STORMWATER PROGRAM

California State University, Sacramento
University of California, Davis (UCD)
California Department of Transportation (Caltrans)

Characteristics of Stormwater Runoff From Highway Construction Sites in California

Presented at:

Transportation Research Record 1743, Paper No. 01-3181, National Academy Press

Authors:

Masoud Kayhanian, Caltrans/UCD Environmental Program
Kevin Murphy, Caltrans/CSUS Storm Water Program
Louis Regenmorter, Camp Dresser and McKee, Inc.
Richard Haller, Camp Dresser and McKee, Inc.

Disclaimer:

WATER PROGRAMS
Sacramento State
Research
Training
Public Education

CHARACTERISTICS OF STORMWATER RUNOFF FROM HIGHWAY CONSTRUCTION SITES IN CALIFORNIA

Masoud Kayhanian
Center for Environmental and Water Resources Engineering
Department of Civil and Environmental Engineering
University of California
Davis, CA 95616
Phone: (916)278-8112
FAX: (916)278-8140
e-mail: mdkayhanian@ucdavis.edu

Kevin Murphy
Office of Water Programs
California State University
Sacramento, CA 95826
Phone: (916)278-8105
FAX: (916)278-8140
e-mail: kevin.murphy@owp.csus.edu

Louis Regenmorter and Richard Haller
Camp Dresser and McKee, Inc.
2920 Inland Empire Boulevard, Suite 108
Ontario, CA 91764
Phone: (909)945-3000
FAX: (909)945-1333
e-mail: regenmorterlc@cdm.com, hallerre@cdm.com
Paper No. 01-3447

ABSTRACT

Fifteen highway construction sites were monitored by the California Department of Transportation (Caltrans) to help assess the water quality of stormwater runoff exiting from the sites. This study was conducted by Caltrans to generate sufficient water quality data to further develop management strategies and evaluate existing best management practices (BMPs). A wide range of construction sites were selected for monitoring throughout the State. Both flow-paced composite and single grab samples were collected and analyzed at these sites for a total of 72 station-storm events during the 1998/99 and 1999/00 wet seasons. Results obtained during the two-year characterization study indicate that:

- Caltrans' construction site runoff constituent concentrations detected during this study are less than typical Caltrans' and Non-Caltrans' highway runoff constituent concentrations with the exception of total chromium, total nickel, total phosphorus, TSS, and turbidity.
- The concentrations of TSS and turbidity are likely due to the disturbed soils present at most construction sites.

- The origin of the high concentrations of total chromium, total nickel, and total phosphorus concentrations is unknown. Concentrations of these constituents varied between sites so it is possible site-specific soils and vegetative conditions may have contributed to the concentrations of these constituents.
- A correlation (R^2 values greater than 0.5) was observed between TSS runoff concentrations and particulate runoff concentrations of chromium, copper, and zinc, indicating that minimizing particulate matter may reduce total metals concentrations.

INTRODUCTION

Construction is performed yearly at hundreds of Caltrans' highway and freeway sites. Because construction site activities differ significantly from typical highway/freeway activities, the storm water runoff water quality characteristics are expected to differ as well.

A two-year (1998-99 and 1999-00) monitoring study was performed to evaluate the quality of storm water runoff from a variety of Caltrans' highway construction projects. The characterization data is being used to estimate constituent loadings to receiving waters, and to help establish a baseline for construction site water quality and mass loading data. Data obtained was also compared to highway runoff data and general urban runoff data.

Stringent criteria were used to select these highway construction sites to ensure that a wide range of Caltrans' construction activities were represented. During the 1998-99 wet season nine sites were monitored. Six sites were monitoring during the 1999-00 wet season. A total of 72 station-storm events were monitored for the two-year period. Figure 1 presents the locations of the 15 construction sites and Table 1 summarizes the physical characteristics of these sites. The main focus of this paper is to present the storm water runoff characteristics that were obtained from the California highway construction sites during the 1998-99 and 1999-00 wet seasons.

METHODOLOGY

Site Selection Process

The following criteria were used to select the 15 construction sites that were monitored during the 1998-99 and 1999-00 wet seasons:

- The sites should represent a wide range of typical Caltrans construction projects (see Table 1 for the types of construction projects monitored);
- The sites should represent a wide range of geographic areas (see Figure 1);
- The sites should represent a wide range of hydrometeorologic conditions;
- The sites should have active construction planned for the entire monitoring period;
- Storm water from a significant portion of the construction site should flow to one centralized collection point;

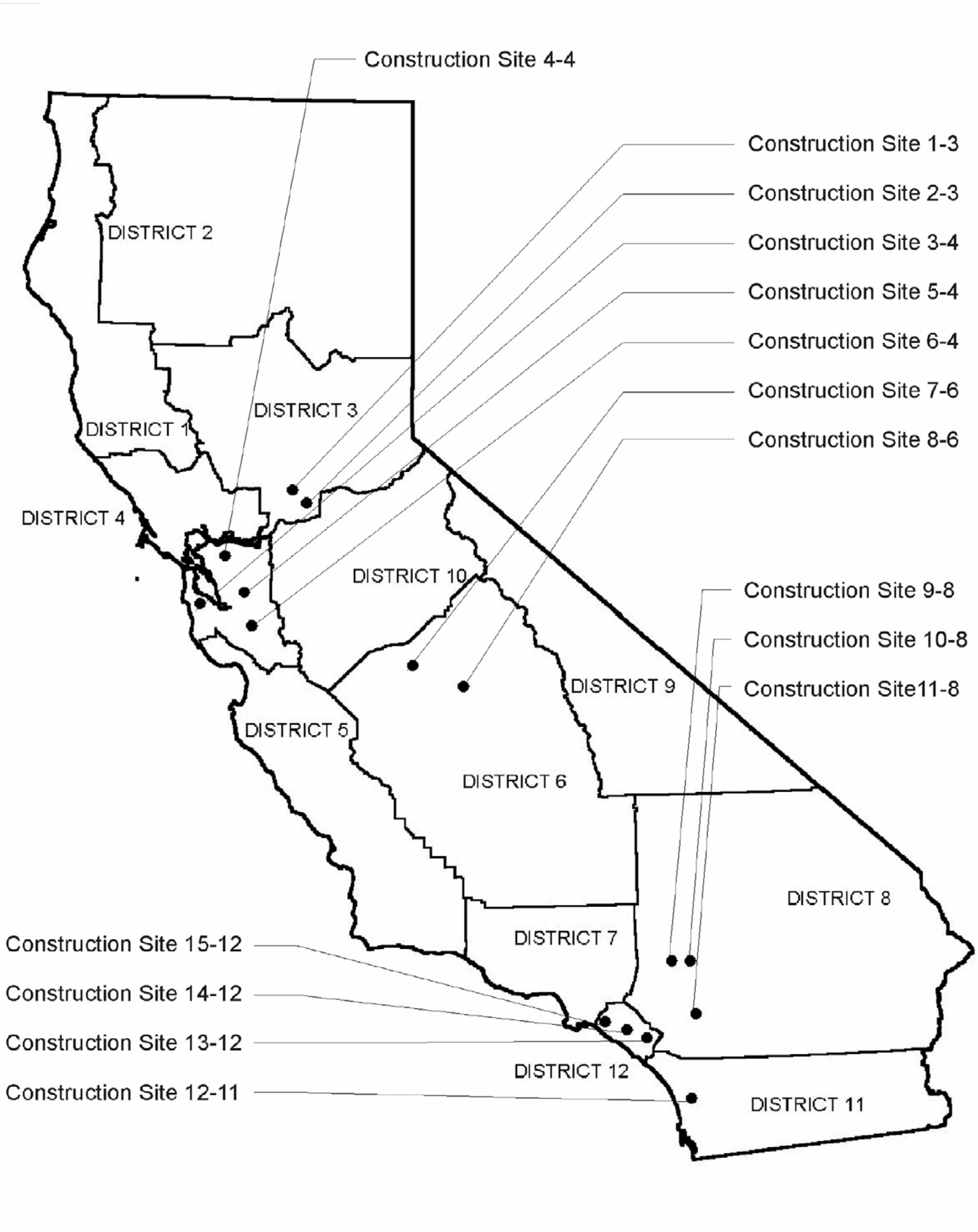

Figure 1 Highway Construction Sites Used for Storm Water Runoff Characterization Study

Table 1 Physical Characteristics of Construction Sites

Construction Site-District	Highway	Construction Type	Construction Activities	Sample Location	Flow Measurement	BMP in Place
1-3	I-80	Roadway Widening/ Rehabilitation	Bridge embankment and pier, new entrance ramp	Pipe outlet	Bucket and stop watch	Silt fence, vegetative berms, channel rock
2-3	SR-99	Roadway Widening/ Rehabilitation	Rail replacement, resurfacing	Bridge deck drain	Bucket and stop watch	Gravel bags, Filter fabric
3-4	I-80/ SR-580	Roadway Widening/ Rehabilitation	Heavy equipment work on highway supports	Drain Inlet	Area velocity meter	Sand bags, silt fence, gravel bags
4-4	I-80	Roadway Widening/ Rehabilitation	Bridge embankment and pier	Gutter	Area velocity meter	Straw bale
5-4	I-580/ I-680	Freeway Interchange Modification	Highway bridge pier, bridge and roadway	Pipe outlet	Area velocity meter	Sand bag dams
6-4	SR-237/ I-880	Freeway Interchange Modification	New interchange with bridge	Drain pipe	Area velocity meter	Sand bag dams, channel rock
7-6	SR-168	Roadway Facility Construction	Mass grading	Concrete vault	Area velocity meter	Concrete vault with steel grate cover
8-6	SR-168	Roadway Facility Construction	Mass grading, wood work	Drain inlet	Area velocity meter	Silt fence, sand bags
9-8	SR-30	New Roadway Facility Construction	Site grading	Bypass drain pipe	Area velocity meter	Gravel bags
10-8	I-15/ SR-210	New Highway Construction	Site grading for new highway	Pipe outlet	Area velocity meter	Silt fence, sand bags, straw bales
11-8	I-15/ SR-215	Roadway Widening/ Rehabilitation	Recent concrete paving	Drain inlet	Bucket and stop watch	Sand bags
12-11	SR-78	Interchange Modification	Roadway excavation, storm drain excavation	30-inch RCP inlet	Area velocity meter	Sand bags
13-12	I-5	Roadway Widening/ Rehabilitation	Dirt removal, grading, storm drain installation	30-inch RCP inlet	Area velocity meter	Sand bags
14-12	SR-55/ SR-22	Roadway Widening/ Rehabilitation	Construction debris and material stockpile	Pipe inlet	Area velocity meter	Silt fence, straw bale, channel rock
15-12	SR-55	Widen freeway/ Construct New Overpass	Grading, street approach, bridge piers and bridge	Pipe Outlet	Area velocity meter	Sand bags

I = Interstate

SR = State Route

- There should be no possibility of co-mingling construction site runoff with runoff from offsite or nonconstruction areas;
- The collection points should be located downstream of any BMPs commonly used at the sites.

Figure 2 presents photographs of a typical highway construction site and a typical sample location point.

Storm Event Monitoring

All storm events were monitored in accordance to the Caltrans "Guidance Manual: Storm Water Monitoring Protocols," (1). Depending on the site location, two to seven storm events were monitored during the 1998-99 and 1999-00 wet seasons.

The minimum criteria used to consider each storm event as a representative event were as follows :

- Depth of storm rainfall must be greater than 0.25 inch accumulation
- At least 24 hours must have elapsed since the last storm

(a) (b)

Figure 2 Typical Monitoring Site: (a) Typical Highway Construction Site, (b) Enclosed Pipe for Sample Collection.

Sample Collection

Flow-paced composite samples were collected for all constituents except for coliform and oil & grease, which were collected as single grab samples. For storm events that lasted 8 hours or more, a composite sample was prepared from a series of aliquot samples collected every 20 minutes for up to 8 hours. If the storm lasted less than 8 hours in duration, aliquot samples were collected every 20 minutes until the end of storm water runoff. Manual sample collection was performed at all sites and portable flow/velocity meters and rain gages were used to continuously measure flow rate and rainfall volume. Composite samples were prepared on a flow proportional basis with the amount taken from each aliquot calculated from the flow volume that occurred during each sampling interval and the percentage of total flow volume during the storm event.

Grab samples were collected when the flow rate was typical of full site flow (when the entire drainage area is contributing flow). Grab samples were not intended to represent first-flush conditions or peak flow conditions.

Constituents and Analytical Methods

The constituents, the analytical methods and reporting limits used for this study are presented in Table 2. As shown, the analyzed constituents were organized in six major groups: (i) metals (total and dissolved), (ii) nutrients, (iii) conventional, (iv) oil & grease, (v) biological, and (vi) pesticides. All laboratory analyses were conducted in accordance to Standard Methods and the USEPA analytical methods.

Standard lab QA/QC procedures were performed in accordance with the sampling and analysis plan (2, 3). Analytical results were qualified as necessary based on the results of the QA/QC evaluations.

RESULTS AND DISCUSSION

Results of the California highway construction site stormwater runoff characterization study conducted during the 1998-99 and 1999-00 monitoring seasons are summarized in Table 3. As shown, a simple statistical analysis was used to determine the range of values, mean, and coefficient of variance (CV). In addition to the data presented in Table 3, herbicides, pesticides (other than diazinon and chloropyrifos), and semi-volatile organic compounds were analyzed during the 1998/1999 monitoring season and more than 90% of the samples collected were reported as non-detect. To provide a better perspective of this raw data set, an evaluation was performed as follows:

- Comparing the highway construction site runoff data with historical highway runoff characteristics in California and other states in the nation as well as National Urban Runoff Program (NURP) data.
- Determining the influence of BMPs applied at these construction sites.
- Correlating total suspended solids (TSS) concentrations to other pollutant concentrations.

Table 2 Constituent List for Construction Site Runoff Characterization Study

Constituent	Units	Reporting Limit	Analytical Methods
Metals			
Cadmium	µg/l	0.5	EPA 200.8
Chromium	µg/l	1	EPA 200.8
Copper	µg/l	1	EPA 200.8
Lead	µg/l	1	EPA 200.8
Nickel	µg/l	1	EPA 200.8
Silver	µg/l	0.5	EPA 200.8
Zinc	µg/l	1	EPA 200.8
Nutrients			
Phosphorus	mg/l	0.1	EPA 365.2, 365.3
Nitrate	mg/l	0.1	EPA 300
Nitrite	mg/l	0.1	EPA 300
Ammonia	mg/l	0.1	EPA 350.1
Total Kjeldahl Nitrogen	mg/l	0.5	EPA 351.2
Conventional			
Hardness	mg/l	2	EPA 130.1
Total Suspended Solids	mg/l	4	EPA 160.2
Total Dissolved Solids	mg/l	1	EPA 160.1
Turbidity	NTU	1	EPA 180.1
Chemical Oxygen Demand	mg/l	5	EPA 410.1
Specific Conductivity	µS/cm	1	Field Meter
pH	pH units	0.01	Field Meter
Temperature	°C	0.1	Field Meter
Oil and Grease	mg/l	1	EPA 1664
Biological			
Total Coliform	MPN/100 ml	20	SM B9221/C9221
Fecal Coliform	MPN/100 ml	20	SM B9221/C9221
Pesticides			
Chlorpyrifos	µg/l	0.03	ELISA
Diazinon	µg/l	0.03	ELISA
Other Pesticides/PCBs[a]	µg/l	0.05-1	EPA 608
Herbicides[a]	µg/l	1-100	EPA 615
Semi-Volatile Organics[a]	µg/l	5-50	EPA 625

[a] These constituents were analyzed for the first monitoring season and over 90% of the results were below the reporting limits. These analyses were discontinued for the second monitoring season.

For the purpose of comparison, constituent concentrations detected from Caltrans highways during the 1997/1998 and 1998/1999 wet seasons are provided in Table 3. In addition, Figure 3 presents a bar

Table 3 Statistical Summary of Caltrans Construction Site Storm Water Runoff Quality and Highway Runoff Quality.

		Construction Site Runoff (1998-2000)				Caltrans Highway Runoff (1997-1999)[a]			
Constituent	**Units**	**Min.**	**Max.**	**Mean[b]**	**CV**	**Min.**	**Max.**	**Mean[b]**	**CV**
Cadmium Dissolved	ug/L	0.25	0.25	NA	NA	0.02	6.1	0.45	1.27
Cadmium Total	ug/L	0.25	4.1	0.63	1.14	0.10	13	1.25	1.04
Chromium Dissolved	ug/L	0.50	30	5.17	1.23	0.55	50	3.01	1.09
Chromium Total	ug/L	6.80	210	38.90	0.99	0.46	100	12.08	1.02
Copper Dissolved	ug/L	1.00	25	6.77	0.81	1.00	140	15.84	0.90
Copper Total	ug/L	3.80	128	32.07	0.80	2.10	770	50.25	1.27
Lead Dissolved	ug/L	0.25	15	0.75	2.46	0.20	300	7.34	3.20
Lead Total	ug/L	1.00	291	44.35	1.31	1.10	1530	120.83	1.69
Nickel Dissolved	ug/L	0.50	15	3.15	0.83	0.47	50	4.85	1.03
Nickel Total	ug/L	2.50	266	36.45	1.54	0.91	317	14.55	1.64
Silver Dissolved	ug/L	0.25	0.5	0.36	0.35	0.04	1.0	0.58	0.36
Silver Total	ug/L	0.25	53.0	1.15	5.48	0.15	82.0	2.43	4.48
Zinc Dissolved	ug/L	1.00	80.0	13.59	1.19	6.56	1300.0	89.46	1.35
Zinc Total	ug/L	6.90	609.0	140.86	0.89	11.00	2400.0	231.99	1.04

Phosphorus Dissolved	mg/L	0.05	0.9	0.33	0.63	NA	NA	NA	NA
Phosphorus Total	mg/L	0.05	10.7	0.95	1.19	0.01	3.3	0.29	1.19
Nitrate (as N)	mg/L	0.05	3.9	0.89	0.87	0.20	8.3	1.55	0.83
Nitrite (as N)	mg/L	0.05	2.8	0.17	2.10	0.01	1.7	0.22	1.13
Ammonia	mg/L	0.03	4.0	0.36	1.49	0.19	10.0	1.79	0.94
TKN mg/L	mg/L	0.25	19.9	2.46	1.20	0.17	57.0	2.81	1.53
Hardness	mg/L	13.0	1680	114.51	1.88	3.30	365.0	59.29	0.89
Suspended Solids	mg/L	12.0	3850	499.21	1.46	4.00	4800.0	160.84	1.98
Dissolved Solids	mg/L	22.0	1270	194.74	0.95	14.00	470.0	118.36	0.67
Turbidity	NTU	15.0	16000	701.61	2.77	9.90	140.0	59.49	0.74
COD	mg/L	12.0	380	86.06	0.67	10.00	480.0	121.16	0.73
Oil & Grease	mg/L	0.5	22.7	2.73	1.16	1.00	226.0	14.42	1.50
Coliform (Total)	MPN/ 100 ml	2.0	540000	31970	3	30	500000	30573	2.05
Coliform (Fecal)	MPN/ 100 ml	2.0	205000	4544	6	2	160000	8172	3.28
Chlorpyrifos	ug/L	0.02	0.5	0.29	0.83	0.02	1.00	0.58	0.77
Diazinon	ug/L	0.02	2.4	0.41	1.09	0.04	2.40	0.65	0.75

CV = Coefficient of Variance

NA = Not Applicable

[a] All Highway Related Runoff Data Collected by Caltrans from 1997 to 1999

[b] A vaue equal to one half of reporting limit was used when a value was reported as non-detect

graph comparison of the construction site data to data available from other highway or urban runoff characterization studies (4, 5, 6, 7, 8). As shown in Table 3 and Figure 3, Caltrans' construction site runoff constituent concentrations are generally less than Caltrans' and Non-Caltrans' highway runoff constituent concentrations with the exception of total chromium, total nickel, total phosphorus, TSS, and turbidity. The generally higher highway runoff constituent concentrations are assumed to be due to typical highway activities (average daily traffic > 60,000) that are more likely to contribute pollutants than construction activities. Likewise, the higher concentrations of TSS and turbidity are likely due to the disturbed soils present at construction sites. The origin of the total chromium, total nickel, and total phosphorus concentrations is unknown. Concentrations of these constituents varied between sites so it is possible that site-specific soils and vegetative conditions may have contributed to the higher concentrations of these naturally occurring constituents.

Types of best management practices (BMPs) used at each of the construction sites monitored during this study are presented in Table 1. Photos of the typical types of BMPs used at the construction sites are presented in Figure 4. The main purpose of these BMPs is to minimize the amount of sediment being discharged from the sites. As expected, the TSS concentrations detected in the construction site runoff indicate that the BMPs did not contain all of the sediment. However, the importance of these BMPs

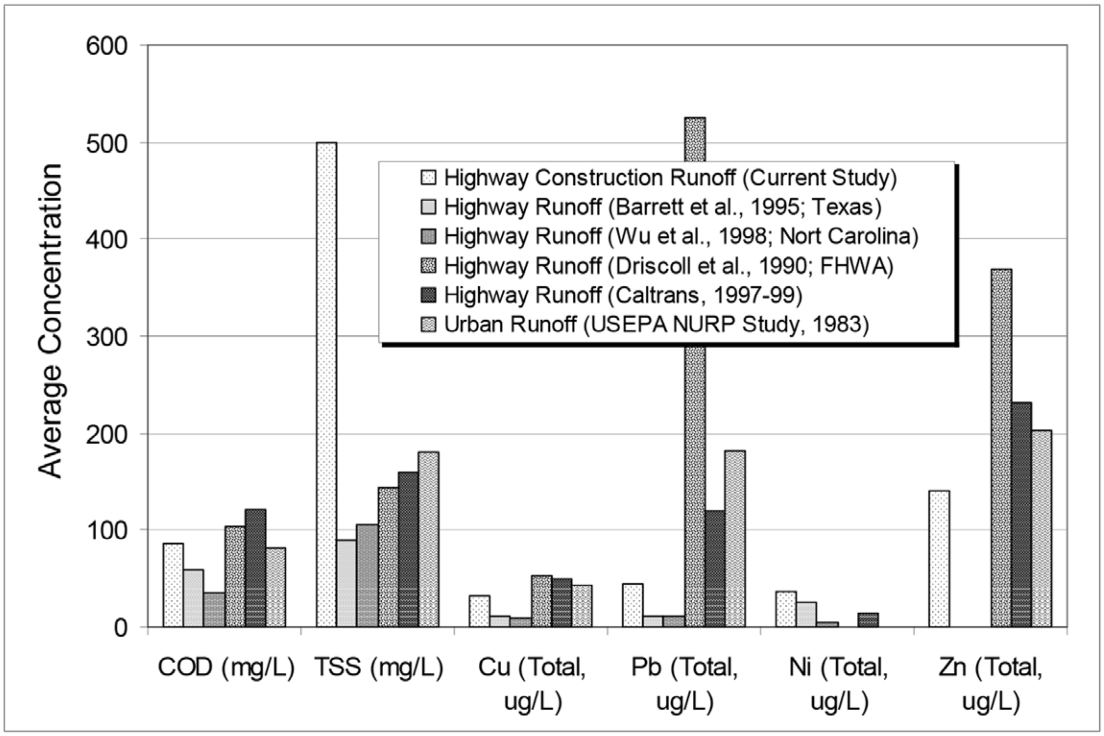

Figure 3 Comparison of Construction Site and Highway Storm Water Runoff Concentration for Selected Constituents

was apparent as visual observations during field activities indicated that silt fences, vegetative berms, sandbags, gravel bags, and straw bales were effective at containing significant amounts of sediment. Because BMPs are among the most useful and important tools in the Caltrans Stormwater Program (9), runoff characterization data from this study will be used to further develop management strategies and to evaluate and optimize existing BMPs.

(a) Channel rock and vegetative berms

(b) Straw bales

(c) Vegetative berms

(d) Silt fence

Figure 4 Typical BMPs Used at Construction Sites to Contain Sediments

Because higher TSS runoff concentrations were expected and observed in the storm water runoff from construction sites, a potential relationship between TSS and constituents reported in the 1998 – 2000 data set was evaluated. Because no linear correlation between TSS concentrations and total concentrations were observed, a relationship between TSS and particulate concentrations was assessed. Particulate values were obtained by subtracting the dissolved concentrations from the total concentrations. Although better correlations were found, no strong correlations were evident for most constituents. However, R^2 values greater than 0.5 (see Figure 5) were observed between TSS and particulate concentrations of copper, chromium, and zinc. This correlation indicates that minimizing particulate matter in stormwater runoff may reduce total metals concentrations; further indication that effective BMP implementation and sediment removal is essential for reducing pollutant loads discharged in runoff from construction sites.

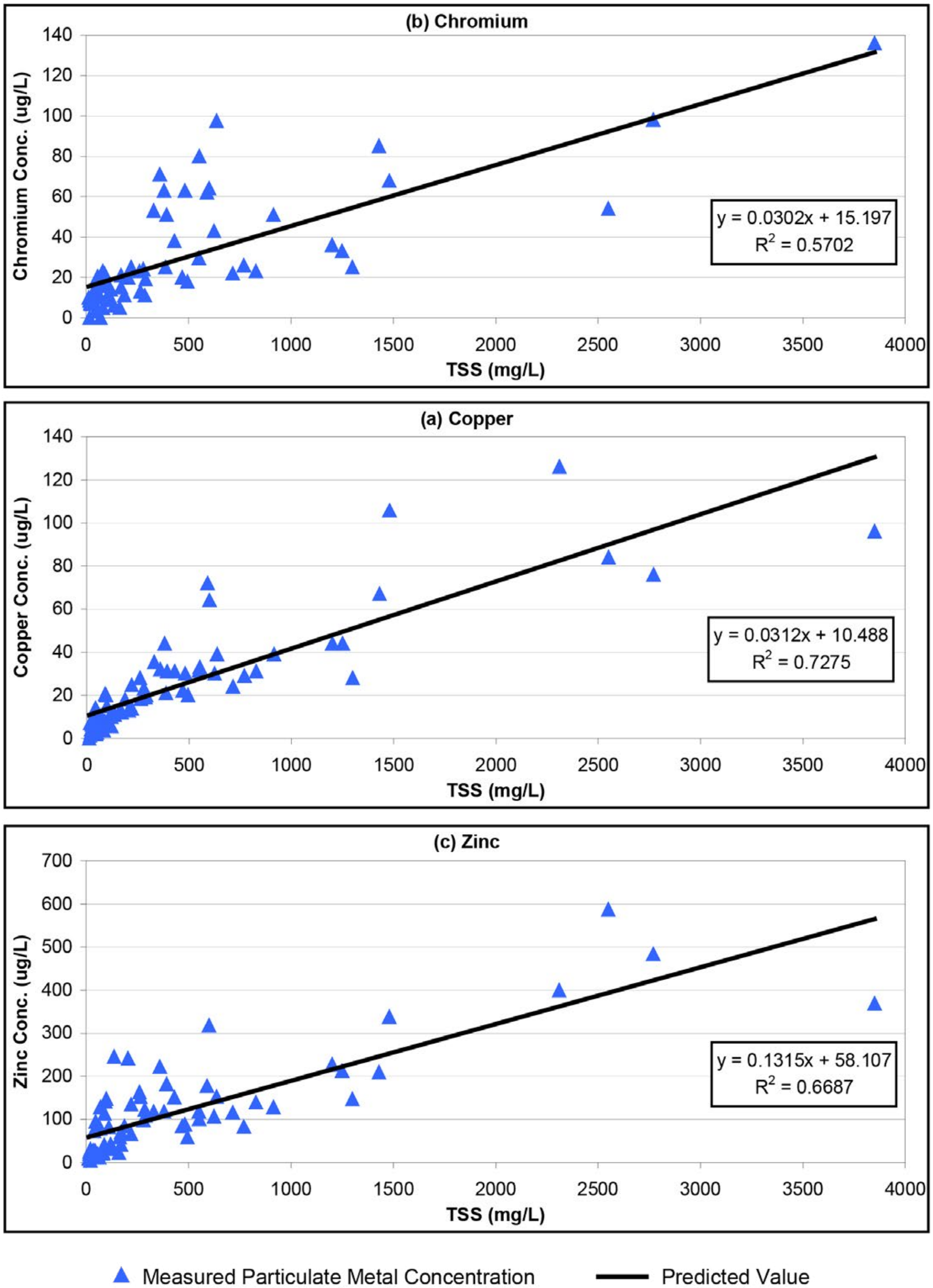

Figure 5 Correlation Between TSS and Particulate Metal for Chromium, Copper, and Zinc

CONCLUSIONS

The following conclusions are based on the two years of construction site runoff water quality monitoring data discussed above:

- Caltrans' construction site runoff constituent concentrations detected during this study are less than typical Caltrans' and Non-Caltrans' highway runoff constituent concentrations with the exception of total chromium, total nickel, total phosphorus, TSS, and turbidity.
- The higher concentrations of TSS and turbidity are likely due to the disturbed soils that construction site runoff is exposed to before exiting the site.
- The origin of the total chromium, total nickel, and total phosphorus concentrations is unknown. Concentrations of these constituents varied between sites so it is possible that site-specific soils and vegetative conditions may have contributed to the constituent concentrations.
- A correlation (R^2 values greater than 0.5) was observed between TSS runoff concentrations and particulate runoff concentrations of chromium, copper, and zinc, indicating that minimizing particulate matter may reduce total metals concentrations.
- The correlation between TSS concentrations and constituent concentrations may be useful when further developing best management practices.

ACKNOWLEDGMENTS

The authors greatly acknowledge all monitoring team members who participated in this study. First year monitoring was conducted by the Montgomery Watson/Chaudary/LAW Crandall/Kleinfelder team. The CDM/AEI CASC/TRS team conducted the second year study. The Caltrans Environmental Engineering, Stormwater Management Program under contract 43A0002A, provided funding for this project. The authors also acknowledge the assistance of Mr. David Alderete, Mr. Amardeep Singh, and Mr. Scott Meyer for the preparation of this article.

REFERENCES

1. Caltrans Environmental Program. *Guidance Manual: Stormwater Monitoring Protocols*. prepared by Larry walker Associates, Davis, CA, and Woodward-Clyde Consultants, Oakland, CA, 1997.

2. Caltrans Environmental Program. Sampling and Analysis Plan for Construction *Site Storm Water Runoff Characterization Study*. Report CTSW-RT-99-91-01, December, 1998.

3. Caltrans Environmental Program. *Sampling and Analysis Plan for Construction Site Storm Water Runoff Characterization Study*. Report CTSW-RT-98-069, December, 1999.

4. Driscoll, E. D., Shelly, P. E., and Strecker, E. W. *Pollutant Loading and Impacts from Highway Stormwater Runoff. Vol. I: Design Procedure.* Tech. Rep. FHWA/RD-88-007. Prepared for the Fed. Hwy. Admin., Washington, D.C., 1990.

5. Kayhanian, M. and S. Borroum. Characterization of the Highway Stormwater Runoff in California, 72nd Annual Conference, California Water Environment Association, Sacramento, CA, 2000, Section B.

6. Barrett, M. E., Irish, L. B., Malina, J. F. and Charbeneau, R. J. Characterization of Highway Runoff in Austin, Texas, Area. J. *Envir. Engrg.*, ASCE, Vol. 124, No. 2, 1998, 131-137.

7. Wu, S. J., C. J. Allan, W. L. Saunders, and J. B. Evett. Characterization and Pollutant Loading Estimation for Highway Runoff. J. Envir. Engrg., ASCE, Vol 124, No. 7, 584-592, 1993.

8. USEPA. Results of the Nationwide Urban Runoff Program. National Technical Information Service (NTIS), Publication No. PB84-185552, December, 1983.

9. Borroum, S. and M. McCoy. The California Experience, Caltrans's Storm Water Plan. *Civil Engineering*, July 2000.