examined. However, a majority of the sediments tested contained low to moderate levels of lead. At one industrial site TCLP test results show levels of approximately 10 mg/l Pb in the extract solution. This level is double the hazardous waste limit for this constituent. None of the samples contained organics in excess of RCRA criteria.

Several of the studies results were interesting and to some extent unexpected. Monitoring results do not show any signs of significant differences by landuse category. Large differences in monitoring frequency made comparisons between landuse categories and BMP's difficult. The question as to whether these materials warrant extreme concern is more close to being answered. In most cases these residuals are not "hazardous waste". However, the material is contaminated with a wide array of inorganic and organic pollutants. We do not recommend disposal without proper precautions (i.e., wise site selection, runoff control, and application limits) regardless of the source of the residue.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

SECTION 1

Introduction

Implementation of Florida's stormwater treatment requirements in 1982 has led to the construction of thousands of stormwater management systems. Many of these systems have been on-line long enough that they require maintenance. In addition the new federal NPDES permits for municipal stormsewer discharges focus increasing attention to the maintenance of structural stormwater controls operated by Florida's Cities, Counties, and Stormwater Utilities. An emerging issue is proper utilization or disposal of the residuals or sediment that accumulates in these systems.

Stormwater pollutants include a wide variety of substances that accumulate on pervious and impervious surfaces between storms, and are transported by the next rainfall. These contaminants include heavy metals, petroleum hydrocarbons, pesticides, and many types of organic chemicals. Concern over the pollution potential associated with urban runoff has led to unofficial requirements that the residue be taken to lined landfills. An alternate proposed by some municipalities is use as clean fill and as a soil amendment similar to composted domestic waste. Motivating factors include local initiatives to reduce the volume of solid waste and recognition of desirable characteristics such as the nutrient and organic content of these materials. Often, a stormwater maintenance entity seeking to comply with both environmental and solid waste reduction concerns, is faced with extensive, and therefore, expensive testing.

In October of 1995, the Stormwater Section presented a paper at the Southwest Florida Water Management District's Annual Stormwater Research Conference. This paper summarized existing data on the characteristics of stormwater sediments deposited in stormwater systems throughout Florida. The availability of data was sparse and not easily correlated due to differences in sampling methods used by the various studies. The primary recommendation of this paper was to collect more sediment and debris sample from stormwater BMPs serving various land use categories from all parts of the state. The objective was to increase our database and get a better understanding of the need to test stormwater sediments before disposal.

The literature search resulted in numerous studies that provide information relative to trace metal and nutrient content associated with BMP's such as wet detention basins. Evaluations of sediment associated with urban lakes, ponds, and canals, predominated the literature.. However, very little data was available relative to organic contaminants, such as, volatile and semi-volatile hydrocarbons, or pesticides. Likewise, sediment data, relative to practices such as retention ponds, highway swales, improved catch basins, sand filters, and street sweeping, was scarce.

These previous studies indicated that sediment quality follows the same hierarchy as runoff. That is, facilities serving more intense uses are likely to be more contaminated than low intensity land use facilities. There are also indications that the number of contaminants isolated in a given stormwater treatment facility, as well as the pollutant concentration, may increase with time since last maintenance.

As may be seen in Tables 1 through 8 in Appendix A, the literature indicates that the average concentration of metals rises sharply as landuse intensity increases. Highway sites and commercial facilities are more likely to display significantly higher levels of trace metals than single family residential treatment systems. Patterns associated with other transportation related contaminants such as petroleum hydrocarbons and PAH's are similar. Land use reconnaissance would seem a practical alternative to screen for facilities needing more intense scrutiny than others so that expensive leachability and extensive chemical analyses is not required in every instance prior to disposal.

Previous studies have primarily involved characterization of in place stormwater residuals. This assessment provides an evaluation of both in place sediment as well as the chemical and physical properties of sediment and street surface contaminants following removal and stock piling. The material in these piles is highly variable in its consistency ranging from relatively unconsolidated soupy muck to compacted clay. The site descriptions provided by participants however, was not sufficient to compare the pollutant concentration associated with these two types of samples.

Due to time and budget constraints, it was important to characterize this materials by analysis of as few samples as possible. A significant amount of best judgment was necessary on the part of the local sampling teams to assure the collection of sample aliquots which would accurately reflect the characteristics of the entire facility or stock pile. As expected, the volume of stormwater sediment and associated debris in these stock piles was often extremely large or of a consistency such that sample collection proved to be very difficult.

SECTION 2

Literature Review

As noted previously, the Department completed a review of available literature concerning the characteristics of stormwater treatment system residuals and urban sediment in October 1995. We have included several sections of that report (Livingston and Cox 1995), herein. The referenced paper summarized both the federal and state regulations that potentially affect the disposal of stormwater sediments. It also provides summaries of data on the chemical and physical characteristics of stormwater sediments from Florida and around the country.

Tables 1 through 4 that follow, list the allowable limits and screening level criteria associated with various federal and state rules that may effect the disposal of stormwater sediment. These screening criteria were utilized in the previous evaluation also. The information contained in the tables presented in this report have been updated with more recent information as appropriate.

Regulation of Stormwater Sediments:

Florida was the first state in the country to require the use of best management practices (BMPs) to treat stormwater from all new development. The adoption of Section 17-4.248, FAC, in 1979, and the subsequent adoption of Chapter 17-25, FAC (now 62-25), in 1982, along with the incorporation of stormwater treatment requirements into the Management and Storage of Surface Waters (MSSW) regulations of the water management districts has led to the construction of tens of thousands of BMPs throughout the state. These stormwater treatment practices are an essential component of the state's management programs to protect, maintain, or restore the quality of Florida's surface and ground waters.

The state's stormwater regulations require stormwater BMPs to be built according to adopted design criteria. These are selected to assure that the effectiveness of the stormwater system meets the stormwater treatment performance standard established in State Water Policy (Chapter 62-40, FAC). Another key element of the stormwater regulations is the need to properly operate and maintain the stormwater system to assure that it continues to provide the desired benefits. The rules require designation of a legal operation and maintenance entity which has the legal, financial, and technical means to conduct needed maintenance activities. Periodic inspections and certifications that the stormwater system is still functioning as designed and permitted is required by some water management districts and local governments.

Stormwater pollutants include a wide variety of substances that we leave on pervious and impervious surfaces. They become contaminants transported by the next rainfall. Additionally, especially in older urbanized areas, there are often connections to the stormwater system that should go to the sanitary sewer system. Consequently, a wide variety of potentially hazardous or toxic contaminants may enter stormwater management systems. These contaminants include heavy metals, petroleum hydrocarbons, pesticides, and a wide variety of organic chemicals. Accordingly, several federal and state laws and regulations may apply to the disposal of sediments that accumulate in stormwater systems or which are captured by street sweepers and vactors used to clean catch basins and stormsewers. State solid waste regulations, together with the potential applicability of hazardous and toxic waste regulations and, contaminated site cleanup criteria may adversely impact the disposal of stormwater sediments.

Several researchers have suggested that the material can be utilized as a soil amendment for land reclamation like a "compost" or "domestic wastewater residual". Other researchers point to the risk and the scarcity of data for decision makers to determine whether these materials are hazardous or toxic wastes, or simply "dirty dirt".

The five federal and state regulations that either directly or indirectly impact maintenance and disposal options available in regard to stormwater management facilities include the following:

1. Resource Conservation and Recovery Act of 1976 (RCRA)

RCRA requires generators of hazardous wastes to monitor and manage them in accordance with specified procedures. A solid waste may be considered a hazardous waste if it contains materials which are specifically listed in Sections 261.31 through 261.33 of 40 CFR or because it possesses any of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity). In nearly all cases concerning stormwater sediments, the reason that they could be classified as hazardous wastes is because they contain listed chemicals rather than because the sediments are hazardous by characteristic. However, it is possible for stormwater sediments to be classified as a hazardous wastes because they could exhibit toxicity if highly contaminated. Stormwater sediments would exhibit toxicity if, using the Toxicity Characteristic Leaching Procedure (TCLP), the extract contains contaminant concentrations which exceed the limits listed in Title 40 Code of Federal Regulations (CFR), Section 261.24. On the following page, Table 1 shows the hazardous waste concentration limits for toxicity associated with the 40 pollutants (8 inorganic metals and 32 organic compounds) listed in the RCRA criteria.

Table 1 RCRA Hazardous Waste Toxicity Limits

Contaminant	Maximum Concentration Limit TCLP (mg/l)
(Inorganic)	
Arsenic	5
Barium (*)	100
Cadmium	1
Chromium	5
Lead	5
Mercury (*)	0.2
Selenium (*)	1
Silver (*)	5
(Organic)	
1,1-Dichloroethylene (*)	0.7
1,2-Dichloroethane	0.5
1,4-Dichlorobenzene	7.5
2,4,5-TP (*)	1
2,4,5-Trichlorophenol	400
2,4,6-Trichlorophenol	2
2,4-D (*)	10
2,4-Dinitrotoluene	0.13
Benzene	0.5
Carbon Tetrachloride	0.5
Chlordane (*)	0.03
Chlorobenzene	100
Chloroform	6
Cresol	200
Endrin	0.02
Heptachlor (*)	0.008
Hexachlorobenzene	0.13
Hexachlorobutadiene	0.5
Hexachloroethane	3
Lindane (gamma-BHC)	0.4
m-Cresol	200
Methoxychlor (*)	10
Methyl Ethyl Ketone (*)	200
Nitrobenzene	2
o-Cresol	200
p-Cresol	200
Pentrachlorophenol	100
Pyridine (*)	5
Tetrachloroethylene (*)	0.7
Toxaphene (*)	0.5
Trichloroethylene (*)	0.5
Vinyl Chloride	0.2

Notes:
(*) No TCLP analyses were conducted for this parameter in the current study.

2. Chapter 62-640, FAC, Domestic Wastewater Residuals:

This rule establishes standards and criteria for the management and disposal of domestic wastewater residuals, also known as sludge or biosolids. The application limits shown became effective on 3-30-98. The Chapter 62-640 FAC criteria apply to residuals used for agricultural purposes or land reclamation: or, distributed and marketed to the public as a fertilizer product. It does not apply to disposal of residuals in a landfill or co-composting with solid waste. With respect to the disposal of stormwater sediments, Section 62-640.700 criteria for land reclamation, provides a guide sometimes used to establish land application limits.

Table 2. Heavy Metals Limits in Domestic Wastewater Residuals Used for Land Reclamation (Chapter 62-640 FAC., Effective 3-30-98)

Parameter	Land Application Ceiling Concentration (mg/kg dry wt)	Total Cumulative Loading Applied kg/ha (lbs/acre)
Arsenic	75	41 (36.6)
Cadmium	85	39 (34.8)
Copper	4300	1502 (1340)
Lead	840	300 (268)
Mercury	57	17 (15.2)
Nickel	420	420 (375)
Selenium	100	100 (89.3)
Zinc	7500	2802 (2500)

3. Chapter 62-701, FAC, Solid Waste Management Facilities

This rule establishes standards for the construction, operation, and closure of solid waste management facilities. Under this rule, stormwater sediments are defined as "solid waste". The rule prohibits disposal of hazardous wastes in a landfill unless the facility is permitted under Chapter 62-730 as a hazardous waste disposal facility. An operation plan is required which includes monitoring and controlling the type of waste received, and specifying procedures to follow if prohibited wastes are discarded. Section 701.520 outlines requirements for "special wastes" including soils contaminated with petroleum or other products which are not hazardous wastes. These may be disposed into permitted lined landfills. Stormwater sediment may be used as landfill cover if the material meets the rule's definitions of "final cover", "initial cover", or "intermediate cover".

4. Chapter 62-770, FAC, Petroleum Contamination Site Cleanup Criteria:

This rule establishes petroleum or petroleum product contamination cleanup criteria and a cleanup process to be undertaken at all petroleum contamination sites. The rule applies only to petroleum contaminated soils at cleanup sites to be treated. Since they typically contain contaminants derived from petroleum products however, these criteria are often indirectly applied to stormwater sediments that are to be land spread, used as clean fill; or, are being disposed of in C&D landfills. The rule establishes Soil Cleanup Target Levels (SCTLs) depending on the potential use of the site following cleanup and requires soils which have the hazardous characteristic of toxicity to be treated or disposed of at an approved hazardous waste treatment/disposal facility.

Updated Clean Soil Criteria (May 1997) are listed in Table 3a and Table 3b for select organic and inorganic pollutants respectively. These are target goals for the cleanup of contaminated sites. Goals for the listed contaminants are applicable to the upper two feet of soil.

Table 3a: Selected Soil Cleanup Target Levels

Chemicals of Concern		Direct Exposure		Leachability based on:			
(Organic)		I (#) (mg/kg)	II (##) (mg/kg)	Table V(a) (mg/kg)	Table VI(b) (mg/kg)	Table VII(c) (mg/kg)	Table VIII(d) (mg/kg)
PAH's:							
Acenaphthene		2300	22000	4	0.6	0.6	40
Acenaphthylene		1100	11000	22	0.003*	0.003*	220
Anthracene		19000	290000	2000	0.3	0.3	20000
Benzo(a)anthracene		1.4	5.1	2.9	0.4	0.4	29
Benzo(a)pyrene		0.1	0.5	7.8	1.2	1.2	78
Benzo(b)fluoranthene		1.4	5	9.8	1.5	1.5	98
Benzo(g,h,i)perylene		2300	45000	13000	2	2	130000
Benzo(k)fluoranthene		15	52	25	1.5	1.5	250
Chrysene		140	490	80	0.5	0.5	800
Dibenzo(a,h)anthracene		0.1	0.5	14	2.2	2.2	140
Fluoranthene		2800	45000	550	0.4	0.4	5500
Fluorene		2100	24000	87	9.4	9.4	870
Indeno(1,2,3 c,d)pyrene		1.5	5.2	28	4.3	4.3	280
Naphthalene		1000	8600	1	1	1.3	10
Phenanthrene		1900	29000	120	0.02*	0.02*	1200
Pyrene		2200	40000	570	0.8	0.8	5700
VOAs:							
Benzene		1.1	1.5	0.007	0.007	0.5	0.07
Ethylbenzene**		240	240	0.4	0.4	7.7	3.8
Toluene		300	2000	0.4	0.4	4.8	4
Total Xylenes**		290	290	0.3	0.3	5.3	2.9
OTHER:							
2-dichloroethane		0.6	0.9	0.02	0.02	0.7	0.2
MTBE		350	6100	0.2	0.2	150	1.6
TRPH's		350	2500	340	340	340	3400

Table 3b: Selected Soil Cleanup Target Levels

Chemicals of Concern	Direct Exposure		Leachability based on:				
(Inorganic)	I [(#)] (mg/kg)	II [(##)] (mg/kg)	Table II (mg/kg)	Table V[(a)] (mg/l)	Table VI[(b)] (mg/l)	Table VII[(c)] (mg/l)	Table VIII[(d)] (mg/l)
METALS:							
Arsenic	0.8	3.7	100.0	TCLP	TCLP	TCLP	TCLP
Barium	5200.0	87000.0	2000.0	TCLP	TCLP	TCLP	TCLP
Cadmium	75.0	1300.0	20.0	TCLP	TCLP	TCLP	TCLP
Chromium	290.0	430.0	100.0	TCLP	TCLP	TCLP	TCLP
Lead***	500.0	1000.0	100.0	TCLP	TCLP	TCLP	TCLP
Mercury	3.7	28.0	4.0	TCLP	TCLP	TCLP	TCLP
Selenium	390.0	10000.0	20.0	TCLP	TCLP	TCLP	TCLP
Silver	390.0	9100.0	100.0	TCLP	TCLP	TCLP	TCLP

Notes:

Values based on residential use assumptions.
Values based on worker industrial exposure assumptions.
* Unless the Method Detection Limit (MDL) using the most sensitive and currently available technology is higher than the specified criterion.
** Direct Exposure values based on Soil Saturation Limit (Csat).
*** Direct Exposure values from EPA Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities,OSWER Directive.
TCLP=Toxicity Characteristics Leaching Procedure in mg/l. The analyses should be performed if the concentrations listed in Table II (column 3) are exceeded. Need to pass hazardous waste test limits and comply with appropriate criteria as outlined in Tables V through VIII.
a) Table V - Ground Water Resource Target Levels for Resource Protection/Recovery.
b) Table VI - Lower of Table V and Fresh Water Surface Water Criteria.
c) Table VII - Surface Water Criteria for Resource Protection/Recovery.
d) Table VIII - Low Yield/Poor Quality.

5. Florida Preliminary Sediment Quality Assessment Guidelines (MacDonald, 1994)

Biological-effects based sediment quality assessment guidelines (SQAGs) were recently developed by MacDonald Environmental Sciences Ltd. under contract with the Department. These guidelines identify ranges of contaminant concentrations that have low to high probabilities of being associated with adverse biological effects. Data were assembled and evaluated to derive preliminary SQAGs for 34 contaminants. The numerical SQAGs are defined using two break points in concentration: a threshold effects level (TEL) and a probable effects level (PEL). Table 4 summarizes the SQAGs for Florida coastal waters.

Table 4
Sediment Quality Assessment Guidelines for Florida Coastal Waters

Substance	Threshold Effects (mg/kg)	Probable Effects (mg/kg)
Arsenic	7.240	41.600
Cadmium	0.676	4.210
Chromium	52.300	160.000
Copper	18.700	108.000
Lead	30.200	112.000
Mercury	0.130	0.696
Nickel	15.900	42.800
Silver	0.733	1.770
Zinc	124.000	271.000
(Organics)	(ug/kg)	(ug/kg)
Acenaphthene	6.710	88.900
Acenaphthylene	5.870	128.000
Anthracene	46.900	245.000
Fluorene	21.200	144.000
2-methylnaphthalene	20.200	201.000
Naphthalene	34.600	391.000
Phenanthrene	86.700	544.000
Benz(a)anthracene	74.800	693.000
Benzo(a)pyrene	88.800	763.000
Chrysene	108.000	846.000
Dibenzo(a,h)anthracene	6.220	135.000
Fluoranthene	113.000	1494.000
Pyrene	153.000	1398.000
Bis(2-ethylhexyl)phthalate	182.000	2647.000
(Pesticides and PCB's)	(ug/kg)	(ug/kg)
Chlordane	2.300	4.800
DDT	1.200	4.800
DDD	1.200	7.800
DDE	2.100	3.700
Dieldrin	0.720	4.300
Gamma BHC	0.320	0.990
PCB's Total	21.600	189.000

These guidelines may be used by the Department on a case by case basis to evaluate the potential for stormwater residuals to exert localized chronic to acutely toxic effects on benthic species in the vicinity of outfalls associated with sediment disposal sites. In general, disposal of stormwater sediment with contaminants in excess of PEL's would be viewed to have a high potential for localized biological effects in the absence of good site runoff management practices. Conversely, material characterized by values less than TEL's present a low probability for adverse biological effects.

Discussion of Results:

During the course of this literature survey stormwater sediment data contained in 17 investigations of stormwater management systems were reviewed, summarized, and analyzed relative to the 1995 criteria discussed in the preceding paragraphs . These investigations contained substantial data relative to the concentrations of trace metals and nutrients in stormwater sediments but relatively few data on organic contaminants such as petroleum hydrocarbons and pesticides. Additionally, more data were available on stormwater sediments from wet detention systems than from infiltration practices or any other BMP examined.

Sediment data reported in the literature tends to provide information about the top layer of loose sediments, generally the top few inches of material. Such samples typically are collected with a dredging device such as an Eckman dredge. In some cases, sediment cores allow for the determination of contaminant concentrations in different layers of the sediments.

Data reviewed for the literature survey is summarized in a series of tables in Appendix A. The tables include the following:

- Table A-1 summarizes data characterizing the sediments in different types of Florida stormwater systems serving a variety of different land uses.
- Table A-2 summarizes the effect of land use on sediment trace metal concentrations.
- Table A-3 compares sediment trace metal concentrations in different BMPs.
- Table A-4 compares trace metal concentrations in the top one inch, top 0-4 inches, and top 0-8 inches of stormwater BMP sediments.
- Table A-5 summarizes data on organic priority pollutants found in stormwater sediments.
- Table A-6 compares trace metal concentrations in roadside soils as the distance from the pavement increases.
- Table A-7 summarizes TCLP data for detention pond sediments.

The data in Tables A-1 and A-3 indicates that stormwater sediments, especially in the top inch of sediment, often exceeded 1995 soil cleanup goals for chromium and lead. In comparison to the 1997 criteria, there would be fewer instances of exceedance since limits for both these parameters have increased. Similar to stormwater loadings, concentrations of trace metals in sediments increase with the intensity of the land use and the associated stormwater loadings. As expected because of the characteristics of pollutants left on surfaces over which motor vehicles travel, sediments in BMPs capturing highway runoff have the highest concentrations of trace metals. However, with the exception of lead stormwater BMP sediments contain concentrations of trace metals which are less than the (1995) limits for metals in domestic wastewater residuals used for land reclamation.

Table A-4 compares the concentrations of trace metals in three different layers of stormwater BMP sediments. Surface sediment samples, especially those collected in the vicinity of inflows and from systems receiving highway or parking lot runoff, are most likely to contain contaminant concentrations exceeding the clean soil criteria. As expected, concentrations decline as the loose surface sediment is combined with more consolidated deeper sediments. However, even in composite samples of the top 0-8 inches of BMP sediments, lead concentrations from highway wet ponds and dry swales can exceed the clean soil criteria.

A growing concern among ecologists is the effects of petroleum hydrocarbons and volatile organic compounds on the biota of water bodies receiving stormwater discharges. Unfortunately, few investigations have been undertaken to determine the ecological effects of these materials which have become almost ubiquitous in the urban environment because of civilization's reliance upon the motor vehicle. Additionally, very few investigations have determined the levels of volatile organic aromatics or petroleum hydrocarbons in stormwater BMP sediments.

Table A-5 summarizes the maximum levels of PAH's and other organic compounds in stormwater sediments as reported in the literature. As may be seen from the data, concentrations of PAH's vary considerably, from less than one to more than 3,000 mg/kg. Only one study (i.e., the Lake Tuscawilla Restoration Project) provides sufficient data that allows a comparison of stormwater sediment characteristics with the clean soil criteria. The levels of total recoverable petroleum hydrocarbons and the polynuclear aromatic hydrocarbons in sediments from Lake Tuscawilla greatly exceeded the clean soil criteria. The City of Ocala treated these sediments by spreading them in sludge drying beds, exposing them to light and oxygen.

Another interesting observation can be made with respect to lead concentrations in the soil along the edges of highways (Table A-6). At the edge of the pavement and in a swale located 18 feet away from the pavement's edge, the lead concentrations greatly exceeded the clean soil criteria in the top two inches of soil. However, values declined with increasing distance from the road surface. This investigation was conducted by Dr. Wanielista back in 1978 before leaded gas had been eliminated The results should be much improved today.

Sediments from stormwater BMPs were not found to be "hazardous waste as seen from the TCLP data summarized in Table A-7. No sample in the 1995 data base exceeded the TCLP limits that would cause stormwater sediments to be classified as a hazardous waste.

SECTION 3

Goals and Objectives

The primary objective of this project is to augment the information established during the previous survey and help to establish a database relative to sediment characteristics that contains data collected in a standard uniform manner. This data can then be used to refine current policies for stormwater sediment disposal in the state of Florida.

In order to develop a useable database for characterizing stormwater sediment (from here on the term "sediment" will refer to any solid material, organic or inorganic, deposited by stormwater or collected by mechanical methods such as filtration or sweeping), samples were collected from the most common stormwater BMPs located in the varying land uses found throughout the state of Florida. These samples were collected and analyzed in a standard uniform manner that makes for valid correlation of data.

The sampling sites for this project (102 total) were distributed over 14 cooperating local program areas. On the following page, Figure 1 illustrates the distribution and approximate location of the participating members of the Florida Association of Stormwater Utilities that were involved with this study. In each sample area, sediment from the common stormwater BMPs applicable to the area were sampled. Common BMPs included: wet detention ponds, dry retention ponds, swales, water quality inlets, sand filters, and street sweepers. For comparative purposes, samples of native soil were also collected at control sites to determine background levels of metals and organics associated with open land areas in each municipality.

Due to time constraints and personnel limits the number of samples collected by each cooperating local program was not standardized. The number of sites sampled varied from a high of 14 by the City of Clearwater to a minimum of 4 submitted by Polk County.

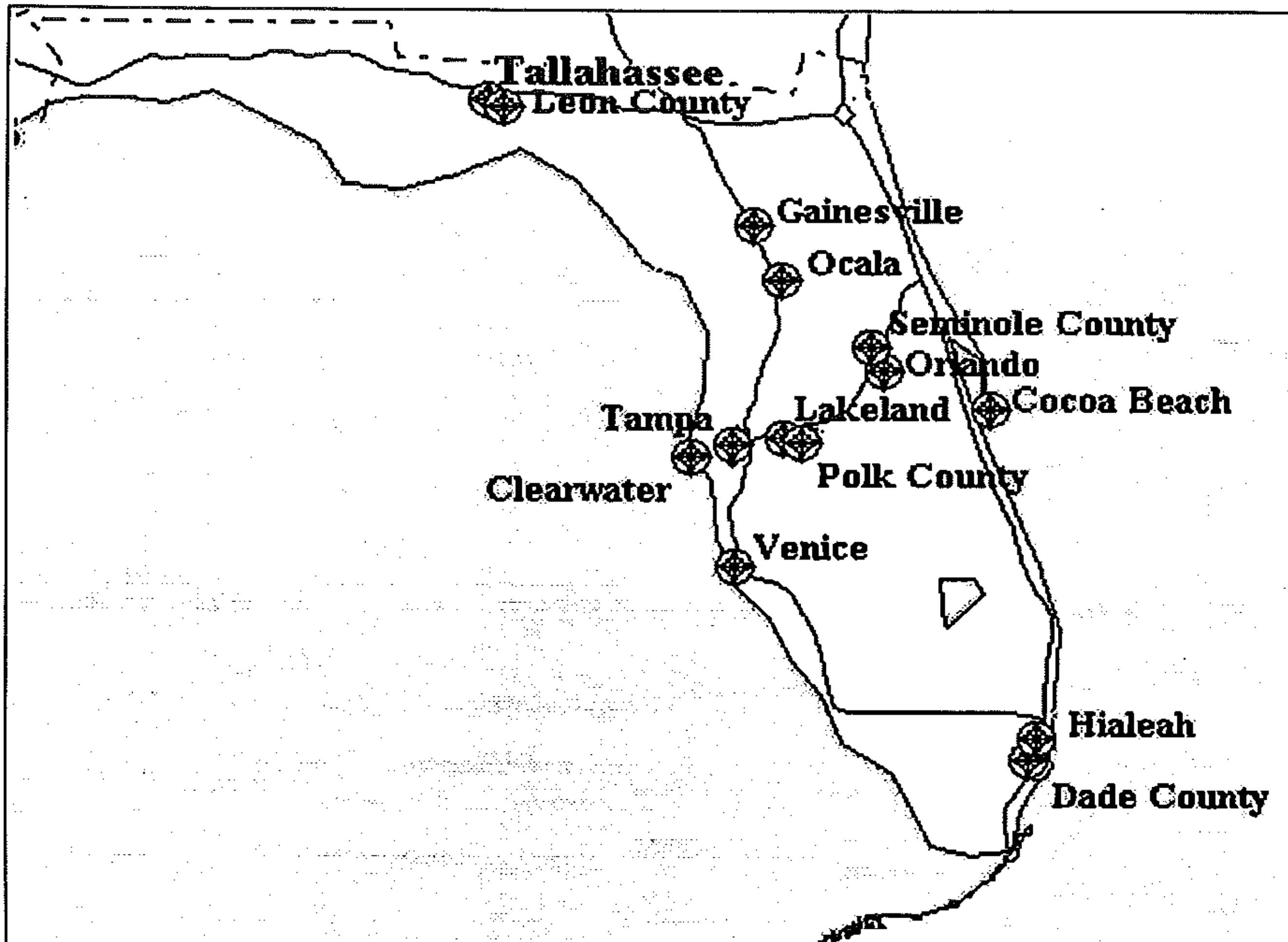


Figure 1 - Location of Participating Municipalities

SECTION 4

Methodology

Sediment Sampling and Testing Procedures:

Sample collection associated with this project was a cooperative effort between FDEP and personnel from local government stormwater programs around the state. The samples collected at each location were preserved on ice and immediately sent to the DEP Central Laboratory in Tallahassee for analysis. Each sample was examined for heavy metals and organic content, base neutral acid extractable organic compounds, select pesticides, physical properties (grain size distribution), and TCLP metals and organic compounds.

In most instances, composite samples formulated from 3 to 7 individual aliquots were collected at each site. Approximately 24,000 analyses were conducted during the course of the study. When possible a background sample of native soil was taken along with samples of sediments from the most common types of stormwater treatment facilities (i.e., BMP's) found in the sample area. Each of these (15) samples was analyzed for the same array of parameters as shown in Table 5. In addition, sediment removed from half of the facilities within each of the local areas were tested using TCLP procedures for the parameters shown in Table 6. A total of 44 sites were tested in this manner.

Chemical contaminants were selected from a standard list of organic and inorganic parameters that could be associated with urban or industrial stormwater treatment areas. An array of common organic contaminates and pesticides were evaluated including polychlorinated biphenols (PCBs), chlorinated pesticides, polyaromatic hydrocarbons, total recoverable petroleum hydrocarbons, and volatile organic compounds (VOC's). The targeted inorganic parameters were total recoverable metals for the short list of elements (arsenic, cadmium, chromium, lead, copper, nickel, and zinc). Physical characteristics of the sediment was evaluated via particle size (sieve) distribution. Organic content was determined using total organic carbon (TOC) analysis. In addition, Toxicity Characteristic Leaching Procedure (TCLP) was requested for selected sites (those with excessive amounts of color or odor) in which the sample collectors indicated that potential hazardous level of contaminants might be present. All sample analyses except TOC, were performed by the Florida Department of Environmental Protections Chemistry and Biology laboratories. The TOC analyses were overflowed to a local private laboratory (Savannah Laboratories, Tallahassee, Florida).

The composition of samples appeared to be mixtures of street debris, large and small particulate soil matter and oily particulate matter, presumably from asphalt and automobile wastes. Most samples were very heterogeneous and would ultimately pose problems for analytical reproducibility. To preserve the sample leaching characteristics as much as possible, no particle reduction or grinding was attempted on any TCLP sample. Instead, all samples were stirred vigorously and subsampled with efforts to reproduce an aliquot that was reflective of the original sample.

List of Parameters:

As shown in the tables which follow each sample was examined for its physical characteristics relative to percentage particle size distribution in six (6) categories ranging from fine silt and clay to coarse sands. In addition the organic matter content of samples was evaluated via the total organic carbon (TOC) concentration. The samples were tested for a total of one hundred and twenty eight (128) pollutants. These were distributed as follows among two groups: (*Inorganics* Metals-7, *Organics* Cl. Pesticides and PCB's-26, Volatile Organics-34, Semi-Volatile PAH's

Phthalates and Phenolic Compounds-60, and Total Recoverable Petroleum Hydrocarbons). Sediment leachability, the potential for these pollutants to be release adsorbed pollutants to runoff or rainfall that infiltrates the ground was evaluated via the TCLP procedure for forty (40) constituents. Most of the parameters examined in this manner were included in the previous array relative to the total recoverable sediment concentration.

Table 5
Stormwater Sediment Study- Parameters and Method Detection Limits (MDL's)

Sediment Analysis	EPA Method/Standard Method Reference	MDL (ug/kg)
Total Solids (1)	NA 1	--
Sediment Grain Size	See Note # 5	--
Total Organic Carbon (2)	EPA 9060	50 mg/kg
Volatile Organics	EPA 8260 (GC/Mass Spectroscopy)	see page 4-3
PAH's (4)	EPA 8270 (GC/Mass Spectroscopy)	see page 4-4
Total Recoverable Petroleum Hydrocarbon	FL-PRO	10 mg/kg
Cl Pesticides/PCBs	EPA 8081 (GC/ECD)	see next page
Metals (3) (Furnace)	EPA 7000 method series (Graphite Furnace AA)	
As		400
Cd		20
Cr		200
Cu		200
Ni		200
Pb		200
Zn		--

Notes:

1- Determined as % Dry Solids by drying sub-sample at 105 deg. C. overnight and using gravimetric determination
2- Performed by Overflow Laboratory
3- HNO3/Peroxide Digestion
4- included in of EPA 8270(GC/MS) acid/base-neutral analysis complete list.
5- Method modified from "Procedures for Handling and Chemical Analysis of Sediment and Water Samples ", 1981. EPA/ACE Technical Committee on Criteria for Dredged and Fill Materials. Vicksburg, MS.

Method Detection Limits for Select Sediment Analyses		
Parameter	**MDL (ug/kg)**	**EPA Method Reference**
Cl Pesticides/PCBs		
Aldrin	0.40	8081
Alpha-BHC	0.40	8081
Beta-BHC	0.70	8081
Delta-BHC	0.40	8081
Gamma-BHC	0.40	8081
Chlordane	5.0	8081
DDD-p,p'	0.7	8081
DDE-p,p'	0.70	8081
DDE-p,p'	0.70	8081
DDT-p,p'	0.70	8081
Dieldrin	0.70	8081
Endosulfan I	0.40	8081
Endosulfan II	0.40	8081
Endosulfan Sulfate	0.70	8081
Endrin	0.70	8081
Endrin Aldehyde	0.70	8081
Heptachlor	0.40	8081
Heptachlor Epoxide	0.40	8081
Toxaphene	17	8081
PCB-1016	7.00	8081
PCB-1221	7.00	8081
PCB-1232	7.00	8081
PCB-1242	7.00	8081
PCB-1248	7.00	8081
PCB-1254	7.00	8081
PCB-1260	7.00	8081
Volatile Organics		
Benzene	2.0	8260
Bromodichloromethane	2.0	8260
Bromoform	2.0	8260
Bromomethane	2.0	8260
Carbon tetrachloride	2.0	8260
Chlorobenzene	2.0	8260
Chloroethane	2.0	8260
2-Chloroethylvinyl ether	2.0	8260
Chloroform	2.0	8260
Chloromethane	2.0	8260
Chloromethane	2.0	8260
1,2-Dichlorobenzene	2.0	8260

Method Detection Limits for Select Sediment Analyses		
Parameter	**MDL (ug/kg)**	**EPA Method Reference**
1,3-Dichlorobenzene	2.0	8260
1,4-Dichlorobenzene	2.0	8260
Dibromochloromethane	2.0	8260
1,1-Dichloroethane	2.0	8260
1,2-Dichloroethane	2.0	8260
1,1-Dichloroethene	2.0	8260
trans1,2-Dichloroethene	2.0	8260
1,2-Dichloropropane	2.0	8260
cis-1,3-Dichloropropene	2.0	8260
trans1,3-Dichloropropene	2.0	8260
Ethylbenzene	2.0	8260
Methylene chloride	2.0	8260
1,1,2,2-Tetrachloroethane	2.0	8260
Tetrachloroethene	4.0	8260
Tetrachloroethene	4.0	8260
1,1,1-Trichloroethane	2.0	8260
1,1,2-Trichloroethane	2.0	8260
Trichloroethene	2.0	8260
Toluene	2.0	8260
Vinyl chloride	2.0	8260
Xylenes (total)	2.0	8260
Trichlorofluoromethane	2.0	8260
Semi-Volatile Organics/PAH's/Cl Pesticides/PCBs		
Acenaphthene	60	8270
Acenaphthylene	60	8270
Aldrin	170	8270
Anthracene	80	8270
Azobenzene/1,2-Diphenylhydrazine	60	8270
Benzo(a)anthracene	60	8270
Benzo(b)fluoranthene	60	8270
Benzo(k)fluoranthene	60	8270
Benzo(a)pyrene	60	8270
Benzo(g,h,i)perylene	60	8270
Butyl benzyl phthalate	60	8270
alpha-BHC	170	8270
beta-BHC	170	8270
gamma-BHC	170	8270
delta-BHC	170	8270
Benzidine	1300	8270

Method Detection Limits for Select Sediment Analyses		
Parameter	**MDL (ug/kg)**	**EPA Method Reference**
Bis(2-chloroethyl)ether	60	8270
Bis(2-chloroethoxy)methane	60	8270
Bis(2-chloroisopropyl)ether	60	8270
Bis(2-ethylhexyl)phthalate	340	8270
4-Bromophenyl phenyl ether	60	8270
2-Chloronaphthalene	60	8270
4-Chlorophenyl phenyl ether	60	8270
Chrysene	60	8270
4,4'-DDD	170	8270
4,4'-DDE	170	8270
4,4'-DDT	170	8270
Dibenzo(a,h)anthracene	60	8270
Di-n-butyl phthalate	400	8270
1,2-Dichlorobenzene	170	8270
1,3-Dichlorobenzene	170	8270
1,4-Dichlorobenzene	170	8270
3,3'-Dichlorobenzidine	1000	8270
Dieldrin	170	8270
Diethyl phthalate	60	8270
Dimethyl phthalate	60	8270
2,4-Dinitrotoluene	60	8270
2,6-Dinitrotoluene	60	8270
Di-n-octyl phthalate	60	8270
Endosulfan I	670	8270
Endosulfan I	670	8270
Endosulfan II	670	8270
Endosulfan sulfate	670	8270
Endrin	170	8270
Endrin aldehyde	670	8270
Fluoranthene	60	8270
Fluorene	60	8270
Heptachlor	170	8270
Hexachlorobenzene	60	8270
Hexachlorobutadiene	170	8270
Hexachloroethane	170	8270
Hexachlorocyclopentadiene	60	8270
Indeno(1,2,3-cd)pyrene	60	8270
Isophorone	60	8270
2-Methyl naphthalene	60	8270
Naphthalene	60	8270
Nitrobenzene	60	8270

Method Detection Limits for Select Sediment Analyses

Parameter	MDL (ug/kg)	EPA Method Reference
N-Nitrosodimethylamine	60	8270
N-Nitrosodi-n-propylamine	60	8270
N-Nitrosodiphenylamine	60	8270
PCB-1016	1300	8270
PCB-1221	1300	8270
PCB-1232	1300	8270
PCB-1242	1300	8270
PCB-1248	1300	8270
PCB-1254	1300	8270
PCB-1260	1300	8270
Phenanthrene	60	8270
Pyrene	60	8270
Toxaphene	1300	8270
1,2,4-Trichlorobenzene	170	8270
4-Chloro-3-methylphenol	60	8270
2-Chlorophenol	170	8270
2,4-Dichlorophenol	60	8270
2,4-Dimethylphenol	60	8270
2,4-Dinitrophenol	170	8270
2-Methyl-4,6-dinitrophenol	60	8270
2-Nitrophenol	60	8270
4-Nitrophenol	60	8270
Pentachlorophenol	60	8270
Pentachlorophenol	60	8270
Phenol	60	8270
2,4,6-Trichlorophenol	60	8270

Table 6
Stormwater Sediment Study TCLP Parameters and Methods

TCLP Parameters	EPA Method/Standard Method Reference
Metals (As, Cd, Cr, Pb)	1311/6010
Volatile Organics [(1)]	1311/5030/8260 (gc/ms)
Semi-Volatile Organics[(2)]	1311/3510/8270 (gc/ms)

Notes:

1. Includes TCLP Sample Prep and Analysis for following VOC analytes:

Benzene
Bromoform
Carbon tetrachloride
Chlorobenzene
Chloroform
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Dibromochloromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
1,2-Dichloropropane
Ethylbenzene
Methylene chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Toluene
Vinyl chloride
Xylenes (total)

2. Includes TCLP Sample Prep and Analysis for following Semi-Volatile Analtyes:

o-Cresol
m,p-Cresols
1,4-Dichlorobenzene
2,4-Dinitrotoluene
Endrin
Hexachlorobenzene
Hexachloroethane
Hexachlorobutadiene
gamma-BHC
Nitrobenzene
Pentachlorophenol
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

Sample Acquisition:

The following procedures were used in the procurement of the samples. The type of sediment or soil collection technique chosen was largely at the discretion of the local sampling team. Consideration was given to the following factors in making these decisions, however.

1. Since volatile organic compounds were analyzed in this project, subsurface mid depth core sampling was preferred when possible.
2. The physical properties of the soil or sediment can limit the applicability of various sample collection devices. Material that is too liquid and/or cohesionless can be difficult or impossible to collect using an auger or coring device such as a push tube unless equipped with a core catcher or other means which physically keeps the sample from slipping back out of the corer.
3. The degree of mixing to which the residuals had been subjected and the size of the facility or stockpile was considered very important for selection of appropriate collection equipment and sampling site(s). Generally, 3 to 5 grab samples were considered for collection if the sediment to be characterized was still in place in the basin (pond) or a large stock pile was sampled. To characterize in place sediment, samples were collected near the inlet and discharge structure as well as from the open pond or canal areas. The individual cores were combined into a single sample to maximize the number of facilities to be tested at the least cost.

In most instances, samples from small well mixed waste piles (a truck load or two in size) were obtained by collecting a single sample from the center of the pile provided the sampling device was capable of satisfying sample volume requirements. Examples include catch basin and exfiltration trench vactor truck sediment and/or street sweeper residue. To characterize large stockpiles of stormwater residuals a similar number of individual grab samples as noted above for a pond or similar facility was requested.

In collecting the sample or composite aliquot for either soil or sediment analysis, the sampling teams were permitted to use shovels or other non stainless steel (SS) equipment to clear away large debris as well as leaves and grass from the area to be sampled. Likewise, since stainless shovels and hand augers may be difficult to acquire and depth samples were needed for volatile organic compound (VOC) analysis, sample teams were advised to excavate to the appropriate depth where a sample was to be collected using non stainless equipment. A precleaned stainless spoon or spatula could then be used to clean away the soil or sediment that contacted the nonstainless instrument. A second precleaned SS spoon or spatula was used to collect the sample.

When appropriate equipment was available, depth samples or cores were collected from the cleared location by forcing a SS push tube into the residuals stock pile or by augering to the desired depth in the soil or sediment profile with a SS hand auger. The teams were advised to clean the auger head with distilled water or use a second precleaned auger head or sleeve to collect mid depth samples for VOC analysis when the desired depth was reached. Rocks and other objects which make these samples hard to mix were discarded.

Sample Handling Following Collection:

Once the sample was acquired, the handling procedures were uniform. The primary differences involved separation and proportioning of multiple aliquots from several locations or layers to characterize the stormwater sediments or soil. The following steps outline the handling process.

1. Participants emptied the contents of the push tube, auger, or other collection device into a stainless mixing tray, bowl or other suitable container.
2. With a precleaned stainless spatula, the sampling teams separated or sliced away the center portion of the sample for analyses of volatile organic compounds (VOC's).
3. The teams immediately transferred the sliced portion of the core or center portion of the bowl contents to the VOC container equipped with a teflon lined seal.
4. The VOC containers were filled with sample until no head space existed.
5. Participants cleaned the outside of each container with paper towels to remove excess sediment or soil. The containers were capped tightly, labeled, and place on ice immediately.
6. Each sample jar was prelabled by the DEP lab for the appropriate size aliquot volume.
7. Sampling teams completed the chain of custody forms provided.

Participants shipped all samples packed in wet ice to FDEP Tallahassee for analysis. The DEP lab paid the cost and provided insulated cooler containers for shipping by common carrier. All documents, including sample tansmittal forms, bill of lading, and the analyses order, were sealed in a plastic bag and taped to the underside of the cooler lid prior to sealing it closed.

SECTION 5

Site Description

Land Use Characteristics of Contributing Area or Watershed:

Each participant in the study was requested to provide information concerning the predominant landuse class associated with the facilities, waterbodies or stormwater conveyances that they examined. Our objective was to collect samples from a wide array of land use areas. Previous studies indicated that land use intensity influences the makeup of pollutants contained in stormwater sediment as well as the concentration of contaminants.

Sampling results were consolidated in accordance with eight land classes as follows;

1. Single Family Residential (21)
2. Commercial and Services (14)
3. Light Industrial Areas and Maintenance Facilities (14)
4. Transportation including Roads and Highways (08)
5. Mixed Residential and Strip Commercial w/ Highways (24)
6. High Density Residential (Mixed SF and MF Housing) (02)
7. Institutional including Offices and Hospitals etc. (03)
8. Open Space/Parks and Recreation (Golf Course) (01)

The predominant type of contributing areas tested primarily involved categories 1 through 5. Most participants elected to examine residuals from areas that were representative of the primary sources of stormwater sediment they were handling. Participants were encouraged to collect samples from facilities that were expected to be problematic.

Description of Stormwater BMP's and Maintenance Categories Associated with Sources:

The samples were further classified in terms of their associated BMP's or type of maintenance operation. As mentioned in regard to previous studies, there is a preponderance of information available to help characterize sediment associated with the maintenance of wet ponds. Very little data was available however, relative to other structural controls. The categories examined included:

1. Wet Detention Facilities (14)
2. Retention Ponds (12)
3. Roadside Swales and Road Shoulders (08)
4. Dry Detention Facilities and Filter Systems (04)
5. Catch Basins (Vactor Truck Residuals) (01)
6. Street Sweeping Residue (11)
7. Sediment Sumps/Forebays at Inlets (04)
8. Screens and Weirs at Inlets (02)
9. Catch Basins and Stormsewer Sediment and Debris in place (08)
10. Sediment Associated with Untreated Runoff in Canals and Ditches (Canal Spoil) (07)
11. Lake or Canal Bottom Sediments in place (15)
12. Filter Sand (01)

Samples were well distributed over these eleven categories. However, each participant was allowed to determine the type of residuals they wished to have examined. Because of staff and time restrictions some participants elected to test as few as two classes of systems. The numbers of facilities examined in each landuse and maintenance category is shown above in the column at the right. Participants showed particular concerned relative to residuals associated with maintenance of canals and lakes followed by wet detention ponds and retention facilities. Participants also show moderate interest in street sweeper and catch basin/vactor truck residue in place, roadside swales, and road shoulder areas.

SECTION 6

Analytical Results

Problems Encountered:
Most analytical problems centered around poor analytical precision on laboratory duplicates. As indicated previously, the samples appeared very heterogeneous and were difficult to homogenize. The laboratory noted much difficulty in reproducing aliquots for precision verification or determining matrix spike recoveries. Ongoing quality control limits for accuracy and precision were 75-125% and less than 20% respectively. If any sample duplicate or matrix spike recovery in a batch exceeded the control limits, then all samples in that batch were qualified with a comment that control limits were exceeded for the given parameter.

In contrast, TCLP analyses use a larger aliquot of sample and therefore tended to even out any sample heterogeneity present. This is reflected in better sample duplicate precision and matrix spike recoveries.

General Discussion:
Because of the substantial array of pollutants examined in this study the data base was very large. The study produced a total of 15,506 contaminant related records. In order to make the data more manageable we have only identified values which exceeded minimum detection limits (MDL's). Filtering the data in this manner resulted in a reduction in the size of the data base to 1,572 records in excess of MDL's. Roughly, only 10% of the test results exceeded the limits of detection.

The following is a list of the pollutant categories found in detectable concentrations at the eighty seven (87) stormwater sediment sites examined. Only fifty three (53) pollutants of the one hundred sixty eight (168) tested for, or 32 percent, were found in detectable concentrations. Similar to our previous 1995 study however, several traffic related metals (i.e., Cr., Pb., and Zn.) were detected at virtually all sites. Copper, cadmium, nickel, and arsenic were also present in samples at frequencies from 94 to 59 percent as shown below. As a group, metals were the most often detected runoff related pollutants in these stormwater sediment samples.

Table 7 Percent Frequency and Pollutants Found at Detectable Levels

PARAMETERS DETECTED >MDL	TOTAL # SITES	FREQUENCY %
Inorganics-Metals		
Chromium	87	100
Lead	87	100
Zinc	87	100
Copper	82	94
Cadmium	63	72
Nickel	58	67
Arsenic	51	59
Organic Compounds		
TRPH	78	90
Chlordane	71	82
Pyrene	56	64
Benzo(b)fluoranthene	53	61
Fluoranthene	52	60
Chrysene	47	54
DDE-p,p'	47	54
Benzo(a)pyrene	43	49

Table 7 Percent Frequency and Pollutants Found at Detectable Levels (cont.)

PARAMETERS DETECTED >MDL	TOTAL # SITES	FREQUENCY %
Benzo(a)anthracene	42	48
Phenanthrene	41	47
Benzo(k)fluoranthene	38	44
DDD-p,p'	34	39
Benzo(g,h,i)perylene	34	39
"Indeno(1,2,3-cd)pyrene"	33	38
PCB-1260	26	30
DDT-p,p'	21	24
Toluene	13	15
Bis(2-ethylhexyl)phthalate	13	15
Dieldrin	11	13
Butyl benzyl phthalate	11	13
Anthracene	10	12
Fluorene	9	10
"Dibenzo(a,h)anthracene"	9	10
PCB-1248	8	9
Di-n-octyl phthalate	7	8
Xylenes (total)	6	7
PCB-1254	5	6
Gamma-BHC	4	5
Toxaphene	4	5
Acenaphthene	3	3
Ethylbenzene	3	3
Dimethyl phthalate	2	2
Heptachlor Epoxide	2	2
Delta-BHC	1	1
1,4-Dichlorobenzene	1	1
RCRA/TCLP Leachability Test (44 SITES)		
Lead TCLP TRP	35	80
Chromium TCLP TRP	11	25
Lead TCLP ICP	11	25
Chromium TCLP ICP	7	16
Toluene TCLP VOC	5	11
m,p-Cresols TCLP	4	9
Arsenic TCLP TRP	4	9
Cadmium TCLP TRP	4	9
Arsenic TCLP ICP	2	4
Cadmium TCLP ICP	1	2
Xylenes (total) TCLP VOC	1	2
Total Parameters Detected = 53		

Relative to organic contaminants, five of the thirty five compounds detected occurred at a frequency equivalent to the inorganic pollutants (i.e., heavy metals). Most notably, total recoverable petroleum hydrocarbon (TRPH) levels exceeded MDL's at 90% of the test sites followed by the pesticide Chlordane which was detected at an 82% frequency.

Finding detectable levels of Chlordane at such a frequency was somewhat surprising. Sale of the material has been banned since 1989. However, this pesticide was used extensively in years past for termite control and is known to be very persistent. We would expect detectable levels to be found in older sediment particularly from wet detention ponds, lakes and canals.

We were surprised to find high concentrations of this pesticide in newer more recent sediment associated with catch basins and street sweeper residue. The concentration a some sites exceeded the levels associated with older pond sediment. Hopefully, this does not indicate that this material is still being used for pest control. Most likely, previously contaminated soil deposited onto streets via mud on vehicle tires or wind and water erosion from lawns is the primary source of this contaminant in street sweeper and catch basin debris.

In 1983 USEPA reported results of one of the most intense efforts ever conducted to characterize the pollutants in urban stormwater runoff. The study went well beyond previous research in that it included monitoring to determine the extent and magnitude of priority pollutants contained in stormwater runoff. Results indicated that the inorganic metals were frequently present in concentrations exceeding water quality standards. As noted in the final report, "the organic pollutants were detected less often and at lower concentrations than the inorganic pollutants." Of a possible 106 organics, only 13 occurred in 10% or more of the samples. Plasticizers (i.e., phthalates) were the most commonly found organics at a 22 percent rate. Recent stormwater monitoring results from the NPDES Municipal Separate Storm Sewer System (MS 4) permitting program for Florida cities, beginning in 1994, show similar results and generally lower levels of these contaminants.

When stormwater sediments are examined it becomes apparent that these low level organic contaminants are concentrated following deposition. NURP results show only four organic compounds associated with petroleum products from roads and highways that were detected in runoff samples at frequencies in excess of 10%. This study found detectable levels of the same four poly aromatic hydrocarbons or PAHs (i.e., Chrysene, Fluoranthene, Phenanthrene, and Pyrene) present in 64-47 % of the samples collected. A total of 13 PAH's, 2 pesticides plus DDT and derivatives, 2 phthalate compounds and PCB 1260 were detected in 10 percent or more of sediment samples.

Appendix B and C contain tables of test results of detectable constituents found in stormwater sediments and background soils in the urban environment of Florida. In Appendix B information is consolidated in individual tables for each of the participating entities. Likewise data in Appendix C is consolidated by the individual municipalities that collected background data. The background information in Table C is shown in a single table.

As may be seen, all samples examined contain detectable levels of some constituents. The background sites, with the exception of those submitted by the City of Hialeah in Dade County, contained lower levels and substantially fewer contaminants than found in stormwater sediments.

Comparison with Various Screening Level Criteria:

Appendices D through G respectively illustrate how the samples compared relative to Soil Cleanup Target Levels, Pollutant Limits for Land Application of Bio-solids (i.e., domestic waste water residuals), Florida's Sediment Quality Assessment Guidelines (SQAGs), and RCRA Hazardous Waste (TCLP) Toxicity Limits. Data presented in Appendix H and I provide a similar comparison for these criteria relative to background soil.

Background Vs Soil Cleanup Target Levels:

Six of the fifteen background sites show values of some parameters above soil cleanup criteria. As expected most of the exceedances involve detectable levels of Arsenic. A high value of 3.1 ppm was seen in the Tallahassee area soils.

Stormwater Sediment Compared with Soil Cleanup Target Levels:

Arsenic is also the most problematic pollutant found in stormwater sediment relative to Soil Cleanup Goals. This element was found in the National Urban Runoff Program studies conducted by USEPA during the 1980's at relatively low levels and frequencies. These low levels are concentrated beyond the screening level criteria in sediment, however. Arsenic may enter the urban environment primarily as a by-product in pesticides and possibly to some extent via the use of treated lumber and rodenticides.

In contrast to our previous literature study, traffic related PAH's were shown to be more of a problem in stormwater sediments than expected. While these contaminants were not detected as frequently as their inorganic counter parts, as a group they exceeded the various screening level criteria more often than the seven heavy metals which were examined in this study. The primary sources of these semi-volatile organic compounds are by products of incomplete combustion, fuel spillage on parking lots and roadways, and vehicle lubricants. The most frequently detected of these organic compounds were Pyrene, Benzo(b)fluoranthrene, Fluoranthene, Chrysene, Benzo(a)pyrene, Benzo(a)anthracene, Phenanthrene, and Benzo(k)fluoranthrene in 60 to 40 percent of the samples examined.

The heavy molecular weight benzolated compounds comprise the most problematic group of these pollutants. They were not detected as frequently as some of the other compounds like Pyrene. However, limits established for these more carcinogenic hydrocarbons are highly restrictive. Maximum levels of Benzo(a) pyrene (6900 ug/Kg), Benzo(b) fluoranthrene (14,000 ug/Kg), and Benzo(a) anthracene (7200 ug/Kg) exceeded the clean soil criteria by factors of 69, 14, and 5 times respectively. Benzo(a) pyrene was shown in excess of residential criteria at 42 of the 87 sites, or 48% of the stormwater facilities examined. Percentages of 36% and 23% were lower, but still significant relative to the other two compounds.

<u>Stormwater Sediment Compared with Soil Cleanup Target Levels for Leachability and Surface Water Protection:</u>

Sediment from 44 of the 87 stormwater treatment and conveyance facilities or activities examined in this study were tested using the Toxicity Characteristic Leaching Procedure (i.e., TCLP) test. These tests were run based on the presence of objectionable odors, extremely dark coloration, or a land use that presented a high probability of contamination. These aliquots were tested regardless of the amount of the total pollutant concentration measured in an individual sample.

Relative to Clean Soil Target Levels we compared our results with the Groundwater Cleanup Target Levels listed in Table V, Chapter 62-770, F.A.C. We also evaluated results in comparison with the Table VII, Freshwater Surface Water Criteria in this rule. As noted earlier , our intent was to determine the potential for adsorbed pollutants to leach with rainfall that infiltrates the ground or be released to surface runoff.

We examined levels of arsenic, cadmium, chromium and lead in the TCLP element of the project. These pollutants represent the four primary toxic heavy metals observed in urban runoff. Of these, lead exceeded groundwater leaching criteria in the extract at 80% of the sites tested. Cadmium, Chromium and Arsenic also exceeded the criteria, but only rarely in 6% to 9% of samples.

With the exception of arsenic, direct comparisons with freshwater surface criteria could not be performed. The rate of exceedance for this parameter (i.e., 9%)is unchanged. In this instance the groundwater criteria and the surface water standard is equivalent. Standards for the other parameters are dependent on water hardness and consequently are variable by location. However, with the exception of chromium the rate of exceedance would be very high. At hardness values typical of most Florida lakes, streams, and canals, surface water limits for cadmium and lead are both much lower than groundwater limits.

Unfortunately, the Leachability test (i.e., TCLP analyses) for organic pollutants which was conducted in this study did not cover any of the PAH's listed in Clean Soil Target Levels. However, values reported for the four VOC's that were examined via TCLP analysis did not present a problem from a groundwater protection standpoint. The mean concentration values recorded in Appendix L for both the volatile organics and semi-volatile PAH compounds do not exceed the groundwater protection thresholds for clean soil as listed in column four Table 3a of this report. However, the maximum values for several of the PAH's listed (i.e., benzo (a) anthracene and benzo (b) fluoranthene) did exceed these limits.

Relative to Soil Cleanup Target Levels, 10 of the 16 PAHs listed would be in excess of surface water protection criteria also shown on the referenced table. Even mean values shown in Appendix L for nearly all of these parameters exceed the surface water protection criteria listed in column six of Table 3a. Based on these results, pollutant concentrations, particularly those associated with PAH's and chlorinated pesticides such as chlordane, dieldrin and toxaphene, could lead to localized exceedances of surface water standards. Such occurrences would be enhanced by circumstances associated with greater soil erosion and more effective sediment delivery than normal. Disposal or temporary storage locations along the banks of lakes or other water bodies and swales should be avoided. Likewise, steep highly erosive land should not be considered without proper site controls.

Background Vs Sediment Quality Assessment Guidelines:

Background exceedances above SQAG's low level effects screening criteria (i.e., threshold effects level) occurred at two of the fifteen sites, both in the Hialeah vicinity. In this area these soils contain detectable levels of a wide array of pollutants including the metals Cd., Cr., Cu., and Pb. and five PAH's. These pollutants are normally automobile related, and have been identified in higher concentrations in close proximity to roadway surfaces. Since the City of Hialeah is located in the center of one of the most urbanized areas of Florida it is not surprising that background conditions show increased pollutants over the other sites examined. The results are probably related to an increased level of atmospheric deposition near the roadway where these samples were collected.

Stormwater Sediment Compared with Sediment Quality Assessment Guidelines (SQAGs):

Similar to results from our previous study, the Florida Sediment Quality Assessment Guidelines (SQAG's) represent the most frequently exceeded screening criteria. 196 records exceeded Probable Effects Level (PEL) screening criteria and (349) exceeded the lower level threshold (TEL) criteria. The heavy metal lead was the most frequently detected inorganic pollutant in excess of SQAG screening level criteria. This element exceed threshold levels at 39 % of the test sites. As a group the metals were not as problematic as they were in comparison to the Soil Cleanup Target Level criteria. All seven of the inorganic pollutants examined were found to exceed these criteria on occasion. However, in a reversal of the results of the soil cleanup goal comparison, arsenic exceeded these guidelines least often, at only 3 of 87 sites. Lead, copper, zinc, and cadmium were more problematic in 22% to 11% of the samples.

Contamination associated with the organic priority pollutants was the most important aspect of the project relative to this screening criteria. A total of 16 toxic organic compounds were identified at levels in excess of threshold criteria at 10% or more of the test sites. These were arranged as follows:

Pollutant	No. Exceeding TEL	% Exceeding TEL
PAHs (9)		
Pyrene	53	61
Fluoranthene	48	55
Chrysene	44	51
Benzo(a)pyrene	43	49
Benzo(a)anthracene	42	48
Phenanthrene	40	46
Anthracene	10	12
"Dibenzo(a,h)anthracene"	9	10
Fluorene	9	10
Pesticides (5)		
Chlordane	71	82
DDE-p,p'	47	54
DDD-p,p'	29	33
DDT-p,p'	20	23
Dieldrin	11	13
Other (2)		
Bis(2-ethylhexyl)phthalate	13	15
PCB-1260	16	18

A pollutants capacity to cause carcinogenic human health effects results in tighter limits relative to soil cleanup criteria. However, compounds that exhibit low level acutely toxic effects are the primary focus of the SQAGs. Consequently, the more toxic lighter molecular weight PAHs and Pesticides are most problematic. Pyrene, fluoranthene, and chrysene top the list relative to petroleum hydrocarbons. Chlordane along with DDT and derivatives head the list of problem pesticides.

RCRA Solid Waste (TCLP) Toxicity Screening Criteria:

The historical data examined during our 1995 study failed to show any values that would be considered *Hazardous* relative to the RCRA Solid Waste screening criteria. However, as noted earlier in this report, a substantial data base was not available to judge stormwater sediment relative to many of the parameters listed. Several studies had examined the inorganic metals TCLP extract concentration of stormwater sediment. But, there was a noticeable paucity of information relative to leachability and the 33 organic pollutants listed as hazardous for toxicity. In contrast to the inorganic constituents, not even the total recoverable concentration characteristics have been closely examined relative to organic priority pollutants in stormwater residuals. Consequently, it was one of the primary goals of this study to add to the body of information available for evaluation.

Appendix G shows the results of the TCLP/RCRA evaluation. Only three (3) of the thirty six (36) organic pollutants tested were detected at levels in excess of MDL's. These consisted of two volatile compounds (Toluene and Total Xylenes) and one semi-volatile (m,p-Cresols). Only one of the three compounds detected (m-p-Creosols) is specified in the RCRA limits. None of the samples contained organics in excess of Hazardous Waste criteria.

All of the four inorganic TCLP metals (As, Cd, Cr, and Pb) that were tested for in this study were detected at levels in excess of minimum detection limits at multiple sites. Cadmium was the least frequently detected heavy metal. Of the 44 sites evaluated, only 4 sites recorded detectable levels of Cd in TCLP extract, all below .05mg/l. Lead was the most frequently detected inorganic TCLP constituent (80%) followed by Chromium (32%) and Arsenic (11%). It should be noted that these percentages are not equivalent to those shown in Table 7. Values for Cr. and As. are higher because two test methods were used for analysis and this resulted in added numbers of sites over either of the individual test results shown on the table...

By far the most problematic pollutant identified was lead. It was found at low to moderate levels in a majority of the sediments tested. At an industrial site in Dade County, three related samples show extremely high levels of total lead in the sediment tested. TCLP test were requested and run on one of these samples. The results show levels of approximately 10 mg/l Pb in the extract solution. This level is double the hazardous waste limit for this constituent. Given a level of total recoverable lead in the sample of 838 mg/Kg, a TCLP extract concentration of 10 mg/l is roughly equivalent to a 25% leachability factor. This level is equivalent to values shown in previous studies conducted by Yousef 1990.

A total of twenty four (24) out of the forty (40) RCRA parameters listed in Table 1 were evaluated in this project. No other samples tested exceeded the RCRA screening criteria. Several others contained total recoverable lead values potentially great enough to result in exceedances, however.

Following the conclusion of the original project Dade County scheduled six of these sites for follow-up sampling and analysis by the DEP Central Lab. All six samples were tested for TCLP Toxicity Characteristics and total recoverable metals concentration to confirm the previous results. Sample collection was completed on September 17 and 18, 1997. Results for both total recoverable lead as well as TCLP lead extract concentration were much improved as shown on Figure 2 and 3 below.

Figure 2 - Comparison in Sediment Lead Concentration at Dade County Sites

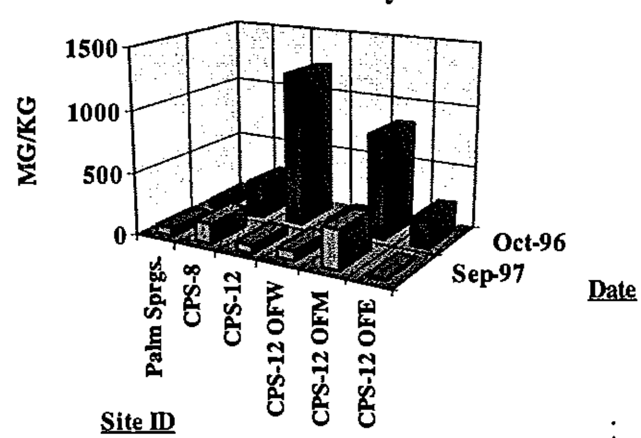
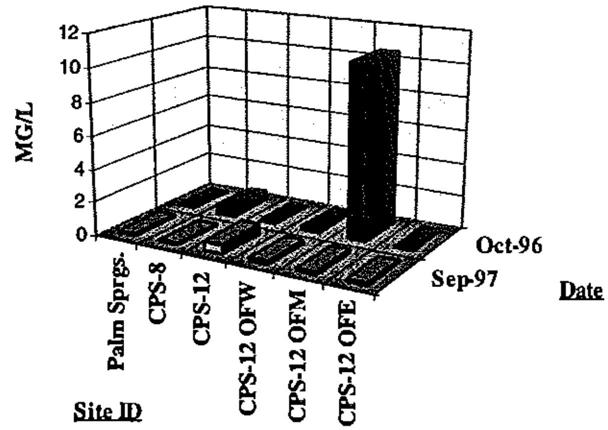


Figure 3 - Comparison in Sediment TCLP Lead Concentration at Dade County Sites



The improvement in the September 1997 samples could be due to variability associated with the heterogeneous nature of the stormwater sediment. However in the interval between the two collection efforts the City of Hialeah installed an exfiltration system designed to prevent the direct discharge of stormwater from the CPS 12 outfall. Hopefully the improvement is the result of these changes.

Stormwater Residuals Characteristics by Maintenance Category (BMP Type) and Landuse Classification:

Similar to the 1995 study we also examined the data relative to it's origin in terms of BMP category and associated Landuse. The data above minimum detection limits has been summarized and is contained in Appendix L. It should be stressed that these statistics do not include data for sample results reported as below detection limits. Consequently, the actual average concentration associated with many parameters would be substantially less than shown in the appendix.

Similar to previous studies wet detention ponds and in-place sediments in canals and lakes represented the facilities (BMP's) and sediment maintenance categories of most interest to participants. The number of pollutants identified and the average concentration is similar between most BMP and use classes. The exception would be a few landuse and maintenance categories associated with systems that were sampled by only a few participants. Examples include sand filters, dry detention ponds and vactor truck waste; as well as, high density residential landuse. These systems show unexpected very low levels of pollutants as well as numbers of constituents at detectable concentration in stormwater sediment. The low pollution potential of these facilities is likely the result of the extreme difference in sample number compared to the other BMP categories.

The most frequently identified inorganic pollutants relative to the twelve BMP / Maintenance categories and the eight landuse classes are chromium, lead, and zinc. These constituents were identified as being present in detectable levels in virtually all sediment samples tested. As noted previously, lead and arsenic were the most problematic in that levels of these two constituents at a few locations were sufficient to exceed RCRA (Pb) and Wastewater Residuals Thresholds (Pb and As).

Relative to organic contaminants TRPH and Chlordane values were of major concern showing up in over 80% of the sites tested. As a group the organic priority pollutants examined in this study were more problematic than the inorganic contaminants. This represents a reversal from previous study results.

Ranking by Landuse Class and BMP Type:

Appendix M contains a summary of sampling results by BMP type and Landuse Class as compared to the screening level criteria discussed in section two. The tables presented in Appendix M list the array of pollutants and number of sites which exceeded the various screening level criteria used in this study. A ranking of the twelve BMP and eight Landuse categories is also included. The ranking procedure used, and shown following each summary table, is based on the decimal percentage score of the sum of total exceedances associated with each category compared to the total number of exceedances possible. The maximum number possible is the number of sites in each BMP or Land class recorded in parentheses in the upper left hand column of each table times the total number of parameters evaluated (i.e., 94) in association with the five screening criteria. The five criteria evaluated were as follows:

1. Soil Cleanup Target Levels, Direct Exposure Limits for Residential Use (SCTL R) - 25 of 30 parameters.
2. Soil Cleanup Target Levels, Leachability for Groundwater Protection (CS/LEACH) - 9 of 30 parameters.
3. Sediment Quality Assessment Guidelines Threshold Effects Level (SQAG TEL) - 30 of 34 parameters.
4. Limits for Domestic Wastewater Residuals Used for Land Reclamation Without Management Constraints (WWR WO) - 6 of 9 parameters.
5. Resource Conservation and Recovery Act Hazardous Waste Toxicity Limits (RCRA) - 24 of 40 parameters.

The ranking procedure provides a comparison between BMP's and Landuse classes across parameters normalized for differences in the number of sites evaluated. The decimal score multiplied by 100 is equivalent to the mean percentage exceedance rate associated with each practice and land class. As may be seen, based on this procedure the mean rate of exceedance would vary from a high of 18 percent for in place catch basins and stormsewer sediments to a minimum of 0 percent associated with sand filter spent media. Relative to the eight land use categories examined the high rate was slightly lower. Institutional lands ranked first in this respect with an 15 percent rate while the low category was a 1 percent score associated with high density residential.

Rankings for several Land Use categories were higher than would have been expected based on the theory that sediment quality follows the same hierarchy as runoff loading rates. Most notable in this respect was institutional land which ranked first ahead of commercial, industrial, and highway facilities. The single golf course related sampling site also ranked surprisingly higher, scoring in the middle of the categories examined.

Several BMP's on the other hand show the opposite anomaly. That is, facilities such as sand filters which are generally regarded among the most proficient techniques for the removal of metals, PAH's, pesticides and other organic compounds failed to show anything more than minor accumulations of these constituents. Both BMP's and Landuse categories that were sampled infrequently (i.e., 4 sites or less) tended to rank either much higher or much lower than would be expected based on historical treatment efficiency and loading rate characterization studies. Much more data is needed in order to make comparisons and effectively characterize sediment quality associated with these stormwater residuals.

The following figures illustrate the rank and average percentage score relative to the maximum potential exceedance level possible by landuse and BMP type as recorded in Appendix- M.

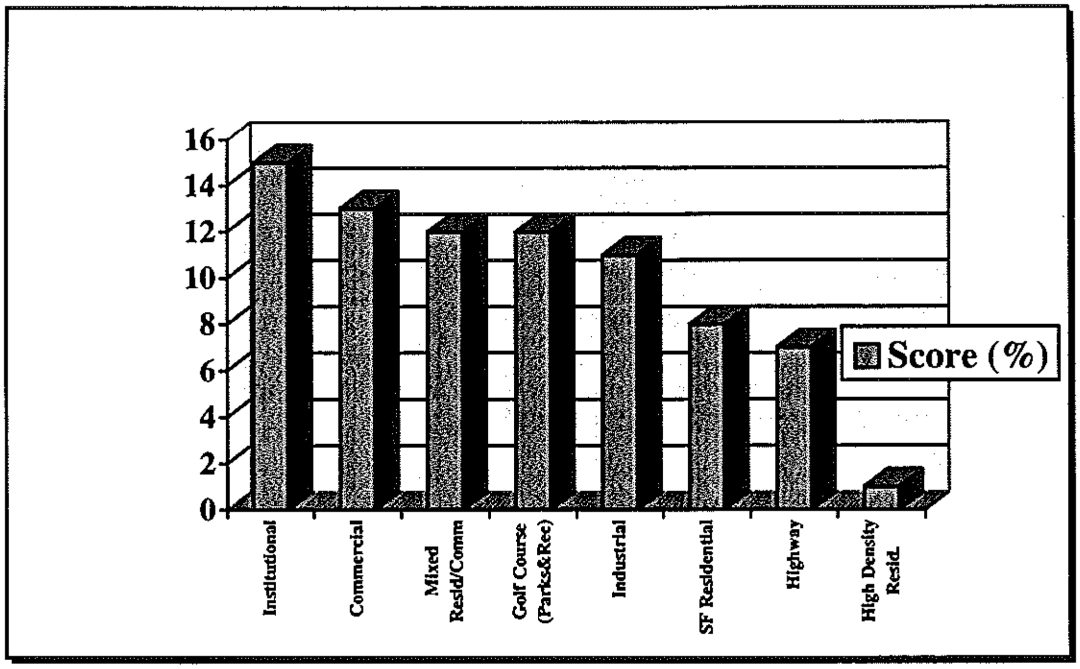


Figure 4 - Land Use Ranking

The reader is cautioned that the relative potential for problems associated with sediment disposal **would not** necessarily follow the hierarchy based on this ranking procedure. Added weight was not given to exceedances associated with RCRA limits. Material contaminated to these levels, albeit limited in scope, would certainly be considerably more problematic and deserving of precaution than those which exceed numerous clean soil target levels or sediment quality assessment guidelines.

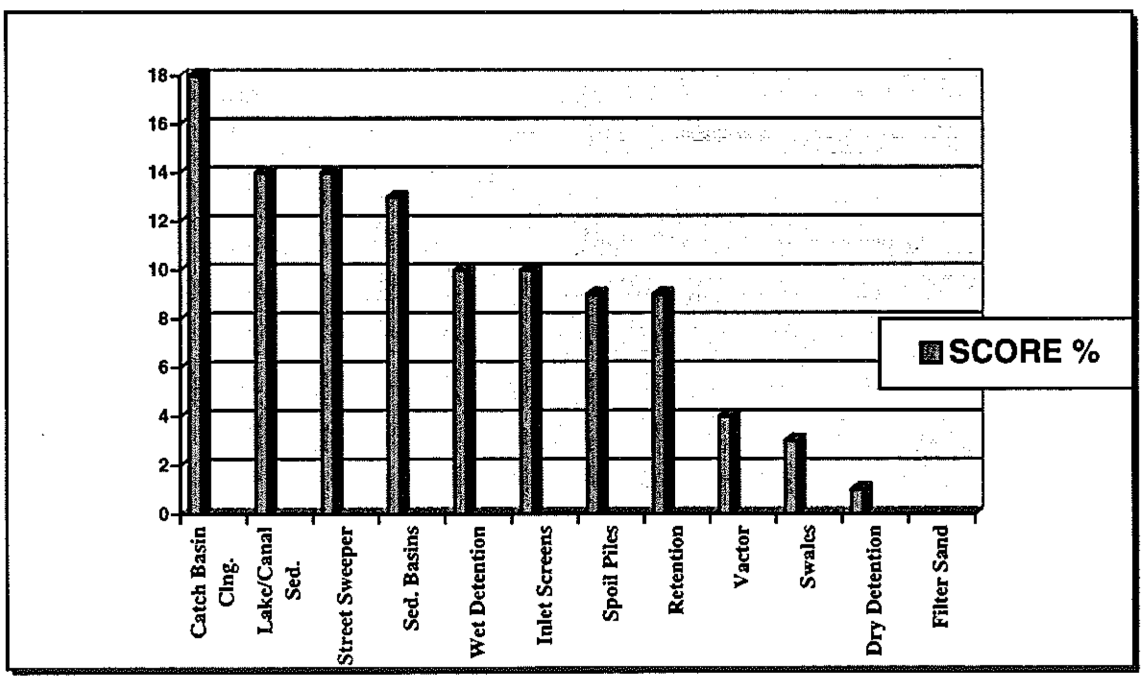


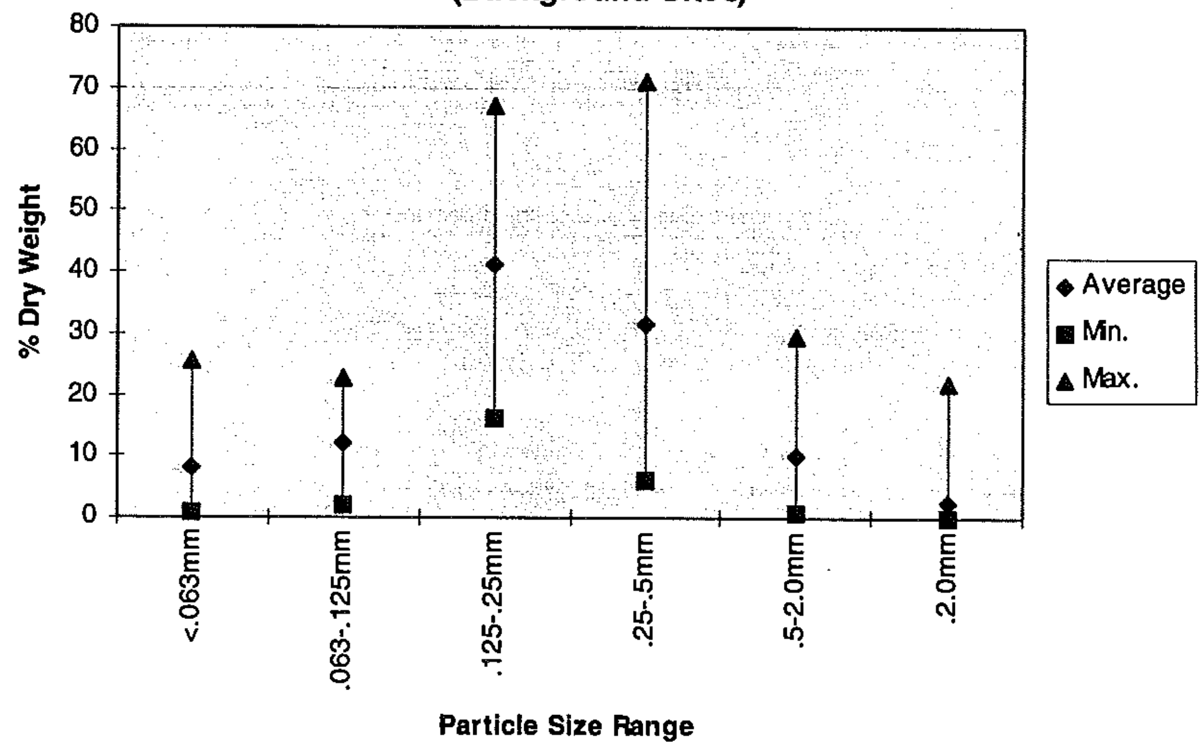
Figure 5 - Stormwater BMP Ranking

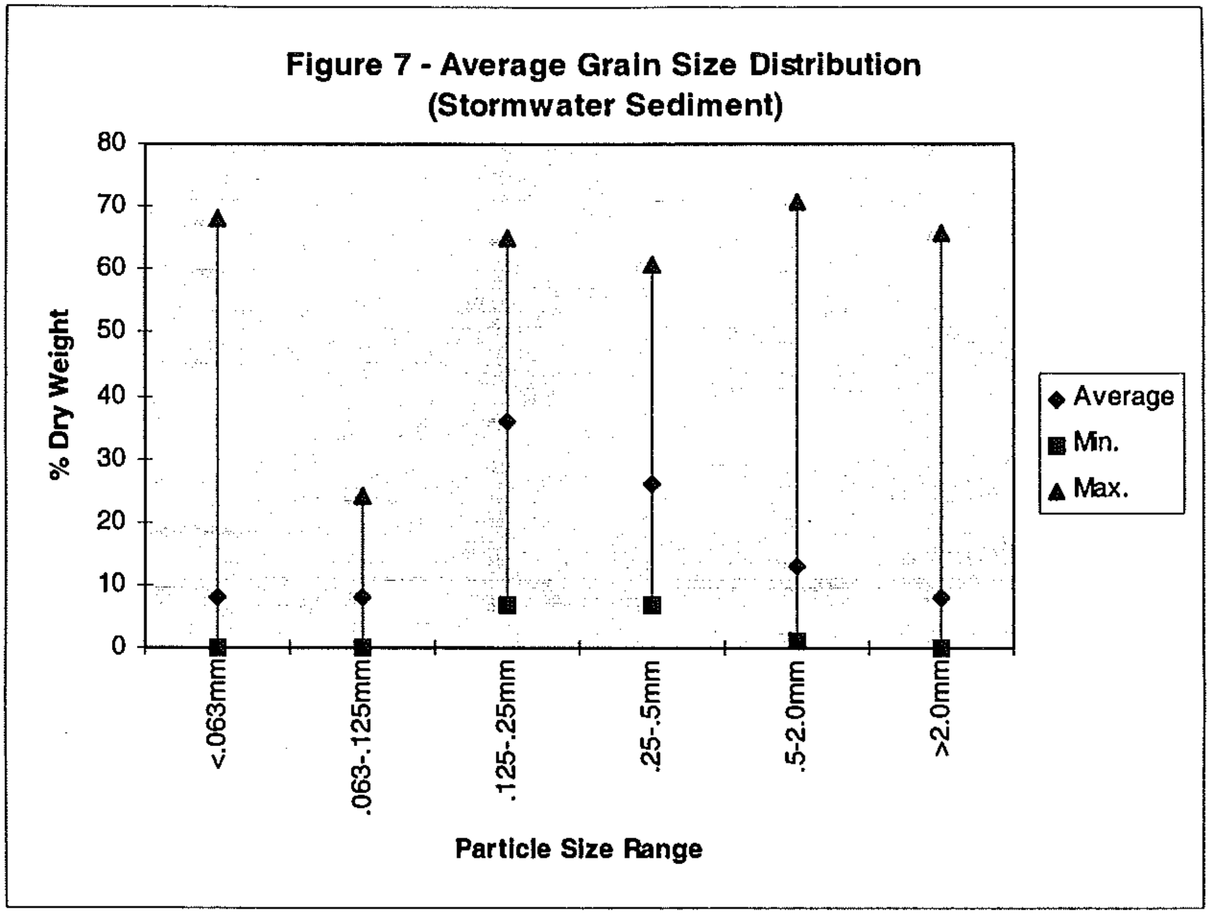
Results of Grain Size Distribution and Total Organic Carbon Analyses:

Results of particle size analyses may be found in Appendix J. Figures 6 and 7 respectively illustrate the results of sieve test which were done to help characterize the physical aspects of area soils vs stormwater sediment. As noted previously, the appearance of the majority of stormwater residuals examined could be best described as dark colored muck having a soupy texture and strong odor.. The composition of samples appeared to be mixtures of street debris, large and small particulate soil matter and oily particulates presumably from asphalt and automobile wastes.

Grain size and TOC are routinely evaluated in sediment studies primarily because these parameters effect the benthic community structure and bioavailability / toxicity associated with sediment bound contaminants. Correlation between leachability and the occurrence of fine particulates (i.e., % clay sized particles) and organic matter content was not possible in this study due to time constraints and minimum limits associated with sieve analysis for grain size distribution. However, in general a higher degree of contamination would be expected in association with dark color and higher TOC content and percent fine particulates. Conversely, the retention capacity of sorbed contaminants to resist leaching should be greater in association with the % clay minerals present in the sediment.

Figure 6 - Average Grain Size Distribution (Background Sites)





As may be seen from Figures 6 and 7 above, stormwater sediment tends to mimic area soils. Both background soils and stormwater residuals are primarily fine sand. Stormwater sediment however is much more variable in character. As noted earlier in this report, the heterogeneous nature of these residuals made chemical analysis difficult from a quality assurance perspective.

Organic content of both stormwater residuals and area soils, as represented by analysis of total organic carbon (TOC), is presented in Appendix K. As may be seen from the table TOC values associated with stormwater sediment samples varied from 4,400 to 91,000 mg/Kg (ppm). The average value was approximately 30,000 ppm or 3% organic content.

It is interesting to note that the single sample which exceeded RCRA criteria had an associated TOC value of 3%. The corresponding level of fine particles (< .63mm) was low at 1%. The rate of lead release was approximately 25%. Conversely, at a second site in this area (CPS 8) where significant Pb was also identified, the release rate was only 4% with an associated fine particulate value of 4% which is much closer to the average shown in Figure 7 above. The corresponding TOC was lower than average at 2%. Percent fines rather than TOC seems to exert a more direct influence on release of metals. While it was not possible to test this relationship in this study, the results mentioned above would indicate that further evaluation is warranted. The development of variable leachability thresholds for determining when there is a potential for exceedances of groundwater protection criteria and RCRA limits may prove practical in the future with additional investigation.

SECTION 7

Conclusions and Recommendations

Existing data on the characteristics of stormwater sediments deposited in stormwater systems throughout Florida is sparse and not easily correlated due to differences in sampling methods used by the various studies. The primary goal of this study was to collect more sediment and debris samples from stormwater BMPs serving various land uses from all parts of the state to increase our database and get a better understanding of the need to test stormwater sediments before disposal.

A major hypothesis based on previous research results, which we hoped to be able to evaluate, was that facilities serving more intense uses are likely to be more contaminated than low intensity land use facilities. It was hoped that landuse screening would prove to be a useful tool to derive variable monitoring and potential disposal options. In this manner, the testing frequency and handling requirements for the largest part of these materials could be relaxed without sacrificing environmental and direct exposure protection concerns.

The results of this effort has led to several interesting and to some extent unexpected findings. Monitoring results do not show any signs of significant differences by landuse category. Large differences in monitoring frequency however, made comparisons between landuse categories and BMP's difficult. Infrequently sampled facilities produced highly variable results and caused rankings to be extreme in both directions.

The question as to whether these materials warrant extreme concern is more close to being answered. In most cases these residuals are not "hazardous waste". However, the material is contaminated well beyond levels associated with the raw stormwater itself with a wide array inorganic and organic pollutants. Disposal without proper precautions (i.e., wise site selection, runoff control, and application limits) would not be recommended regardless of the source of the residue at this time. Levels of several metals, PAH's, and chlorinated pesticides such as chlordane routinely exceed criteria published in DEP rules pertinent to soil cleanup of petroleum contaminated sites and sediment quality assessment guidelines. These screening criteria currently constitute the best available information for evaluating potential environmental risk associated with the disposal of sediment at locations other than landfills.

Based on results of the previous literature survey conducted by the Department and this project the following recommendations are offer relative to the disposal of stormwater generated residuals:

1. Sediment samples from stormwater BMPs should be collected with coring devices allowing the determination of contaminant concentrations in different layers of the sediments. This allows a better determination of the depth of sediments which need to be removed from a BMP. More importantly, by compositing these sediment samples, a more accurate characterization of overall sediment quality is obtained since sediment removal operations will inherently lead to the mixing of different sediment layers.

2. If the objective is to evaluate the potential acute and chronic effects of sediment contaminants on the biota living in stormwater facilities or stormwater impacted systems, then surface sediments should be collected and characterized. This sampling approach will also determine the "worst case" conditions for sediments that are to be removed from stormwater systems. However, when used to characterize sediments to determine appropriate disposal options, the resulting elevated contaminant concentrations can lead to unfounded concerns associated with disposal.

3. Stormwater sediments should be disposed of by taking them to a permitted lined landfill and using them for landfill cover. In general, such disposal should not require characterization of the sediments except perhaps on an infrequent basis. Sediment from BMPs serving industrial/business areas, fuel transfer facilities and equipment maintenance yards where poor house keeping and evidence of excessive contamination is obvious should be screened for toxicity relative to RCRA criteria. The use of holding areas where the latter are kept separate from other stormwater residuals would allow testing levels to be minimal and provide better protection against inadvertent unlawful disposal of highly contaminated sediment.

4. If it is preferable to dispose of stormwater sediments in an unlined landfill, a borrow pit or via land application, then the sediments need to be tested to assure that they meet the Clean Soil Criteria specified in Chapter 62-770, FAC (Table 3). Based on our current data base, concentrations of arsenic, lead and several PAH's can be expected to exceed the Clean Soil Criteria.

5. Yousef et.al. (1991) recommended that sediments accumulating in wet detention ponds be removed every 25 years based on sediment accumulation rates. However, data collected by Fernandez and Hutchinson (1992) indicates that both the types of contaminants and their concentration in a wet detention system are likely to increase with age. More data are needed to develop guidelines on the frequency of removing sediments from wet detention systems, especially when considering the land use draining to the system.

6. We need to collect more samples from street sweepers and from different types of BMPs serving various land uses from all parts of the state to increase our data base and get a better understanding of the need to test stormwater sediments before disposal. While much maligned in most studies of BMP treatment efficiency, the performance of catch basins and street sweeping based on the strength of the residuals examined during this study appears to be better than we would have projected. These BMP's ranked first and second respectively in terms of the percent exceedance rate of various screening criteria used in this evaluation. Their use as source controls and pretreatment devices would be highly recommended based on these results. However, it should be stressed that these results also point to their primary failing. The effectiveness of these controls, or the lack thereof, is dependent on frequency of cleaning. Conventional practice has resulted in poor performance as measured in the past.

7. There currently are no state rules and programs that pertain directly to the disposal of stormwater sediments. Often times however rules developed for the control of other problems are indirectly applied when owners of stormwater treatment facilities elect to elicit approval to dispose of these materials in a more uncontrolled manner than at a lined landfill. Clean S oil Target Levels and Sediment Quality Assessment Guidelines are the two most commonly applied screening criteria applied by the Department in these instances. The Department, in conjunction with the water management districts, local governments, and the public, needs to determine which criteria to apply to stormwater sediments when land application and use as clean fill are the preferred use for these materials.

REFERENCES

Camp, Dresser and McKee, Inc. 1993. "Letter Report to FDEP, Lake Tuscawilla Demonstration Project, Contract WM473" prepared for Florida Department of Environmental Protection, Stormwater and NPS Management Section, Tallahassee, Florida.

Carr, D. W. and B. T. Rushton. 1995. "Integrating a Native Herbaceous Wetland into Stormwater Management", Final report, Contract WM 434, submitted to FDEP SW/NPS Management Section, by the Stormwater Research Program, Southwest Florida Water Management District, Brooksville, Florida.

Fernandez, M. and C. B. Hutchinson. 1993. "Hydrogeology and Chemical Quality of Water and Bottom Sediment at Three Stormwater Detention Ponds, Pinellas County, Florida." WRI Report 92-4139, USGS Tallahassee, Florida.

Frydenborg, R. B., K. M. Lurding and L. T. Ross. 1990. "Biological Water Quality Characteristics of the Crescent Lake Basin", Florida Department of Environmental Regulation, Biology Section.

Harper, H. H., B. M. Fries, D. M. Baker and M. P. Wanielista 1986. "Stormwater Treatment by Natural Systems." Final Report STAR Project 84-026 submitted to FDEP, SW/NPS Management Section by the University of Central Florida Engineering School.

Harper, H. H. 1988. "Effects of Stormwater Management Systems on Groundwater Quality". Final Report, Contract WM 190, submitted to FDEP SW/NPS Management Section by Environmental Research & Design Inc., Orlando, Florida.

Harper, H. H. 1993. "Evaluation of Sediment Loadings From the Dolphin Cove Outfall, Hypoluxo, Florida." Environmental Research & Design, Inc., Orlando, Florida.

Harper, H. H. and J. L. Herr. 1993. "Treatment Efficiencies of Detention with Filtration Systems." Final report, Project 90B103, submitted to SJRWMD by Environmental Research & Design, Inc., Orlando, Florida.

Harper, H. H. 1994. "Stormwater Loading Rate Parameters for Central and South Florida." Environmental Research & Design, Inc., Orlando, Florida.

Jones, J., S. Anderson, J. Fognani, and F. R. McGregor. 1995. "BMPs and Hazardous Sediment." Public Works, May, 1995, pp.51-54.

Leersnyder, H. 1993. "The Performance of Wet Detention Ponds for the Removal of Urban Stormwater Contaminants in the Auckland (NZ) Region." MS Thesis, Environmental Sciences and Geography, University of Auckland.

Livingston, E. H. and J. H. Cox. 1995. "Stormwater Sediments: Hazardous Waste or Dirty Dirt?" Proceedings of the 4th Biennial Stormwater Research Conference. Published by Southwest Florida Water Management District, Brooksville, Florida.

Livingston, R. J. and S. E. McGlynn 1994. "Polynuclear Aromatic Hydrocarbons in the Lakes of Leon County", Center for Aquatic Research and Resource Management, Florida State University, Tallahassee, Florida.

MacDonald, D. D. 1994. "Development and Evaluation of Sediment Quality Assessment Guidelines." Final report submitted to the FDEP Sediment Research Group, Tallahassee, Florida, by MacDonald Environmental Sciences, Ltd., Ladysmith, British Columbia.

Rushton, B. T. and C. W. Dye 1993. "An In-depth Analysis of a Wet Detention Stormwater System." Final report, Contract WM435, submitted to FDEP, SW/NPS Management Section by the Stormwater Research Program, Southwest Florida Water Management District, Brooksville, Florida.

Martin, E. H. and J. L. Smoot. 1986. "Constituent - Load Changes in Urban Stormwater Runoff Routed Through A Detention Pond - Wetlands System in Central Florida." USGS, WRI Report 85-4310, Tallahassee, Florida..

Schiffer, D. M. 1989. "Effects of Three Highway - Runoff Detention Methods on Water Quality of the Surficial Aquifer System in Central Florida." USGS, WRI Report 88-4170, Tallahassee, Florida.

Tonner-Navarro L. and S. M. Roberts. 1997. Technical Report: Development of Soil Cleanup Target Levels (SCTLs) for Chapter 62-770, FAC Center for Environmental and Human Toxicology, University of Florida, Gainesville. Prepared for the Division of Waste Management, Florida Department of Environmental Protection.

U. S. Environmental Protection Agency. 1994. "Assessment and Remediation of Contaminated Sediments (ARCS) Program Guidance Document". Great Lakes National Program Office, Chicago, Illinois. EPA 905-B94-002.

Wanielista, M. P., R. N. Gennaro and J. H. Bell. 1978. "Shallow Water Roadside Ditches for Stormwater Purification". University of Central Florida, Orlando, Florida.

Yousef, Y. A., M. P. Wanielista, H. H. Harper and T. H. Jacobsen. 1986. "Effectiveness of Retention/Detection Ponds for Control of Contaminants in Highway Runoff". University of Central Florida, Department of Civil and Environmental Engineering. Prepared for Florida Department of Transportation, Bureau of Environment and Environmental Research. Document No. FL-ER-34-86.

Yousef, Y. A., M. P. Wanielista, J. D. Dietz, L. Y. Lin, and M. Brabham. 1990. "Efficiency Optimization of Wet Detention Ponds for Urban Stormwater Management". Final report, Contract WM159, submitted to FDEP, SW/NPS Management Section, Tallahassee, Florida, by the University of Central Florida, Department of Civil and Environmental Engineering, Orlando, Florida.

Yousef, Y. A., L. Y. Lin, J. V. Sloat and K. Y. Kaye. 1991. "Maintenance Guidelines for Accumulated Sediments in Retention/Detention Ponds Receiving Highway Runoff". Final report submitted by the University of Central Florida, Department of Civil and Environmental Engineering to the Florida Department of Transportation, Bureau of Environment and Environmental Research. Document No. FL-ER-47-91.