California State University, Sacramento (CSUS)

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Evaluating Drain Inlet Cleaning as a Storm Water Best Management Practice

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Authors:

E. E. Dammel, Caltrans/CSUS Storm Water Program
B. J. Berger, Caltrans Environmental Program
L.C. Regenmorter, , Camp Dresser and McKee, Inc.
G. S. Lippner, Caltrans/CSUS Storm Water Program

Storm Water Program
CSUS Office of Water Programs
7801 Folsom Boulevard, Suite 102, Sacramento, CA 95826

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EVALUATING DRAIN INLET CLEANING AS A STORM WATER BEST MANAGEMENT PRACTICE

E.E. Dammel, Ph.D.[*], B.J. Berger, P.E.[**], L.C. Regenmorter[***], and, G.S. Lippner, P.E. [****]

[*] *Department of Civil Engineering, California State University, 6000 J Street, Sacramento, CA, 95819-6029*

[**] *California Department of Transportation, Div. of Environmental Analysis, 1120 N Street, MS-27, Sacramento, CA 95814*

[***] *Camp Dresser and McKee Inc., 2151 River Plaza Drive, Suite 200, Sacramento, CA 95833*

[****] *CDS Technologies, Inc., 3028 Panama Ave., Carmichael, CA, 95608*

ABSTRACT

There is concern that flows in the drainage systems used by the California Department of Transportation (Caltrans) may contain pollutants that could adversely affect the beneficial uses of receiving waters. During dry weather, sediments, vegetation, and litter accumulate in the drain inlet vaults. Some have advocated annually removing this material as a best management practice to improve the quality of Caltrans run-off before it enters receiving waters. In response to these concerns, Caltrans implemented an annual drain inlet inspection and cleaning program in selected urban areas. This program includes the inspection and cleaning of more than 21,000 drain inlets in Los Angeles County each fall. To evaluate if this practice improves effluent water quality, Caltrans is conducting the Drain Inlet Cleaning Efficacy (DICE) Study. The objective of the DICE Study is to evaluate whether cleaning drain inlets is a management practice that improves the water quality of highway storm water run-off. The water quality of run-off has been monitored and analyzed to determine if there is a difference in water quality between storm water discharged from a drainage system with cleaned drain inlets versus discharges from uncleaned systems. Water quality constituents analyzed include hardness, pH, nutrients, metals, and other constituents previously detected in highway run-off. This paper discusses the study methodology, protocols, and preliminary results.

KEYWORDS

Best Management Practices; Drain Inlet Cleaning; Storm Water

INTRODUCTION

The water quality of discharges from California Department of Transportation (Caltrans) Facilities is regulated by the Federal Clean Water Act (CWA) and the California Porter-Cologne Water Quality Act (CPCWA). Central to water quality regulations is the requirement for the consideration of implementation of a collection of best management practices (BMPs). These BMPs range from good housekeeping practices such as proper material storage to structural treatment controls such as detention basins. Water quality improvement from the implementation of a collection of BMPs comes from either preventing pollutants from becoming part of the flow stream or by removing pollutants already part of the flow stream.

A BMP employed by Caltrans in the Los Angeles and San Diego areas as a result of CWA citizen lawsuits is the removal of material that accumulates during dry weather in the inlet vaults of the storm drain system prior to the beginning of the rainy season. As a BMP, cleaning drain inlet removes the accumulated materials before they can become part of the storm water flow stream and exert a significant impact on beneficial uses of the receiving waters. The purpose of this paper is to describe procedures used in the Drain Inlet Cleaning Efficacy (DICE) Study, which has been in operation since November 1996 to the present. The study is designed to evaluate the impact that cleaning drain inlets has on the water quality of the discharge emanating from the associated system outfall. As annual cleaning of drain inlets presents a significant expense to Caltrans, particularly in high traffic urban areas, it is hoped that the DICE Study will demonstrate if cleaning drain inlet boxes is an effective allocation of Caltrans water quality resources.

BACKGROUND

Drainage systems for the conventional freeways that are found in large California urban areas are generally designed to handle the 25-year event to address an acceptable level of flood protection. In Los Angeles County, where drain inlet cleaning as a storm water BMP is implemented annually, drainage is often accomplished by collecting the surface runoff in through a drain inlet grate. Drain inlet spacing is dictated by the flooded width along the shoulder or parking lane of the highway as calculated using the aforementioned 25-year storm. When the flooded width begins to approach the traveled lane, a drain inlet vault is placed to intercept the flow.

Drain inlet vaults, designed to be self-cleaning, are placed with the floor of the vault having the same elevation of the outlet pipe invert. The outlet pipe is often connected to a larger lateral pipe that conveys runoff a short distance where it discharges to another drainage system out of the Caltrans Right of Way. Caltrans drainage systems are typically small with catchment areas ranging from one-half to upwards of 25 acres. Each outfall is associated with an average of three to four drain inlets and their associated vaults. (Caltrans, 2000)

Drain Inlet Cleaning Procedures

The Los Angeles Drain Inlet Cleaning Program has been conducted annually for six years, with program implementation changing from year to year. Cleaning procedure adjustments are driven by an iterative approach based on field data collected from the previous years' experiences.

In the Los Angeles area, the Cleaning Program began in the fall of 1994 with the cleaning of all Caltrans inlets in the Los Angeles area. Initial cleaning data indicated that the amount of material removed varied greatly from inlet-to-inlet. Subsequent to 1994, the Program inspects all drain inlets just prior to the rainy season, followed by data analysis and cleaning of only those drain inlets that contain the greatest amount of material.

Caltrans spends approximately 3.5 million dollars each year to inspect approximately 20,000 drain inlets and subsequently clean 7,000 to 8,000 inlets. The high cost is dictated by the need for lane closings due to the high traffic volumes experienced in the Los Angeles area.

Materials found in drain inlet cleaning

Material found in drain inlet vaults is comprised of litter, vegetation, and sediment. Average percentages for the three components obtained by monitoring 72 inlets during a one year period, were identified in the Solids Transport and Deposition Study (STDS) (Camp Dresser and McKee, 1999). Typical values are listed in Table 1.

Table 1: Composition of Material Found in Los Angeles Area Freeway Drain Inlet Vaults.

Material Type	Percent Composition Range by Volume
Litter	4 – 30
Vegetation	18 – 80
Sediment	5 – 71

The STDS data identified a solids accumulation rate of 0.37 to 0.74 L per day per monitored inlet. Further, this study determined that material is transported into the drainage system by both wet and dry processes.

Drain Inlet Contents as Pollutants

Drain inlet material is a concern as litter, vegetation, and sediment can degrade water quality. The sources of each drain inlet material macro-component along with the impact on beneficial uses are listed in Table 2. Also listed are the applicable water quality objectives in each case.

Table 2: Sources of Drain Inlet Material and Pollutant Impact.

Drain Inlet Material	Material Source	Affected Beneficial Use	Applicable Water Quality Objectives
Litter	Anthropogenic	Water Contact Rec., Non-Contact Water Rec., Wildlife Habitat, Navigation	Settleable Material, Suspended Material
Vegetation	Decayed Plant Material	Warm Freshwater Hab., Warm and Cold Spawning, Migration of Aquatic Organisms, Water Contact Recreation, Non-Contact Water Recreation, Wildlife Habitat	Biostimulatory Substance, Settleable Material, Suspended Material
Sediment	Soil Erosion, Tires & Brake Wear, Oil & Grease combustion, paint, electrical, corrosion of building material, industrial emissions	Navigation, Hydropower Generation, Warm Freshwater Habitat, Warm and Cold Spawning, Migration of Aquatic Organisms, Non-Contact Water Recreation	Chemical Constituents (including Pesticides & PAHs), Suspended Solids

METHODOLOGY AND PROTOCOLS

The overall objective of the DICE Study monitoring program (1996-present) was to collect data that could be used to evaluate the potential effectiveness of drain inlet cleaning as a management practice for improving the quality of highway storm water runoff being directed through drain inlets. The study approach involved selecting and using eight catchment areas in the Los Angeles area, which were then divided into two groups. Half of the catchment areas were used as "test" catchment areas and the other half were used as "control" catchment areas. All drain inlets in the "test" catchment group were cleaned three times during the wet season whereas no drain inlet cleaning was performed in the "control" catchment group. In subsequent years, the groups of "control" and "test" catchment areas were switched each season, and the same level of cleaning was performed. Catchment effluent was sampled from the outfall.

Rainfall, flow rate and water quality were monitored at each station during a series of storm events that occurred each season. Water quality samples were collected and analyzed for a suite of constituents. Monitoring was performed so the analytical results were representative of event mean concentrations (EMCs). Statistical analyses were performed on the water quality data to determine if differences existed between data collected from catchment areas that were cleaned and data collected from catchment areas that were not cleaned. (Camp Dresser and McKee, 1998)

Constituents

The chemical parameters selected for the DICE Study were those commonly found in previous highway runoff studies (Caltrans, 2000). The list of chemical parameters applied to the DICE study is presented in Table 3.

Table 3: Target Parameters for DICE Study.

Parameter	EPA Testing Protocol
General:	
Hardness	130.2
pH	150.1
Specific Conductivity	120.1
Total Organic Carbon	415.1
Total Suspended Solids	160.2
Total Dissolved Solids	160.1
Volatile Solids	160.4
Nutrients:	
Total Phosphorus	365.3
Dissolved Phosphorus	365.3
TKN	351.3
Nitrate-N	300.0
Metals (Total and Dissolved):	
Cadmium	200.8
Chromium	200.8
Copper	200.8
Lead	200.8
Nickel	200.8
Zinc	200.8

Sampling Equipment

The primary water quality sampling method utilized in the monitoring program involved collection of a flow-weighted composite sample during the entire hydrograph for monitored storm events. The flow-weighted composite sample was collected using an automatic sampler that was interfaced with a flow meter to provide real time flow pacing. (Camp Dresser and McKee, 1998) Laboratory analysis of a single flow-weighted composite sample provided an estimate of the EMC for the specific run-off event. Details of sampling equipment are listed in Table 4.

Table 4: DICE Study Sampling Equipment.

Equipment Purpose	Make and Model	Notes
Sample Collection	American Sigma 900 Autosampler	Intake mounted in channel invert
Flow Metering	American Sigma 960 Bubbler or American Sigma Ultra Sonic 950 Area-Velocity Flow Meter	Used to trigger aliquot collection at appropriate hydrograph location
Rain Gauging	American Sigma Tipping Bucket Gage	Used in calibration of catchment runoff coefficients

PRELIMINARY RESULTS

During the four rainy seasons completed in the DICE Study, 1996-1997, 1997-1998, 1998-1999, 1999-2000, over 260 sampling events have taken place. A sampling event is defined as a sampled storm at a specific location. These 260 sampling events are divided nearly in half with one set representing data from the catchments where drain inlets are cleaned and the other half of the set represented data from the catchments where drain inlets are not cleaned.

In a typical sampling event, EMC concentrations for the 21 analytes listed in Table 3 are measured. With data pooled into cleaned and uncleaned catchments, 42 data sets have been analyzed; two sets for each analyte. For each set, standard statistical parameters are established including the number of events, minimum and maximum EMC values, and sample set standard deviations.

The null hypothesis established for study is that the cleaned EMC values equal the uncleaned EMC values. This hypothesis is tested using the unpaired (or two-sample) Student's t-tests to compare the water quality of the uncleaned and cleaned drain inlets on an individual parameter basis. The test is performed on original, Ln transformed, or ranked data, depending on the data distributions.

DICE Study results are listed in Tables 5 and 6. Results from general water quality parameters and nutrients are presented in Table 5 and metals analysis is listed in Table 6.

Table 5: Descriptive Statistics and Comparison Test Results for Analysis of the Combined 1996-97, 1997-98, 1998-99, 1999-2000 Nutrients and Conventional Parameters Data. (Camp Dresser and McKee, 2000)

	Hardness (mg/L)		Total-N (mg/L)		Dissolved-P (mg/L)		Total-P (mg/L)		Specific Conductivity (μhms/cm2)	
Parameter	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
N of cases	133	138	86	88	124	138	131	139	126	138
Minimum	3.3	10.	0.19	0.24	0.02	0.01	0.01	0.02	19	28.1
Maximum	365	448	4.0	3.3	0.81	0.74	1.20	1.0	458	923
Mean [1]	36	62	0.75	1.01	0.12	0.14	0.20	0.23	77	127
Standard Dev [2]	2.1	59	1.9	0.62	0.10	0.13	0.20	0.20	1.9	131
Distribution	Ln Normal	Neither	Ln Normal	Neither	Neither	Neither	Neither	Neither	Ln Normal	Neither
Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data	
Significant Difference	NO		NO		NO		NO		NO	

	Total Suspended Solids (mg/L)		Total Kjeldahl Nitrogen (mg/L)		Total Organic Carbon (mg/L)		Total Volatile Solids (mg/L)	
Parameter	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
N of cases	131	139	131	139	132	139	102	107
Minimum	10.	12.	0.25	0.17	0.60	1.60	1.0	1.0
Maximum	983.	1230	57.	11.3	51.0	50.60	152.00	136.00
Mean [1]	102	81	1.94	1.61	7.44	8.79	42	50
Standard Dev [2]	125	3	4.97	1.39	2.18	1.97	31	30
Distribution	Neither	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither
Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data	
Significant Difference	NO		NO		NO		NO	

Notes:
1 Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Neither)
2 Geometric Standard Deviation if distribution is Ln Normal

Table 6: Descriptive Statistics and Comparison Test Results for Analysis of the Combined 1996-97, 1997-98, 1998-99, and 1999-00 Metals Data. (Camp Dresser and McKee, 2000)

		Cadmium (µg/L)		Chromium (µg/L)		Copper (µg/L)		Nickel (µg/L)		Lead (µg/L)		Zinc (µg/L)	
	Parameter	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned	Cleaned	Uncleaned
Total	N of cases	133	139	133	139	133	139	133	139	133	139	133	139
Metals:	Minimum	0.10	0.10	0.46	1.00	3.30	2.10	0.91	1.00	4.50	1.10	21.00	11.00
	Maximum	13.00	7.10	100.00	57.00	770.00	280.00	130.00	175.00	700.00	690.00	2400.00	1400.00
	Mean [1]	1.06	1.08	5.61	8.64	41.3	28.3	5.82	10.9	72.9	48.4	143	192
	Standard Dev [2]	1.26	0.85	2.37	8.06	71.0	2.16	2.31	16.5	95.9	2.99	2.08	163
	Distribution	Neither	Neither	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither	Ln Normal	Ln Normal	Neither
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data	
	Sig. Difference	NO		NO		NO		NO		NO		NO	
Dissolved	N of cases	133	139	133	139	133	139	133	139	133	139	133	139
Metals:	Minimum	0.03	0.02	0.55	0.73	1.60	1.50	0.47	0.52	0.20	0.34	9.0	2.00
	Maximum	3.1	6.1	15.	10.	76.0	76.0	20.0	36.0	42.0	84.0	720.	330.
	Mean [1]	0.47	0.52	2.34	2.49	9.58	10.1	2.88	3.57	5.57	7.04	54.7	76.9
	Standard Dev [2]	0.41	0.58	1.49	1.35	2.05	2.07	2.67	4.41	8.87	11.8	2.07	50.9
	Distribution	Neither	Neither	Neither	Neither	Ln Normal	Ln Normal	Neither	Neither	Neither	Neither	Ln Normal	Neither
	Test	t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ln Normal Data		t-Test on Ranked Data		t-Test on Ranked Data		t-Test on Ranked Data	
	Sig. Difference	NO		NO		NO		NO		NO		NO	

Notes:
1 Geometric Mean if distribution is Ln Normal, Arithmetic Mean if distribution is Normal or not Normal (Neither)
2 Geometric Standard Deviation if distribution is Ln Normal

CONCLUSIONS DRAWN EFFORTS TO DATE

Analysis of the DICE Study results to date yields a limited set of conclusions. Important items include:

1. Within pooled sets, data is characterized by a great deal of variability. The variability of EMC values for a particular analyte under a specific set of test conditions, cleaned or uncleaned, is substantial. As an example, calculating the ratio of the sample standard deviation of the EMCs with the mean EMCs for each of the 42 cases, in 13 cases the ratio is greater than one (sample standard deviation is larger than the mean value), in 15 cases the ratio is between 0.5 and one, in seven cases the ratio is between 0.2 and 0.5, and in seven cases the ratio is less than 0.1. Additional evidence for variability is the large observed concentration ranges. Given this level of data variability, determining if cleaning drain inlets has a noticeable impact on effluent quality is difficult.
2. The distributions of data do not fit a predictable pattern. In no case are the data distributed normally, in 14 cases the data fit a Ln normal distribution, and in 28 cases, no standard distribution pattern is found.
3. The data from four years of monitoring has not indicated a statistically significant difference between cleaned and uncleaned catchments. This is true for all 21 analytes.

CURRENT AND FUTURE EFFORTS

Without any clear conclusions to date, the DICE Study is continuing with additional sampling sites and with the sampling of litter and other macro debris from the flow stream added to the list of monitored constituents. As additional years data becomes available, efforts will be made to determine if cleaning drain inlets does indeed have a measurable impact on the water quality of effluent emanating from Caltrans freeways.

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