# La Jolla Shores Coastal Watershed Sediment Characterization Study

## Final Report

**Prepared for:**

**City of San Diego**
**9370 Chesapeake Drive**
**Suite 100**
**San Diego, CA 92123**

**June 2, 2009**

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**Prepared for:**

**City of San Diego**
9370 Chesapeake Drive
Suite 100
San Diego, California 92123

**Prepared by:**

**Weston Solutions, Inc.**
2433 Impala Drive
Carlsbad, California 92010

June 2, 2009

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| | |
|---|---|
| ASBS | area of special biological significance |
| BMP | best management practice |
| City | City of San Diego |
| DOC | dissolved organic carbon |
| EPA | Environmental Protection Agency |
| LJ CYN | open space land use sampling site |
| LJ END | mixed land use (residential and open space) sampling site |
| LJ RES | residential land use sampling site |
| MS4 | municipal separate storm sewer system |
| NTU | nephelometric turbidity unit |
| Ocean Plan | California Ocean Plan |
| OP | organophosphorus |
| PAH | polycyclic aromatic hydrocarbon |
| PCB | polychlorinated biphenyls |
| QAPP | Quality Assurance Project Plan |
| SIO | Scripps Institution of Oceanography |
| State Board | State Water Resources Control Board |
| TSS | total suspended solids |
| WESTON® | Weston Solutions, Inc. |
| WQO | water quality objective |
| $WQO_a$ | acute effects water quality objective |
| $WQO_c$ | chronic effects water quality objective |

# EXECUTIVE SUMMARY

The purpose of the La Jolla Shores Sediment Characterization Study was to identify sediment sources and characterize sediment loads from different land use areas within the La Jolla Shores Coastal Watershed during storm events and to assess how sediment and related contaminants may affect the two Areas of Special Biological Significance (ASBS) at the base of the watershed. This study was designed to both develop specific Best Management Practices (BMPs) to address sediment loading that may impact the beneficial uses of the La Jolla ASBS and to serve as a Tier II watershed activity identified in the City's Strategic Plan for Watershed Activity Implementation (Strategic Plan) (WESTON, 2007a). The Strategic Plan identifies priority pollutants of concern and source identification data gaps for La Jolla ASBS and is in alignment with the La Jolla Shores Coastal Watershed Management Plan that has been developed for the area (SIO et al., 2008).

The following objectives were developed for this study:

1. Identify how land use influences sediment loading,
2. Identify whether sediment loading patterns or the relative grain size proportions change throughout a storm hydrograph,
3. Calculate the estimated sediment and pollutant load entering the ASBS during a large storm event,
4. Determine if concentrations of constituents in runoff are correlated with specific sediment loads or grain size fractions,
5. Characterize the water quality and sediment conditions in the ASBS receiving water, and
6. Recommend BMPs to protect the ASBS.

*Relevance to Current City Efforts*:
This Sediment Source and Load Characterization Study compliments other City of San Diego plans, programs and cost reduction efforts that include:

- La Jolla Shores Coastal Watershed Management Plan.
- Standard Urban Storm Water Mitigation Plan (SUSMP).
- Watershed Urban Runoff Management Program (WURMP).
- Jurisdictional Urban Runoff Management Program (JURMP).

*Results and Key Findings*:

- Three sub-watersheds were monitored in the La Jolla Shores Coastal Watershed during two storm events for this study: Open Space (a minimally developed canyon at the base of Mount Soledad), Residential (low density residential off La Jolla Shores Drive), and Mixed Used (the largest drainage in the Watershed, representing open space canyons and low density residential land uses).
- Among the three subwatersheds monitored, sediment concentration and sediment load per acre were greatest from the Open Space site, suggesting that the open space land use, represented by steep canyons in the La Jolla Shores Coastal Watershed, are the primary sources of sediment to the ocean receiving waters in the ASBS.
- Sediment loading patterns changed throughout the hydrograph. At all three sites, sediment concentration and load mirrored the hydrograph, peaking with the flow of water as the storm progressed.

- Median grain size varied with location. Among the three sites, the largest grain size was measured at the Residential Site, which consisted primarily of sand. Median grain size in the Canyon and Mixed Use Sites were smaller, consisting primarily of silts and clays. There was not a strong relationship between grain size and the hydrograph.
- The greatest copper, lead, and zinc concentrations were associated primarily with sediments in the 5-35 micron size range.
- Concentrations and loads of total metals (i.e., metals bound to sediment particulates) were correlated with the sediment concentration and the hydrograph (i.e., as the storm peaked so did sediment and total metals). In contrast, concentrations of dissolved metals (metals in solution, not bound to particulates) tended to be greatest before and after the peak of the storm.
- Within approximately 48 hours following a storm event, water quality and sediment conditions within the ASBS appeared to be close to pre-storm conditions. Water samples collected just beyond the surf zone two days after a storm event had detectable concentrations of heavy metals and trace amounts of PAHs. No detectable concentrations of PCBs (aroclors or individual PCB congeners), pesticides, organotins, synthetic pyrethroids, volatiles, or semi-volatile compounds were present in offshore water samples. Exposure to offshore water collected two days following a storm event did not produce acute or chronic toxicity to mysid shrimp and did not produce chronic toxicity to giant kelp or sea urchins.
- Sediment within the ASBS did not contain detectable concentrations of PAHs, PCBs (aroclors or individual PCB congeners), pesticides, organotins, synthetic pyrethroids, volatiles, or semi-volatile compounds. Concentrations of heavy metals were detected but all were below established levels in which toxic effects to benthic infauna would be expected. No toxicity was observed in *E. estuarius* exposure to ASBS sediments.

*Key Recommendations*:

This Phase II Source Study identifies Tier I, Tier II and Tier III BMPs to reduce sediment and contaminant loads. Key recommendations that may be considered include the following:

- Tier I – Develop and implement a Data Management System to consolidate data, track activities, load reductions and effectiveness of storm water program efforts.
- Tier I – Conduct education and outreach programs to keep the public informed about protecting the ASBS.
- Tier II – Continue to assess aggressive street sweeping as a means of reducing loads to the ASBS and consider other source controls such as a runoff reduction program.
- Tier II – Develop a pollutant loading model and load reduction calculations for the La Jolla Shores Coastal Watershed.
- Tier III – Pursue existing plans to implement a dry weather diversion structure at Avenida de la Playa to eliminate dry weather flows as required by the permit.

*Benefits to the City*:

This Study provides the following benefits to the City:

- Supports Permit requirements and future regulations regarding the La Jolla Shores ASBS.
- Identifies areas within the watershed where sediment and contaminant loading are the greatest.
- Provides insight on the potential impacts of storm water flows on the ASBS receiving waters.
- Enhances our understanding of sediment-contaminant relationships that can be used to design effective BMPs.

# 1.0 BACKGROUND

The La Jolla Shores Coastal Watershed is approximately 1,600 acres in San Diego, California that drains to the Pacific Ocean. The watershed extends from the shoreline to an elevation of approximately 800 ft at Mount Soledad and consists primarily of residential and institutional (i.e., University of California San Diego (UCSD) campus) land uses. The majority of the runoff in the watershed is captured by street curb inlets and is conveyed to the ocean through the municipal separate storm sewer systems (MS4s) at multiple locations.

The La Jolla coastal area, which receives runoff from the watershed, has been recognized as a unique biological community of flora and fauna since the early 1920s. In the mid-1970s, the State Water Resources Control Board (State Board) designated 34 areas of special biological significance (ASBS) along the California coast, which were identified as unique coastal habitats worthy of a more stringent level of protection. Two of the 34 designated ASBS are located along the La Jolla coastal area:  the La Jolla State Marine Conservation Area (ASBS No. 29), which is adjacent to the La Jolla Shores community, and the San Diego Scripps State Marine Conservation Area (ASBS No. 31), which is adjacent to the UCSD campus (Figure 1-1). The California Ocean Plan (Ocean Plan) adopted by the State Board and approved by the United States Environmental Protection Agency (EPA) provides special protection to the ASBS in an effort to retain their unique biological characteristics.

In 2003, the State Board began to prohibit waste discharges into ASBS via provisions in the Ocean Plan. In accordance with this prohibition, the State Board notified dischargers to ASBS that they must either cease discharges of waste into ASBS or obtain an exception to the waste discharge prohibition in the Ocean Plan. In response to the discharge prohibition, several dischargers,—including Scripps Institution of Oceanography (SIO), which is located in the La Jolla Coastal Watershed—worked closely with the State Board and San Diego Regional Water Quality Control Board (Regional Board) to obtain an exception to the Ocean Plan. In 2004, the State Board granted SIO an exception to the Ocean Plan that includes 19 special conditions that serve as a road map to Ocean Plan compliance. In 2005, these conditions were added to the SIO National Pollutant Discharge Elimination System (NPDES) Permit for seawater discharges associated with their research aquaria and storm water discharges. The City of San Diego (City) has embarked on a similar process to obtain an exception for storm water discharges to ASBS 29 and has been actively pursuing activities to characterize the City's discharges to the ASBS.

As part of recent efforts to protect coastal resources and ASBS, water quality monitoring has been conducted from drainages that discharge urban runoff to the two ASBS in the La Jolla area (SIO et al., 2008). Storm water monitoring has been conducted by the City since 2005 and has included cooperative programs with SIO under Proposition 50 grant funds to develop the La Jolla ASBS Integrated Coastal Watershed Management Plan (SIO et al., 2008) As outlined in the Final Watershed Management Plan, a triad approach has been recommended to assess the potential impact of storm water on the biological communities in the ASBS. The triad approach considers not only water quality data, but also toxicity, bioaccumulation studies, and biological surveys. Using the triad approach, these monitoring efforts have resulted in the identification of metals, indicator bacteria, and sediment as primary pollutants of concern for waters discharging to the ASBS. However, the studies conducted to date have not identified specific sources of these pollutants, nor have they characterized the nature of the particulates causing suspended sediment concentrations to exceed water quality objectives (WQOs). Although runoff from both residential areas and natural open space areas are thought to contribute to the pollutant loads observed, the relative contribution of fine and course sediment fractions from each land use type is not well understood. Moreover, studies on the germination of giant kelp exposed to La Jolla Shores storm water runoff suggested that sediment and/or sediment-sorbed contaminants may have affected kelp germination. Therefore, additional studies were needed to further understand the potential impacts to the biological resources in the ASBS and the role sediment loading from the watershed plays in these potential impacts. This report presents the finding of this special study on the source and nature of sediment loads from the watershed to the ASBS via storm water flows.

This sediment source study addresses the requirement of a watershed activity under the City's NPDES storm water permit and the results will be used to help develop specific best management practices (BMPs) to address sediment loading that may impact the beneficial uses of the ASBS. This is a Tier II watershed activity that is consistent with the Phase I set of activities defined in the City's 5-Year Watershed Activity Implementation Strategic Plan (Strategic Plan) (WESTON, 2007a). The Strategic Plan identifies the priority pollutants of concern and the source identification data gaps for La Jolla ASBS within the Mission Bay Watershed Management Area. The expected outcome of this activity is the recommendation of specific BMPs to address the sources of sediment that are potentially impacting the biological community of the La Jolla ASBS. This activity is also consistent with the Phase I set of projects recommended in the La Jolla ASBS Integrated Coastal Watershed Management Plan (SIO et al., 2007).

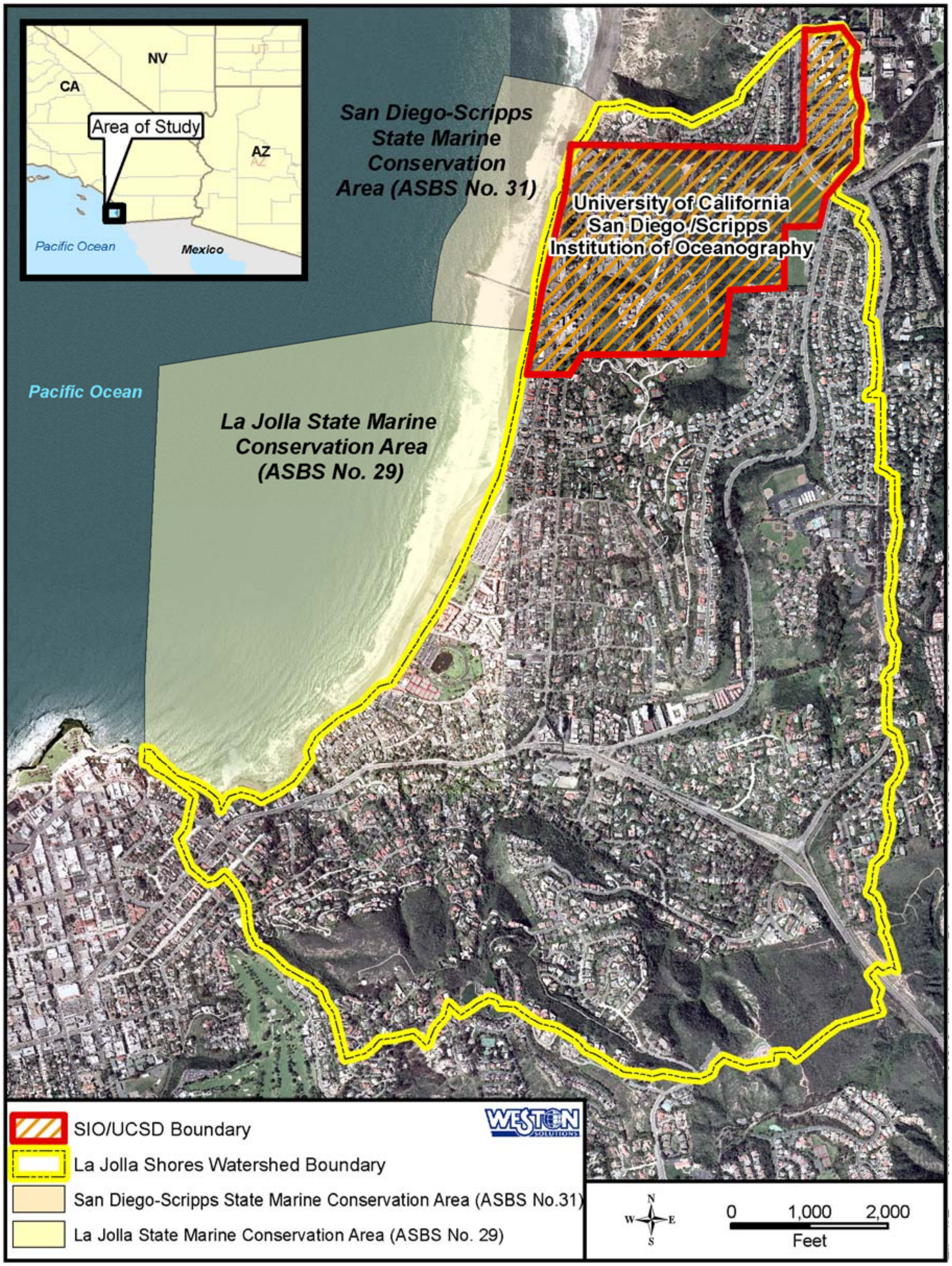



**Figure 1-1. La Jolla Shores Coastal Watershed and Adjacent Area of Special Biological Significance**

## 1.1 Project Goals

The primary goal of this project is to identify sediment sources and to characterize sediment loads from different land use areas within the La Jolla Shores Coastal Watershed during storm events.

The study is designed to answer several key study questions, as follows:

1. **During storm events, how does land use influence sediment loading?**
2. **Do sediment loading patterns or the relative grain size proportions change throughout a storm hydrograph?**
3. **What is the estimated sediment and pollutant load entering the ASBS during a large storm event?**
4. **What are the water quality and sediment conditions in the ASBS receiving water?**
5. **Are concentrations of constituents in runoff correlated with specific sediment loads or grain size fractions?**
6. **What potential BMP solutions are available, applicable, and feasible for implementation in the La Jolla Shores Watershed based upon the data compiled in this study?**

Understanding the source and nature of sediments and associated pollutants entering the ASBS from the watershed as well as their fate once they enter the marine environment will help the City establish a baseline to measure the effectiveness of management actions. In addition, the study will help the City prioritize and implement cost-effective BMPs to reduce pollutant loading. Finally, the study will assist the City in meeting current and future ASBS regulatory compliance requirements by assessing sediment and pollutant loads that travel from the La Jolla Shores Coastal Watershed to the nearby ASBS.

This final report presents and summarizes data collected from sampling events that occurred during the 2007–2008 and 2008–2009 storm seasons.

# 2.0 MATERIALS AND METHODS

## 2.1 Project Description

There are three sampling components in this study: watershed sampling, offshore water sampling, and offshore sediment sampling. The watershed portion of the study is designed to evaluate the amount of sediment and contaminant loading that occurs during storm events (greater than 0.20 inch of rainfall) at different land use areas within the watershed. During the storm events, three sites were sampled within the existing MS4. The sampling sites are located at the bottom of subwatersheds consisting of three different land uses: open space (LJ CYN), residential (LJ RES), and mixed use (residential and open space) (LJ END). The three subwatersheds are shown as part of the larger La Jolla Shores Coastal Watershed on Figure 2-1. At each site, discrete grab samples were taken over the course of the storm and were analyzed for a suite of pollutants. The height of the water column in the MS4 at the time of sampling was also measured to determine flow that was used to produce a hydrograph. Pollutant concentrations were plotted with the hydrograph to produce a pollutograph. Data from the pollutograph (i.e., pollutant concentration and flow) were used to calculate pollutant load over the course of the storm.

In addition to the watershed sampling, coordinated sampling was performed in the marine environment of the ASBS. The offshore water quality and sediment samples were analyzed physically, chemically, and toxicologically and fulfilled monitoring provisions for storm water discharges defined by the State Board. Offshore water quality samples were collected and analyzed following the monitored storm event, and offshore sediment was collected and analyzed during dry weather. Sampling of marine sediment located directly offshore from the Avenida de la Playa MS4 outfall was conducted to compare pollutant concentrations found in ASBS sediment to pollutant concentrations detected in storm water runoff.

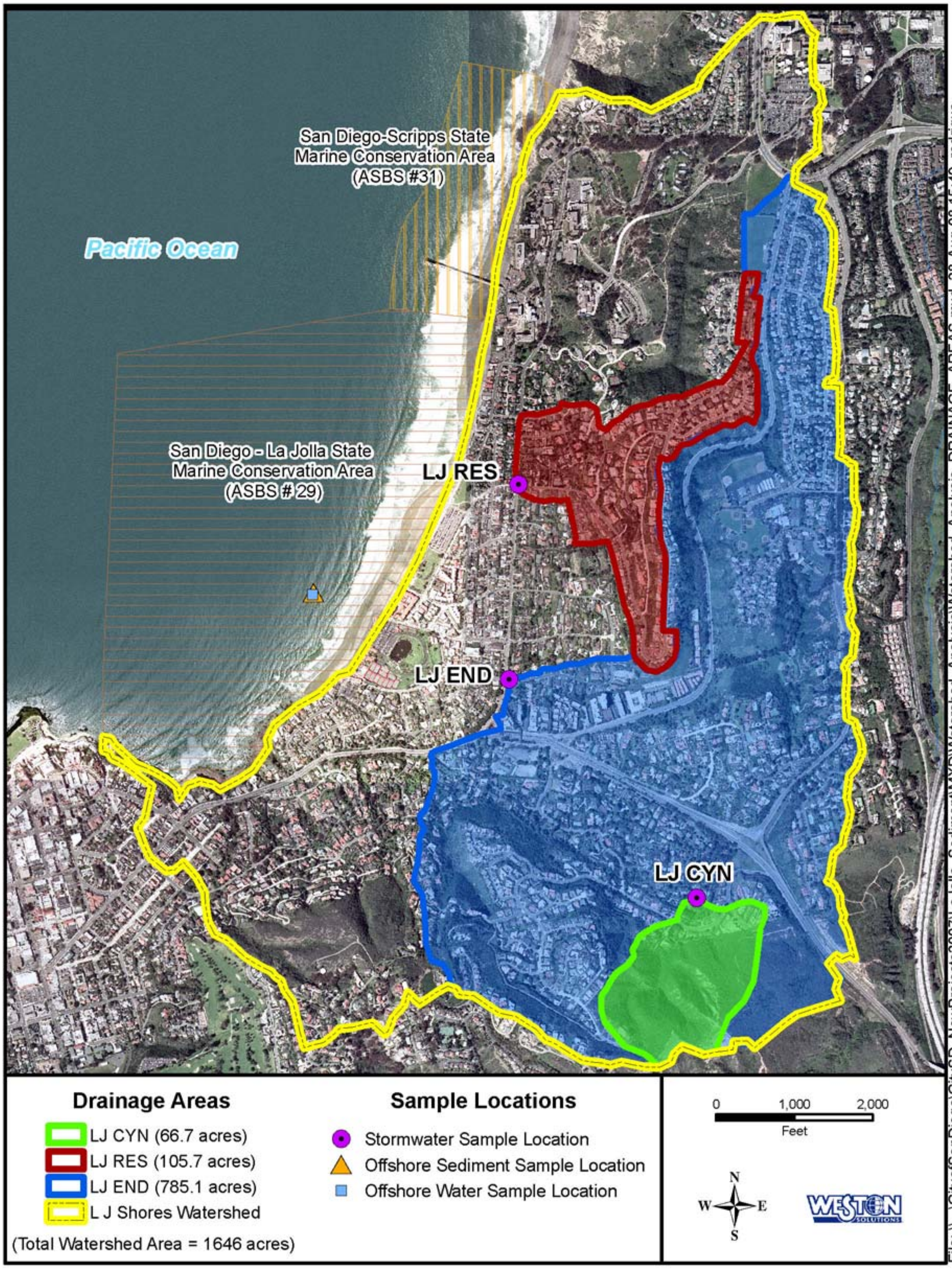



**Figure 2-1. La Jolla Shores Coastal Watershed Depicting Subwatersheds and Sampling Locations**

## 2.2 Watershed Sampling

The monitored storm events occurred on January 5, 2008 and December 15, 2008. Both of the storms met the requirements for sampling as outlined in the Quality Assurance Project Plan (QAPP) (WESTON, 2007b). During the January 5, 2008 storm event, a total of 0.20 inch of rain fell over a 12-hour period according to the Scripps Pier rain gauge. Field teams were deployed at approximately 01:00. A total of nine grab samples were collected at each of the three sites over the course of the storm to produce the desired pollutographs. The storm event on December 15, 2008, dropped 0.23 inch of rain in La Jolla over a 12-hour period according to the Scripps Pier rain gauge. Field teams were deployed at approximately 08:30. A total of nine grab samples were collected at each of the three sites over the course of Storm 1 (January 5, 2008), whereas eight grab samples were collected from each of the sites over the course of Storm 2 (December 15, 2008) to produce the desired pollutographs.

### 2.2.1 Sampling Locations

The three sample locations were selected based on the predominant upstream land use characteristics within the watershed. The three target land use types are residential, open space, and mixed use (Figure 2-1).

- **LJ RES (Figure 2-2)—**This sampling site is located near the intersection of La Jolla Shores Drive and Camino del Oro. The MS4 at this location captures runoff from a predominantly residential area in the central portion of the watershed below Preswick Drive. Grab samples for pollutograph sampling were collected from within the MS4 at this location via a manhole located at street level.

**Figure 2-2. LJ RES Sampling Location on Calle del Oro**

- **LJ CYN (Figure 2-3)—**This sampling site is located near a large open space canyon in the southern portion of the watershed on Caminito Prado. Two adjoining sections of the MS4 connect just upstream of this sampling location and capture runoff predominantly from an open space area on the northern slope of Mount Soledad. Grab samples for pollutograph sampling were collected from the MS4 at this location via a manhole located at street level.

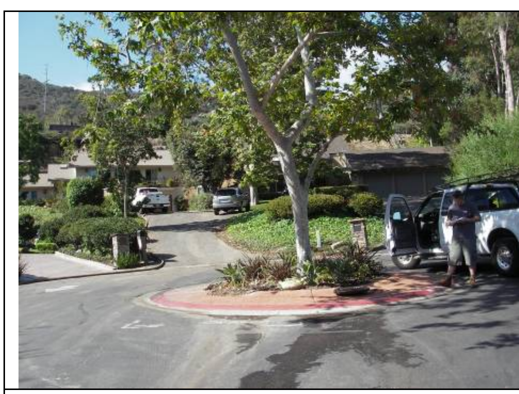


**Figure 2-3. LJ CYN Sampling Location at the Base of Mount Soledad**

- **LJ END (Figure 2-4)—**This sampling site is located near the intersection of La Jolla Shores Drive and Paseo Dorado. The MS4 at this location captures runoff from mixed land uses, including residential, open space, transportation, and commercial. This site is downstream of Site LJ CYN in the MS4. Grab samples for pollutograph sampling were collected from within the MS4 at this location via a manhole located at street level.

**Figure 2-4. LJ END Mixed Use Sampling Site Located on Paseo Dorado**

### 2.2.2 Sampling Methods

Grab samples were taken at the three sites (LJ RES, LJ CYN, and LJ END) using standard procedures, as outlined by the United States EPA and detailed in the QAPP (WESTON, 2007b). A decontaminated bucket and rope were used to collect the storm water sample from the MS4 at each of the three sampling sites. Pollutograph grab samples were collected at regular intervals throughout each storm's hydrograph from manhole access points to track constituent concentrations over the course of the storm event. The velocities in the La Jolla MS4 are extreme during a large storm event and preclude the placement of flowmeters. Instead, stage (i.e., water depth) was measured using the tape-down method (i.e., stage is measured with a weighted tape measure). The distance from a pre-determined point on the manhole at street level to the surface of the water during a storm is measured and subtracted from the distance from that point to the bottom of the channel measured prior to the storm. These tape-down measurements were performed to measure the water level within the MS4 to estimate flow. Loading estimates were then calculated based on flow measurements and constituent concentrations.

Tape-down measurements were taken coincident with the collection of grab samples, which were collected with a pre-cleaned bucket lowered into the storm drain. Storm water captured in the bucket was retrieved and distributed into the appropriate, pre-labeled containers for chemical analyses. All bottles were stored on ice (4° C) in coolers until delivery to the appropriate analytical laboratory in accordance with the chain-of-custody procedures described in the QAPP.

### 2.2.3 Sample Analyses

Wet weather pollutograph samples collected from the MS4 at the three sites during Storm 1 and Storm 2 were analyzed according to the laboratory methods listed in Table 2-1. Water samples collected at the most downstream station (LJ END) were analyzed for the full suite of constituents, whereas water samples collected from the residential (LJ RES) and open space (LJ CYN) sites were analyzed for particle size, total suspended solids (TSS), total metals, dissolved metals, and bacteria. For Storm 2, ammonia was analyzed at LJ END, whereas water column particulates at sites LJ CYN and LJ RES were analyzed for synthetic pyrethroids and the total metals: copper, lead, and zinc. The complete list of analytes can be found in Appendix A. In addition to laboratory analyses, field parameters were measured coincident with the collection of each grab sample. Field measurements of pH, temperature, and electrical conductivity were taken using a calibrated Oakton PH CON 10 water quality probe.

**Table 2-1. Analyses Performed on Subwatershed Pollutograph Samples**

| Analyte | Method | MS4 Water Samples | | |
|---|---|---|---|---|
| | | LJ RES | LJ CYN | LJ END |
| Field parameters | Field WQ probe | X | X | X |
| Grain size | Laser diffraction | X | X | X |
| TSS | SM 2540 D | X | X | X |
| Total and dissolved metals | EPA 200.8 | X | X | X |
| Indicator bacteria | Enterolert and multiple tube fermentation | X | X | X |
| Dissolved organic carbon (DOC) | EPA 415.1 | | | X |
| Turbidity | EPA180.1 | | | X |
| Oil & grease | EPA 1664A | | | X |
| Total organic carbon (TOC) | EPA 415.1 | | | X |
| Hardness | SM 2340 B | X | X | X |
| Polycyclic aromatic hydrocarbons (PAHs) | EPA 625m | | | X |
| Organophosphorus (OP) pesticides | EPA 625m | | | X |
| Synthetic pyrethroids | EPA 625m NCI | | | X |
| Ammonia | SM 4500-NH3 F | | | X |
| Synthetic pyrethroid particulate analysis | EPA 8270m NCI | X | X | |
| Copper, lead, and zinc particulate analysis | EPA 6020m | X | X | |

Shaded cells indicate analyses were performed on samples from Storm 2 only.

## 2.3 Offshore Water Sampling

Offshore water sampling during the 2007–2008 storm season was conducted on January 7, 2008, following the Storm 1 on January 5, 2008. Samples were collected mid-depth (i.e., 10 ft below the water’s surface) immediately seaward of the surf zone offshore from the Avenida de la Playa MS4 outfall at the base of the LJ END subwatershed (Figure 2-1). Multiple mid-depth water grab samples were collected using a pre-cleaned, 2-L Kemmerer bottle to collect a sufficient volume of sample water for analyses listed in Table 2-2. Offshore water samples were collected adjacent to the MS4 discharge pipe to correlate sediment and constituent concentrations observed in the ocean to those observed in the MS4.

After collection, water samples were sent on ice to CRG Marine Laboratories, Inc. (CRG) for chemical analyses and to WESTON for analysis of indicator bacteria and toxicity. All samples were sent to the designated laboratories under the proper storage conditions within holding times described in the QAPP. All chemical analyses were conducted following accepted standard methods and United States EPA protocols listed in Table 2-1 and in accordance with the analytical laboratory’s standard operating procedures.

**Table 2-2. Analyses Performed on Offshore Water and Sediment Samples**

| Analyte | Method | Offshore Samples | |
|---|---|---|---|
| | | Water | Sediment |
| **Chemistry** | | | |
| DOC | EPA 415.1 | X | X |
| Turbidity | EPA180.1 | X | X |
| Oil & grease | EPA 1664A | X | X |
| TOC | EPA 415.1 | X | X |
| Hardness | SM 2340 B | X | X |
| TSS | SM 2540 D | X | X |
| Total metals | EPA 200.8 | X | X |
| PAHs | EPA 625m | X | X |
| OP pesticides | EPA 625m | X | X |
| Chlorinated pesticides | EPA 625m | X | X |
| Synthetic pyrethroids | EPA 625mNCI | X | X |
| Ammonia-N | SM 4500-$NH_3$ F | X | X |
| Cyanide | SM 4500-CN E | X | X |
| Polychlorinated biphenyl (PCB) congeners | EPA 625m | X | X |
| Organotins | Krone et al., 1989 | X | X |
| Indicator bacteria | | X | X |
| VOCs | EPA 8260 B | X | X |
| Base/neutral extractable compounds | EPA 625m | X | X |
| Grain size | Laser Diffraction | X | |
| pH | SM 4500 H+ | X | |
| Dissolved metals | EPA 200.8 | X | |
| Chromium+6 | SM 3500-Cr D | X | |
| Residual chlorine | SM 4500-Cl G | X | |
| Triazines | EPA 625m | X | |
| Dioxins/furans | EPA 1613 B | X | |
| PCB aroclors | EPA 625m | | X |
| **Toxicity** | | | |
| Kelp bioassay | EPA/600/R-95/136 | X | |
| Mysid bioassay | EPA/821/R-02/012<br>EPA/821/R-02/014 | X | |
| Echinoderm bioassay | EPA/600/R-95/136 | X | |
| Amphipod bioassay | EPA/600/R-94/025 | | X |

Bioassay testing of water samples was conducted using giant kelp (*Macrocystis pyrifera*), mysid shrimp (*Mysidopsis bahia*), and purple sea urchins (*Strongylocentrotus purpuratus*). Bioassay testing followed accepted United States EPA procedures and WESTON standard operating procedures. Reference toxicity tests were conducted concurrently with the acute and chronic toxicity tests to establish sensitivity of the test organisms used in the evaluation of the post-storm nearshore water quality of the ASBS.

## 2.4 Offshore Sediment Sampling

Offshore sediment sampling was conducted on February 5, 2008, at the offshore site located seaward from the Avenida de la Playa MS4 outfall pipe (Figure 2-1). Benthic sediments were collected using a stainless-steel, 0.1$m^2$ Van Veen grab sampler deployed from the RV waterline. A sample was deemed acceptable if the surface of the grab was even, if there was minimal surface disturbance, and if there was a penetration depth of at least 5 cm. Rejected grabs were discarded and re-sampled. Sediment samples were collected at a depth of 5 m. Station coordinates, water depth, and other pertinent information in the sample (e.g., sediment type, color, odor, and amount of algal/grass cover) was recorded in field logs and is provided in Appendix B. The top 2 cm of sediment were composited and thoroughly homogenized using a stainless-steel mixing apparatus. Sediment within 1 cm of the sides of the grab was avoided. Subsamples for chemical analyses (Table 2-2) were collected and placed into certified clean glass jars with Teflon-lined lids. Sediment samples were shipped frozen to CRG within one week of collection. All chemical analyses were conducted following accepted standard methods and United States EPA protocols in accordance with the analytical laboratory's standard operating procedures.

In addition to chemical analyses, surficial sediment was also used for acute (10-day) amphipod toxicity testing. Three liters of sediment were collected for toxicity and were placed into three 1-L jars. Toxicity samples were then kept at 4° C on ice in coolers. The samples for acute toxicity were retained and analyzed by WESTON. A solid phase (SP) bioassay was performed in accordance with accepted United States EPA testing procedures outlined in *Methods for Assessing Toxicity of Sediment-Associated Contaminants with Estuarine and Marine Amphipods* (USEPA, 1994) and *ASTM Standard E1367-03* (ASTM, 2006) to estimate the potential toxicity of the collected sediment to benthic organisms. The sediment was tested in a 10-day SP test using the marine amphipod, *Eohaustorius estuarius* (Table 2-2). A 96-hour reference toxicity test was conducted concurrently with the sediment test to establish sensitivity of the test organisms used in the evaluation of the sediments.

# 3.0 TECHNICAL ANALYSIS

## 3.1 Water Quality

The primary water quality constituents identified in the La Jolla Shores Coastal Watershed Management Plan were sediment (TSS and turbidity), metals (particularly copper), and fecal indicator bacteria (SIO et al., 2008). Additional lower-priority water quality constituents were listed as octa-chlorinated dibenzo-p-dioxins (expressed as 2,3,7,8 Tetrachloro-dibenzo-p-Dioxin (TCDD) equivalents), polycyclic aromatic hydrocarbons (PAHs), and synthetic pyrethroids. To assess the relationship among these constituents and land use, grain size, TSS, indicator bacteria, and metals (total and dissolved) were monitored over the course of a storm at all three sites. Additional constituents were monitored only at the bottom of the largest subwatershed, which represents a mixed land use (LJ END), including organophosphorus (OP) pesticides, synthetic pyrethroids, and PAHs. The larger suite of constituents were monitored at LJ END because it incorporates both residential and open space land uses, and it is the largest drainage in the La Jolla Shores Coastal Watershed (Figure 2-1). Discussion of primary and secondary constituents is provided in this section. The entire data set is presented in Appendix C.

### 3.1.1 Primary Constituents

#### *3.1.1.1 Total Suspended Solids and Turbidity*

***Storm 1 – January 5, 2008***
TSS concentrations were monitored over the course of the storm at the three subwatershed sites to produce site-specific pollutographs for the storm event (Figure 3-1 through Figure 3-4). At LJ CYN, a site that receives primarily open space /canyon runoff, TSS concentrations during the first monitored storm event generally increased over time. Water samples collected at LJ CYN had TSS values ranging from 130 mg/L at the onset of the storm to 4,533 mg/L at the end of the storm. In contrast, TSS concentrations ranged from 6–80 mg/L at LJ RES, a site that receives primarily residential runoff. TSS concentrations at LJ RES were highest during the initial portion of Storm 1. On average, TSS concentrations were approximately 45 times higher at LJ CYN than at LJ RES. At LJ END, TSS ranged from 66–408 mg/L and peaked during the middle of the storm event.

Several reasons may exist as to why TSS increased dramatically at the end of the storm during what appear to be low flow conditions. A second small band of rain, which had not yet influenced the hydrograph, occurred at the end of Storm 1 prior to collection of the final sample Figure 3-2. Because the objective of the sampling event was to capture the rise and fall of the hydrograph from a discreet event, sampling was not extended to capture additional flows following the return of the hydrograph to pre-storm flow conditions. This small band of rain, however, may not explain the substantial jump in TSS exhibited at LJ CYN. The rise in TSS at LJ CYN may have been the result of mudflow-like conditions in which saturated ground in the canyon area began sloughing off into the storm drain system and slowly made its way to the sampling location.

Turbidity was analyzed at Site LJ END only. Turbidity values in each of the nine pollutograph samples were above the WQO (20 nephelometric turbidity units (NTUs)) for surface water within the Scripps Hydrologic Area. Turbidity was lowest at the onset of the storm and ranged from 37–195 NTUs over the course of the storm event.

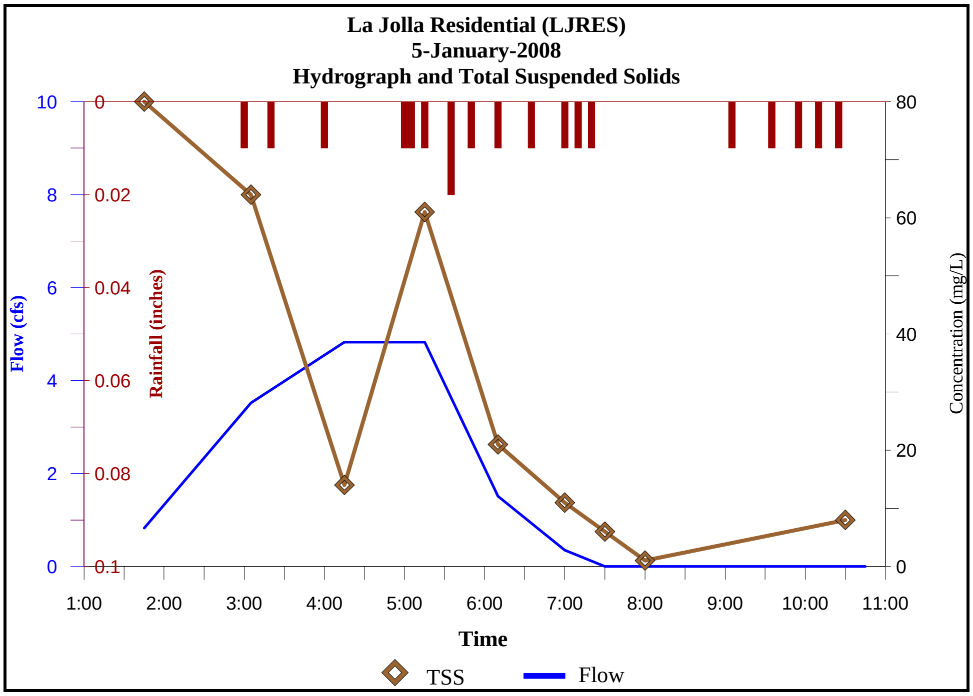



**Figure 3-1. Total Suspended Solids Concentrations at LJ RES (residential land use) over the Course of a Storm Event – January 5, 2008**

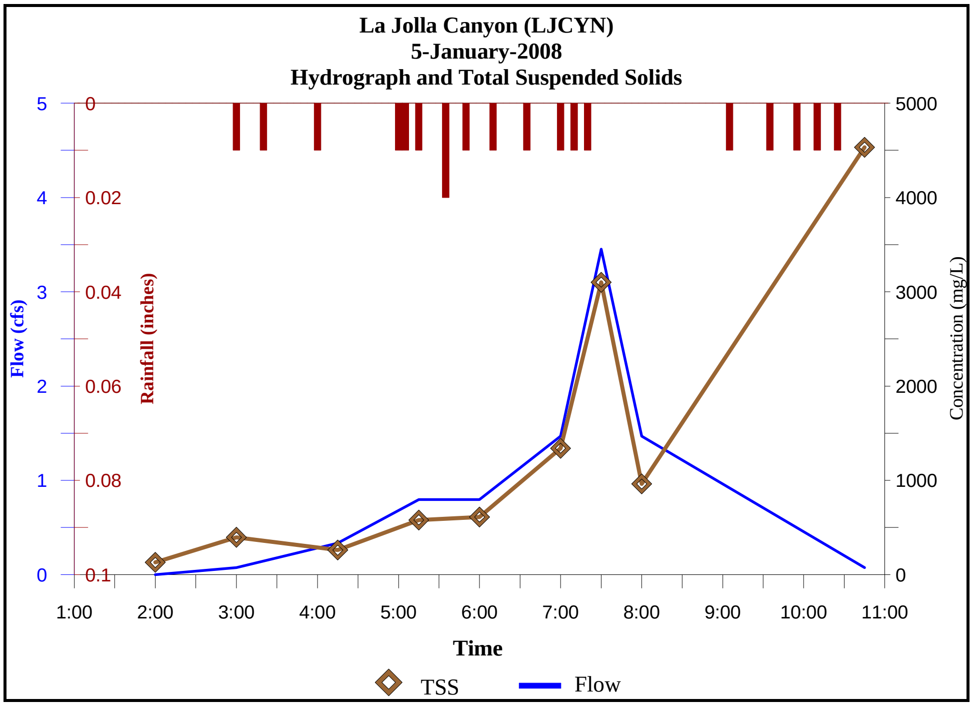



**Figure 3-2. Total Suspended Solids Concentrations at LJ CYN (open space land use) over the Course of a Storm Event – January 5, 2008**

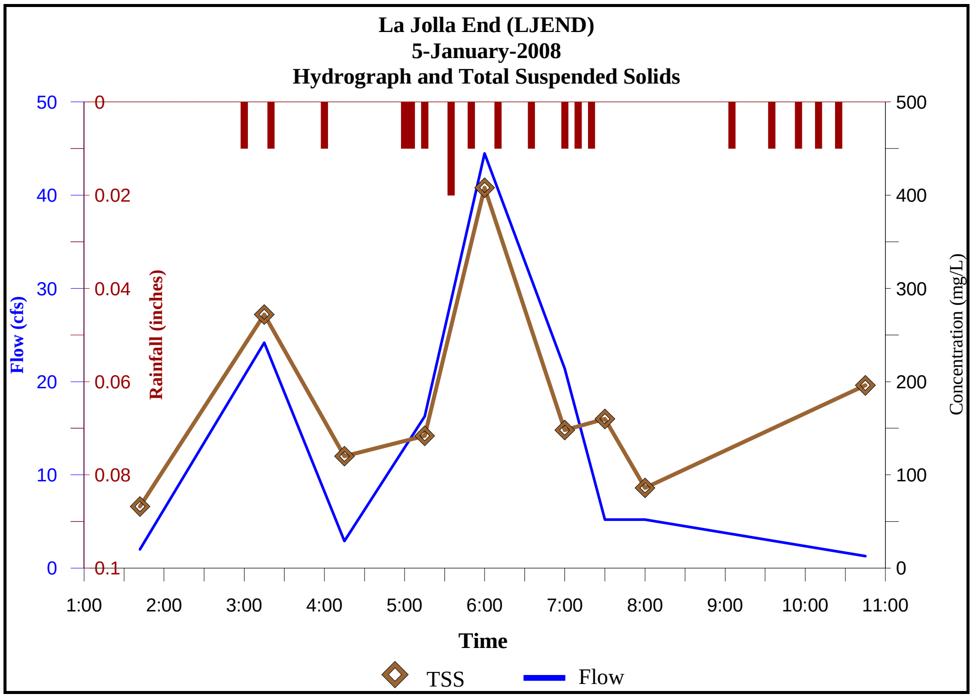



**Figure 3-3. Total Suspended Solids Concentrations at LJ END (mixed land use) over the Course of a Storm Event – January 5, 2008**

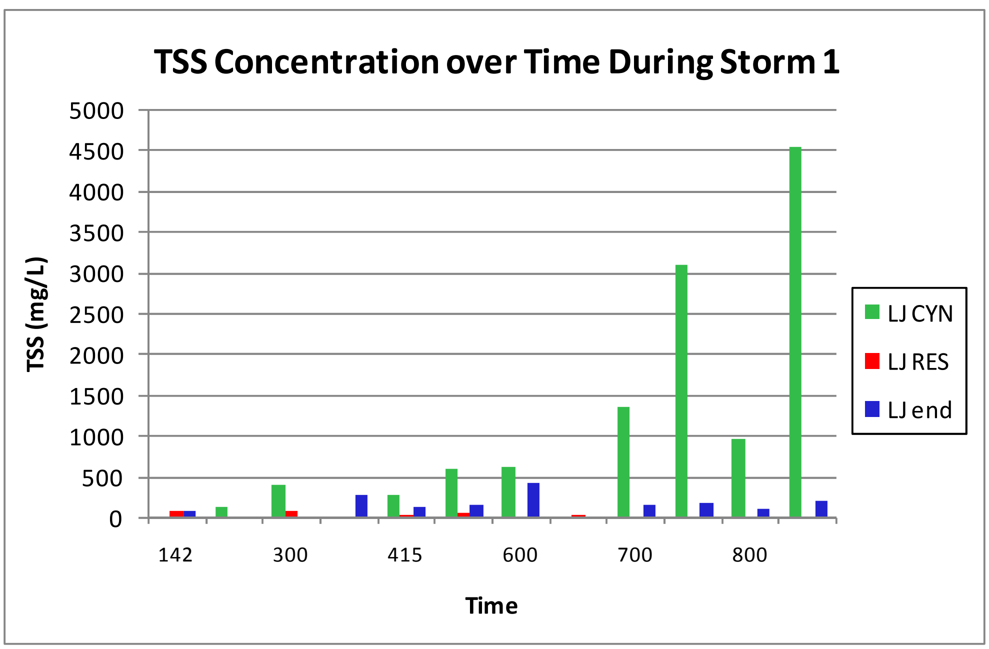



**Figure 3-4. Total Suspended Solids Concentrations across All Sites During Storm Event 1 – January 5, 2008**

***Storm 2 – December 15, 2008***

Site-specific pollutographs of TSS concentrations were produced for Storm 2 (Figure 3-5 through Figure 3-8). At LJ CYN, TSS concentrations remained relatively static during the initial three hours of the storm despite a sharp peak in flow during that time period. Between 13:00 and 14:30, the TSS concentration at LJ CYN increased from less than 100 mg/L to a peak of greater than 7,600 mg/L (Figure 3-6). Two hours following the TSS peak, a decline to baseline levels was observed. At LJ RES and LJ END, the TSS concentrations followed a similar pattern to that of LJ CYN. TSS concentrations declined slightly over the initial portion of the storm (first peak flow) before increasing in concert with the site's hydrograph. Water samples collected at LJ RES and LJ END had TSS values ranging from 14–103 mg/L, respectively, just prior to the second peak of the hydrograph to 202–1,106 mg/L, respectively, during the second peak of the hydrograph. On average, TSS concentrations were approximately 25 times higher at LJ CYN than at LJ RES and five times higher at LJ CYN than at LJ END.

Turbidity was analyzed at LJ END only. Turbidity values in each of the eight pollutograph samples were above the WQO (20 NTUs) for surface water within the Scripps Hydrologic Area. Turbidity peaked with TSS during the second peak in the storm hydrograph and was lowest at the end of the storm event.

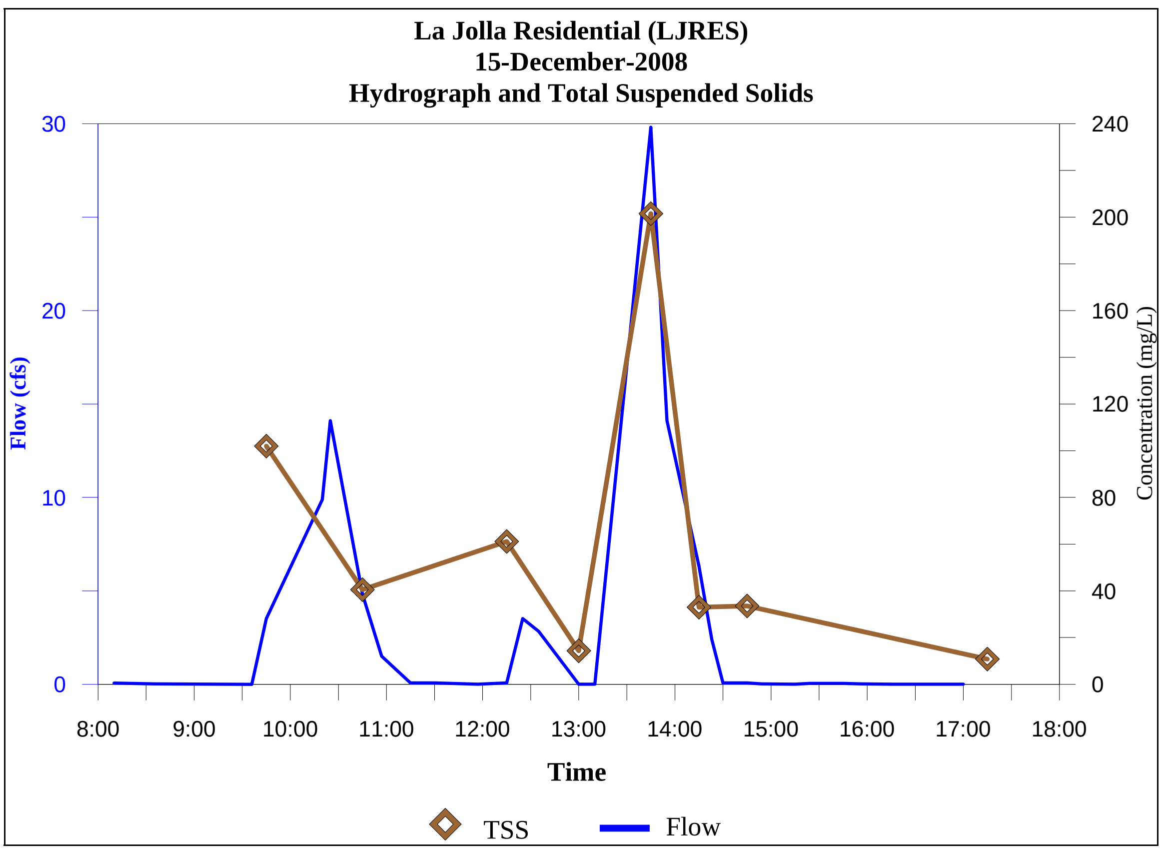



**Figure 3-5. Total Suspended Solids Concentrations at LJ RES during Storm 2 – December 15, 2008**

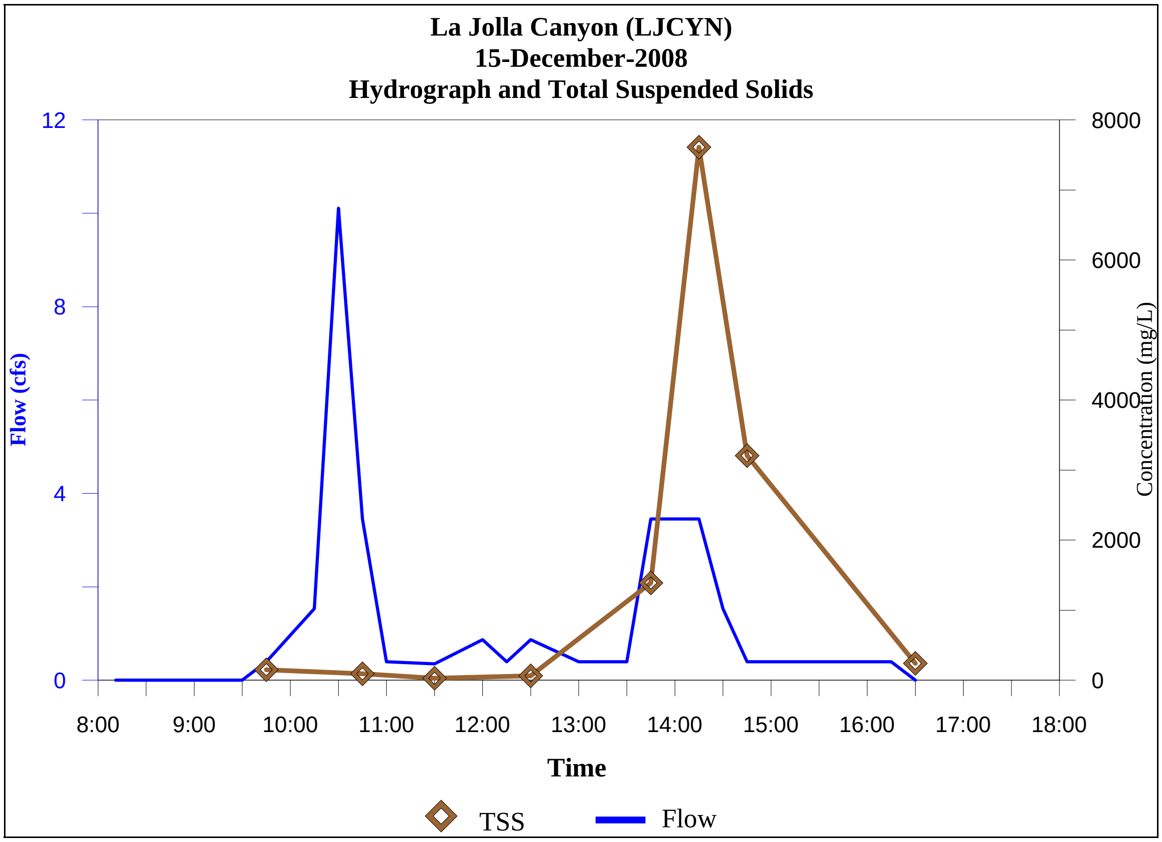



**Figure 3-6. Total Suspended Solids Concentrations at LJ CYN during Storm 2 – December 15, 2008**

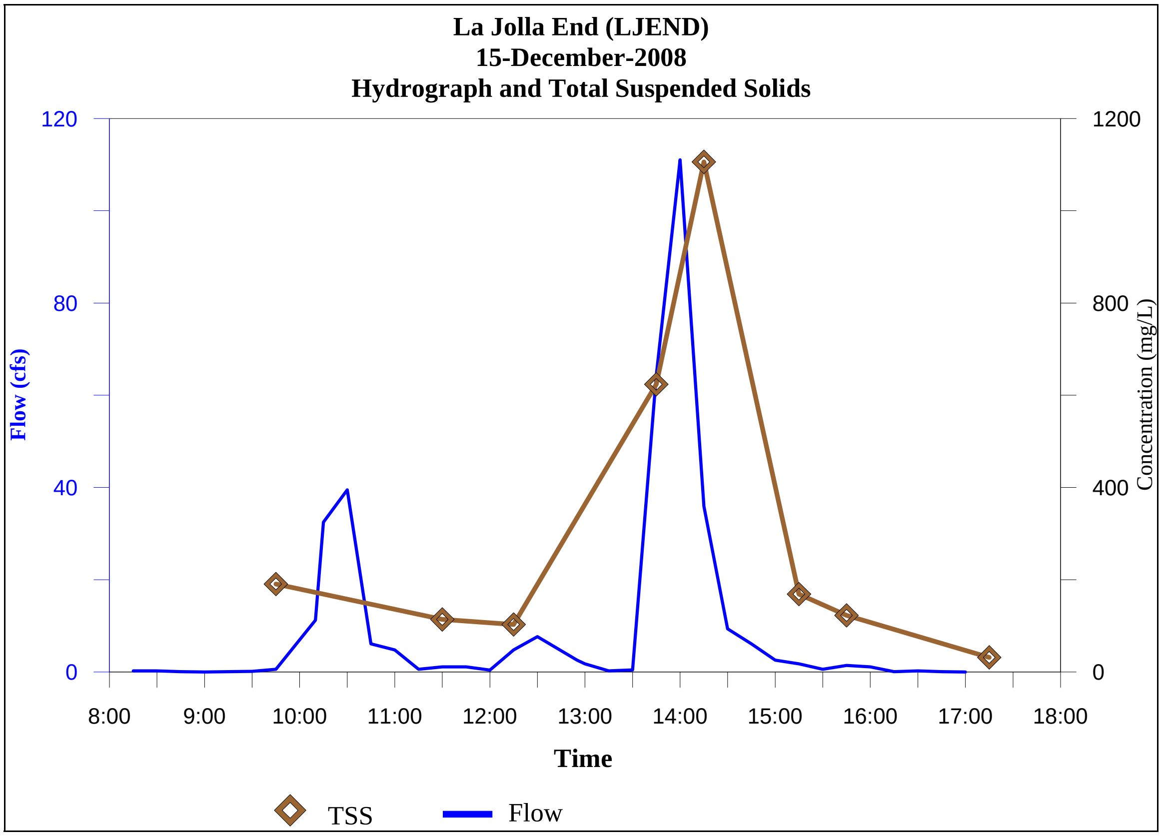



**Figure 3-7. Total Suspended Solids Concentrations at LJ END during Storm 2 – December 15, 2008**

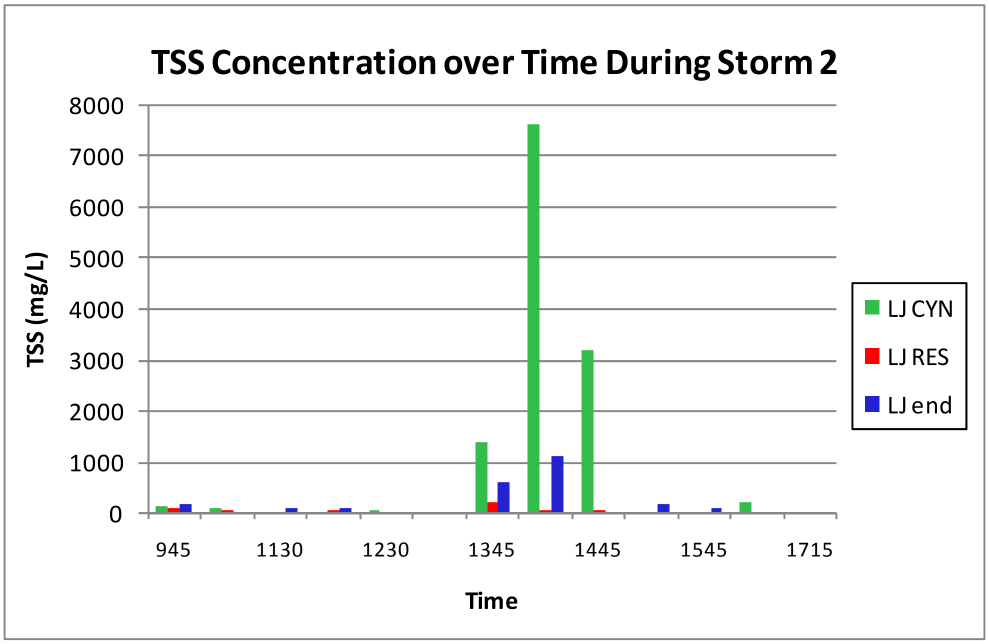



**Figure 3-8. Total Suspended Solids Concentrations across All Sites During Storm Event 2 – December 15, 2008**

#### *3.1.1.2 Grain Size*

***Storm 1 – January 5, 2008***

Due to holding time exceedances, results of grain size analyses for LJ RES and LJ CYN were not used. Results of grain size analysis for LJ END were performed within the holding time. The median grain size at LJ END was greatest during the first flush (65 μm). Following the first flush, a reduction in median grain size at LJ END was observed over the course of the storm. A reduction in median grain size was associated with peak flow, which occurred at approximately 06:00 at LJ END. Grain size ranged from 65 μm during the first flush to 5 μm at the end of Storm 1.

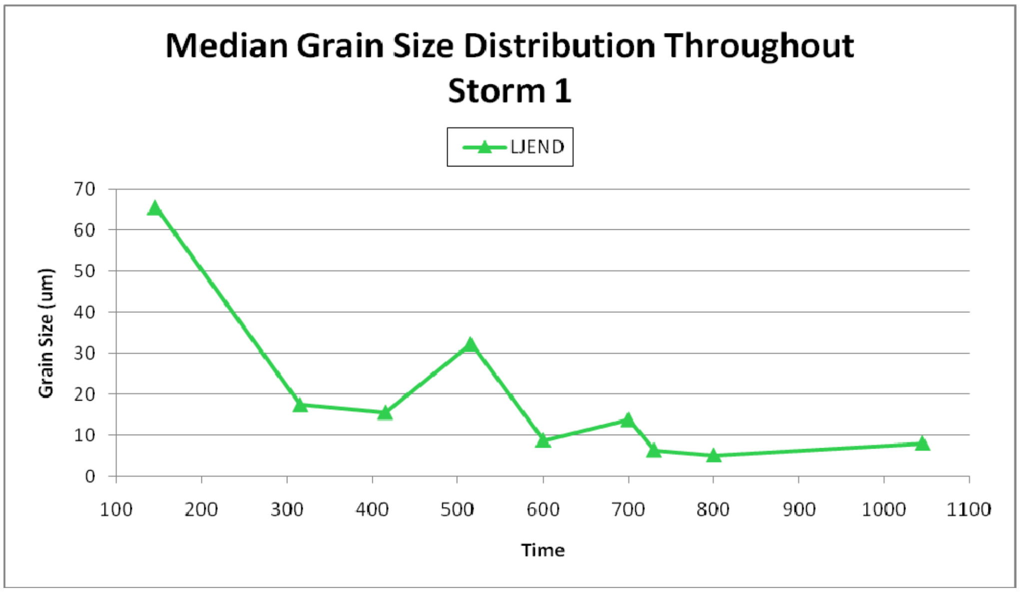



**Figure 3-9. Median Grain Size over Time at LJ END on January 5, 2008**

***Storm 2 – December 15, 2008***

Average grain size from pollutograph sampling at each of the land use sampling locations is shown on Figure 3-10. During Storm 2, median grain sizes at LJ RES were substantially larger (primarily sands and silts) than the grain sizes at LJ CYN and LJ END (primarily silts and clays). Median grain size at LJ RES varied from 12 μm during peak flow of Storm 2 to 141 μm during a low flow period between the first and the second flow peaks. Median grain sizes at LJ CYN and LJ END varied little over the course of the storm event, ranging from less than 5 μm to 18 μm. During the initial portion of the storm, the average grain size at LJ RES was approximately seven times larger than at LJ END and LJ CYN. Although larger particles were detected in the initial stages of Storm 2, approximately 90% of the total TSS volume was generated during the second peak in flow. A similar scenario was observed during Storm 1.

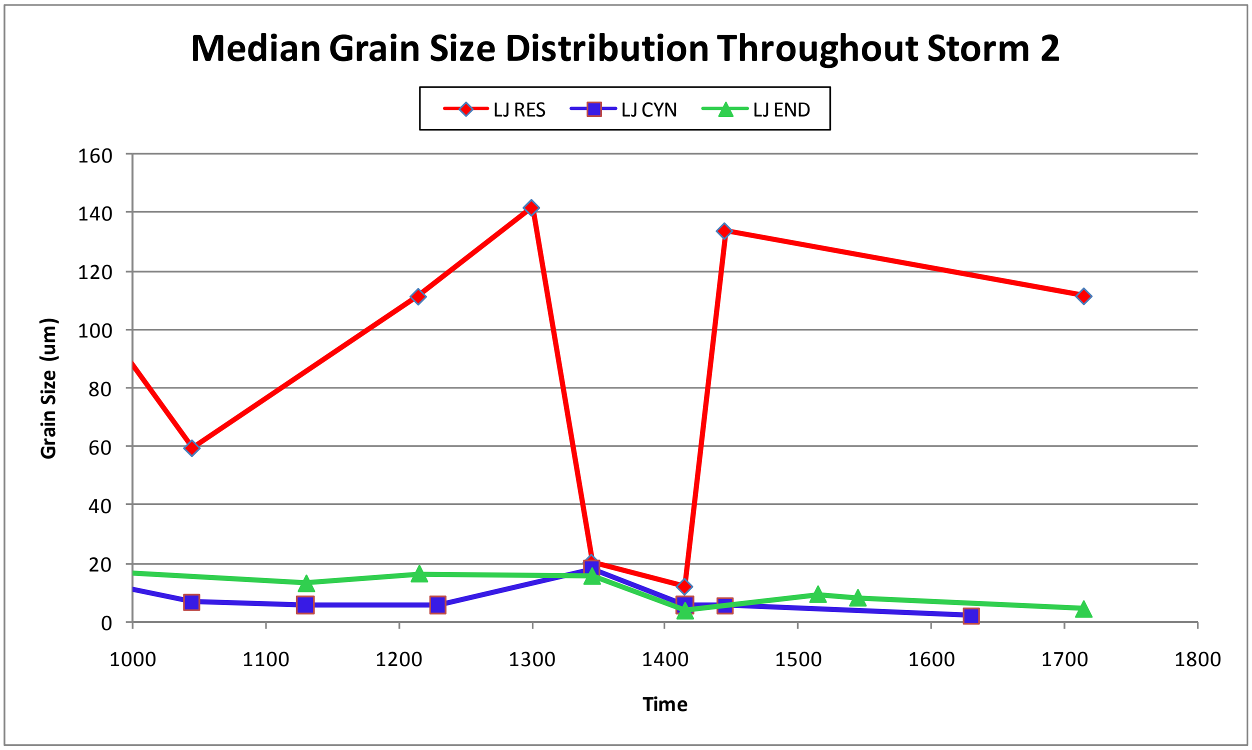



**Figure 3-10. Median Grain Size over Time at LJRES, LJCYN, and LJEND – December 15, 2008**

Grain size as a percentage of the total particulate mass is shown for each land use sampling location on Figure 3-11. As shown on Figure 3-11, clays and silts comprised the majority of the particulates at LJ CYN and LJ END, whereas sand comprised the majority of the particulate mass at LJ RES. Across all sites, the percentage of fined grained particles mobilized in the storm water runoff increased during the second peak of the hydrograph. At the end of Storm 2, almost no sand was detected in storm water runoff at LJ CYN and LJ END, whereas at LJ RES, sand constituted greater than 80% of the suspended particulate mass. Figure 3-11 depicts the fractions of clay, silt, and sand found in storm water at each of the three land use sampling locations throughout the entirety of the storm event.

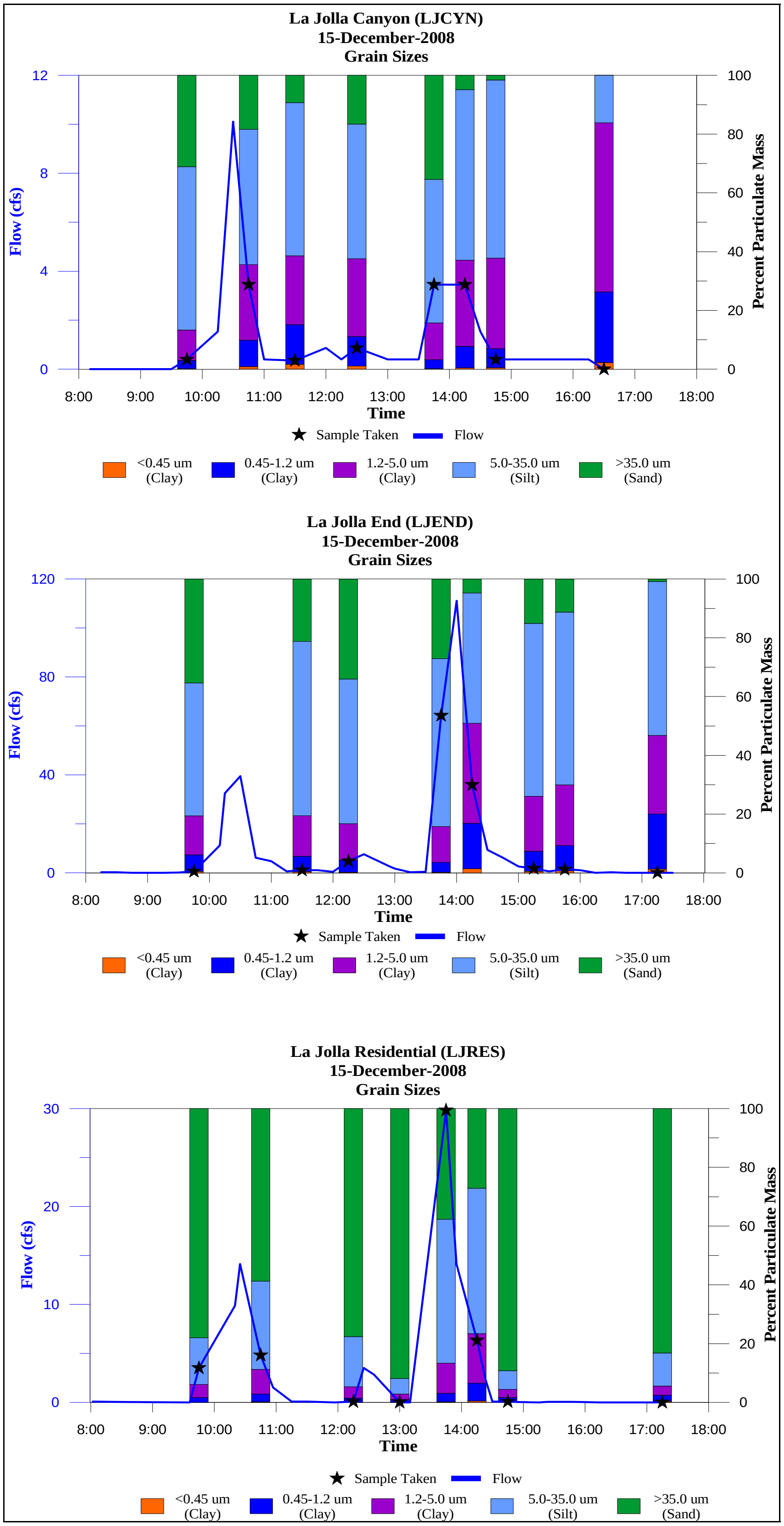



**Figure 3-11. Grain Size as a Percentage of Total Particulate Mass**

#### 3.1.1.3 Metals

***Storm 1 – January 5, 2008***

Pollutographs for total and dissolved copper, lead, and zinc for all three sites are presented on Figure 3-12. Both total and dissolved copper and zinc concentrations exhibited a first flush effect, where concentrations are high at the onset of the storm as easily mobilized pollutants are washed off. Concentrations then typically decrease as rains continue until the hydrograph begins to peak. Total and dissolved lead concentrations did not display a first flush effect and varied little from between sites or over time. At site LJ CYN, total and dissolved zinc peaks preceded the hydrograph peak, whereas total copper and total lead peaks corresponded with peak flow. Concentrations of total and dissolved zinc at LJ RES peaked following peak flow, whereas total and dissolved copper remained relatively static. Dissolved zinc concentrations were substantially higher at LJ RES than at either LJ CYN or LJ END. Total and dissolved zinc and copper concentrations exhibited only minor fluctuations over Storm 1 after the first flush. Across all sites, total and dissolved copper concentrations increased at the end of Storm 1 and were correlated with increased TSS. As previously explained, the increase in TSS at the end of the Storm 1 may have resulted from an additional small band of rain moving through the area or, in the case of LJ CYN, mudflow-like conditions.

Although concentrations were variable, dissolved copper concentrations were above California Toxics Rule acute water quality objectives ($WQO_a$) in 67% of samples collected from LJ CYN and in 100% of samples collected from LJ RES and LJ END during Storm 1. Total copper concentrations during Storm 1 were above the $WQO_a$ in 100% of samples collected across all sites during Storm 1.

Total zinc concentrations from Storm 1 were above the $WQO_a$ in 100% of samples from LJ RES, LJ CYN, and LJ END. Dissolved zinc concentrations at LJ RES were above the $WQO_a$ for all samples, while only first flush samples from LJ CYN and LJ END were above the dissolved zinc $WQO_{a.}$

Total lead concentrations were above the $WQO_a$ in 67% of samples from LJ RES, 11% of samples from LJ CYN, and 33% of samples from LJ END. Dissolved lead concentrations were all below California Toxics Rule acute and chronic water quality objectives at LJ CYN, while at LJ RES and LJ END dissolved lead was above the chronic water quality objective ($WQO_c$) in 78% and 67% of the samples, respectively.

Total and dissolved arsenic, chromium, and nickel concentrations throughout Storm 1 were all below California Toxics Rule $WQO_a$ and $WQO_c$ values.

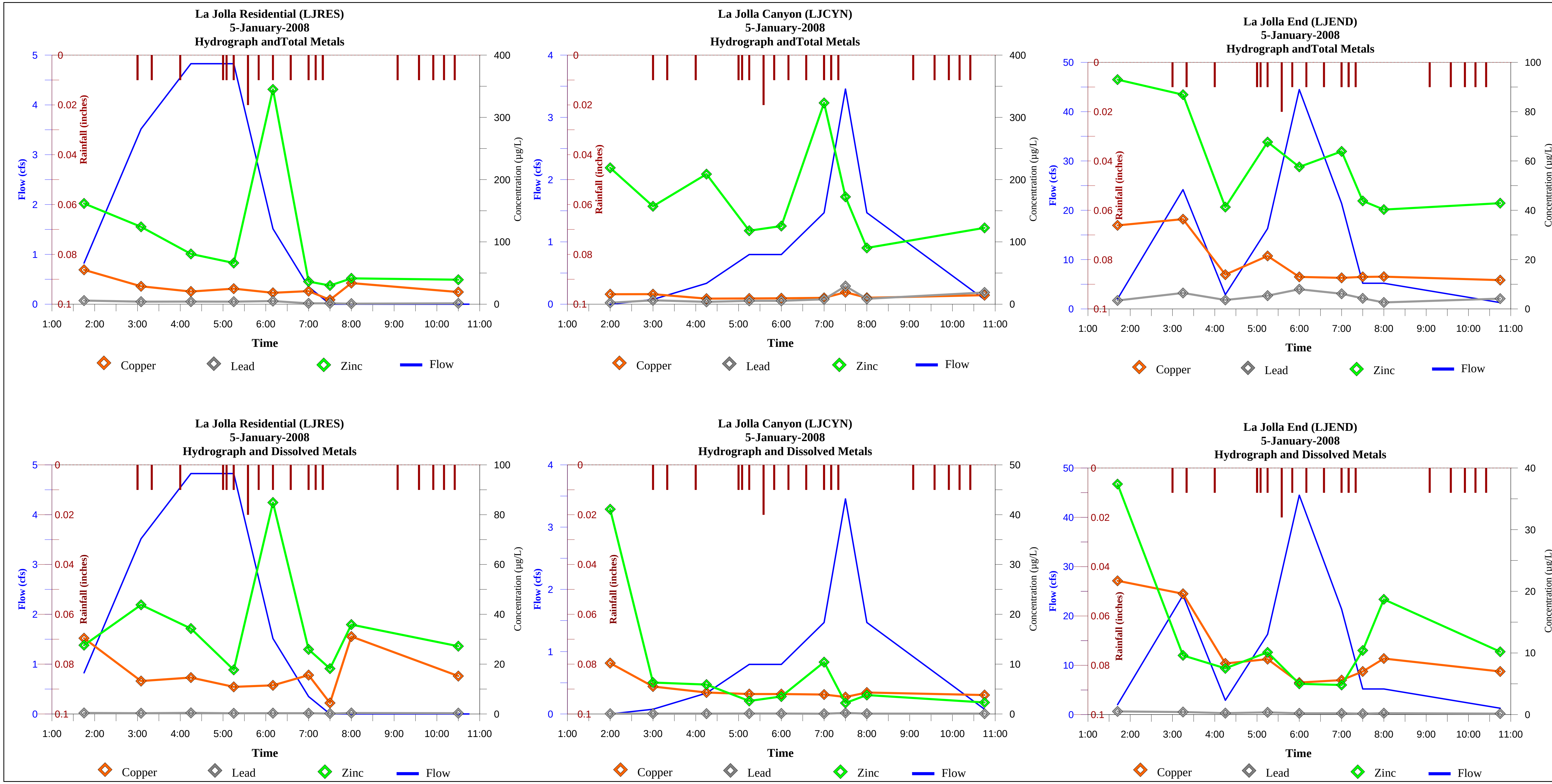



**Figure 3-12. Metal Concentrations over Time at LJ RES (residential land use), LJ CYN (canyon land use), and LJ END (mixed land use) – January 5, 2008**

***Storm 2 – December 15, 2008***

*Metals*

Pollutographs for total and dissolved copper, lead, and zinc for all three sites are presented on Figure 3-13. Similar to Storm 1, both total and dissolved copper and total and dissolved zinc concentrations exhibited a first flush effect across all sites. With the exception of total zinc at LJ CYN, total copper and total zinc concentrations generally followed the storm hydrograph at each site and were well correlated with TSS concentrations. Initial runoff mobilized high concentrations of both total and dissolved metals. As runoff and TSS decreased, total metals concentrations also decreased, whereas dissolved metal concentrations generally increased. Since metals have a propensity to bind to fine particulates, high TSS concentrations can correspond with a lowering of the ratio between dissolved metals and total metals. Similarly, when low TSS concentrations are present, a greater fraction of total metals may enter into the liquid phase. Many different properties, however, can influence the dissolved to total metal ratio. These properties include water temperature, pH, hardness, and concentrations of metal binding sites (e.g., TSS and dissolved organic carbon (DOC)) (USEPA, 1996). As shown on Figure 3-14, the percentage of total copper in the dissolved phase at both LJ RES and LJ CYN was correlated with TSS concentrations (R-square values of 0.83 and 0.58, respectively).

Total lead concentrations increased during the second peak in the hydrograph across all sites. Dissolved lead was generally at or below reporting limits at LJ CYN, whereas it was elevated above the $WQO_c$ at LJ RES and LJ CYN. All samples across all sites, with the exception of one sample collected at the end of Storm 2 at LJ CYN, were above hardness-based $WQO_a$ and $WQO_c$ criteria for total and dissolved copper. The total zinc concentration exceeded the $WQO_a$ and $WQO_c$ criteria in 88%, 63%, and 75% of the samples collected from LJ CYN, LJ END, and LJ RES, respectively. Dissolved zinc exceeded the $WQO_a$ in 21% of the samples collected across all sites.

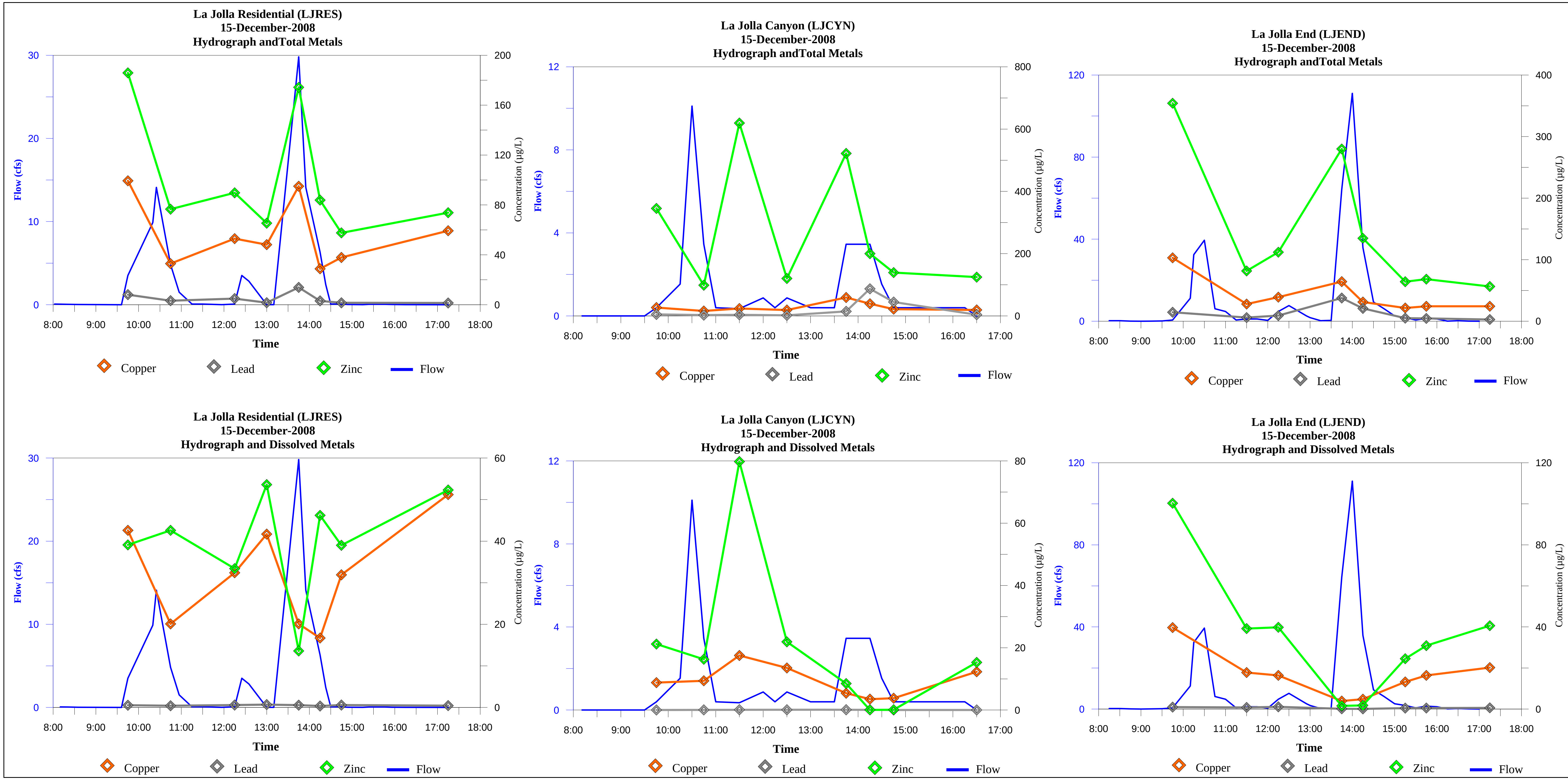
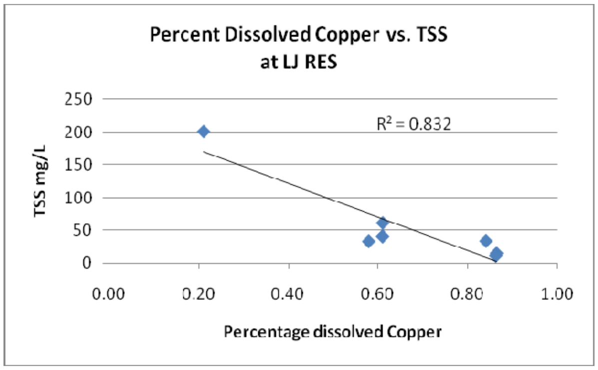



**Figure 3-13. Metal Concentrations over Time at LJ RES (residential land use), LJ CYN (canyon land use), and LJ END (mixed land use) – December 15, 2008**



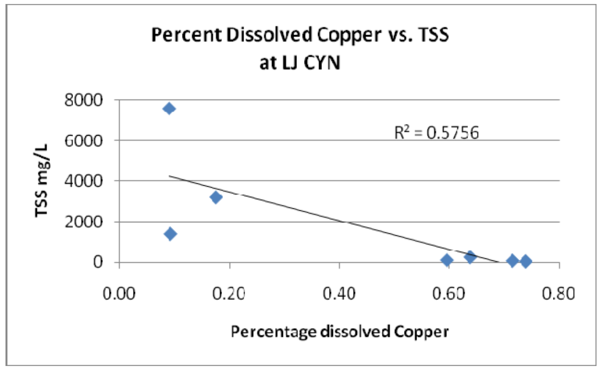




**Figure 3-14. Percentage of Total Copper Comprised by Dissolved Copper at LJ RES and LJ CYN during Storm 2**

### *3.1.1.4 Fecal Indicator Bacteria*

***Storm 1 – January 5, 2008***

Fecal coliform levels within the City's MS4s were elevated above Basin Plan guidance criteria at sampling locations LJ RES, LJ CYN, and LJ END (Figure 3-15). Enterococcus concentrations at the offshore sampling location were below Ocean Plan guidance criteria (Figure 3-15). Fecal coliform concentrations varied over time and between sampling locations. The fecal coliform concentration at LJ CYN peaked during the initial portion of the storm and then declined before rising slightly as flow increased. The enterococcus concentration at LJ CYN varied by approximately one logarithm over the course of Storm 1, rising slightly as flow increased. At LJ RES, fecal coliform concentrations varied by approximately one logarithm, with the exception of one sample which was measured at the reporting limit of 20 MPN/100 mL.

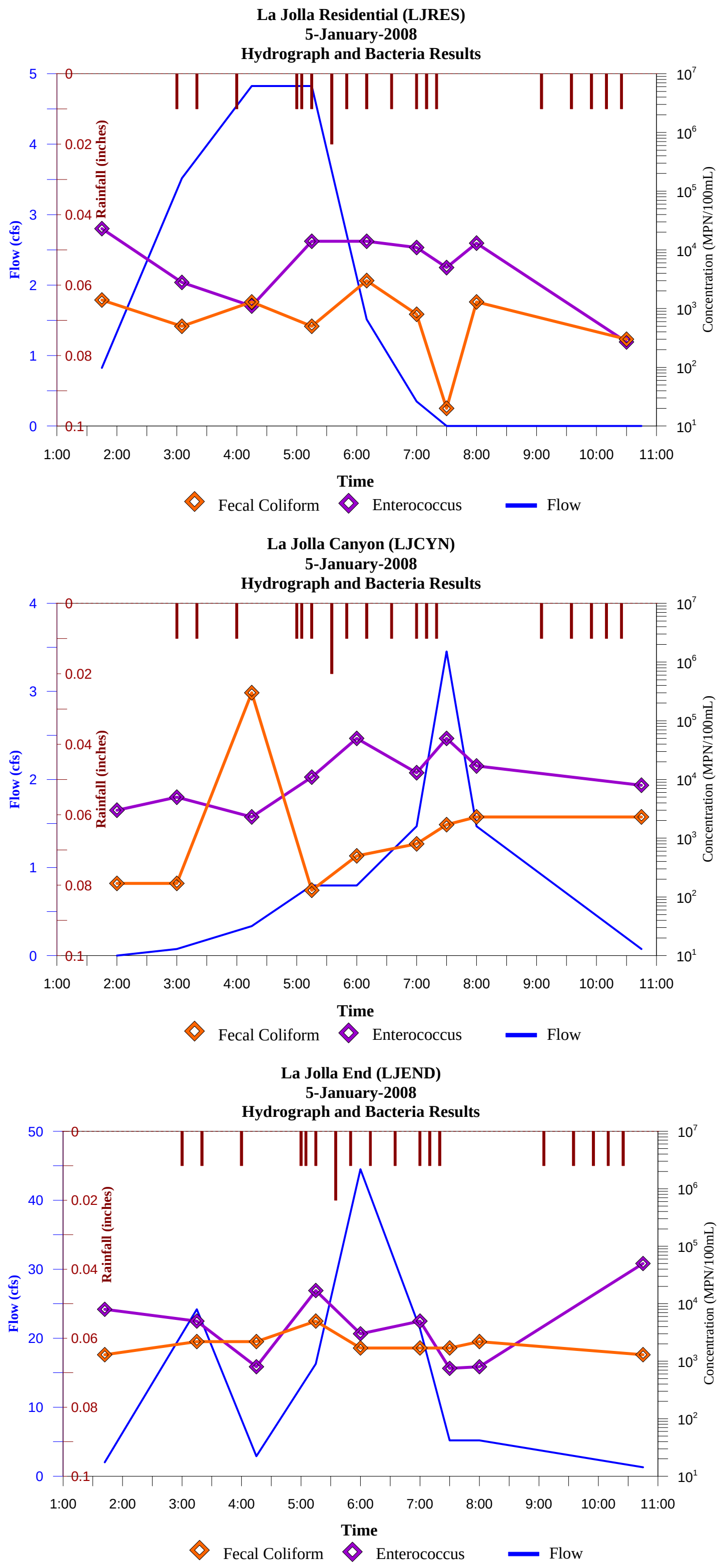



**Figure 3-15. Fecal Coliform and Enterococcus Concentrations over Time at LJ RES (residential land use), LJ CYN (open space land use), and LJ END (mixed land use) – January 5, 2008**

***Storm 2 – December 15, 2008***

Fecal coliform levels within the City's MS4s were elevated above Basin Plan guidance criteria at sampling locations LJ RES, LJ CYN, and LJ END (Figure 3-15). Fecal coliform concentrations at LJ CYN remained relatively constant throughout the majority of Storm 2 before declining sharply at the end of the storm event. Total coliform concentrations at LJ CYN increased substantially during the second peak in flow, whereas enterococcus concentrations fluctuated little from the onset to the end of Storm 2. A decline in total coliform and fecal coliform concentrations at LJ RES was observed between the first peak flow and second peak flow; concentrations increased slightly during the second peak in flow. Enterococcus concentrations at LJ RES remained relatively constant throughout Storm 2. Similarly, at LJ END, enterococcus concentrations varied little across the duration of Storm 2, whereas total and fecal coliform concentrations increased slightly during the second peak in flow.

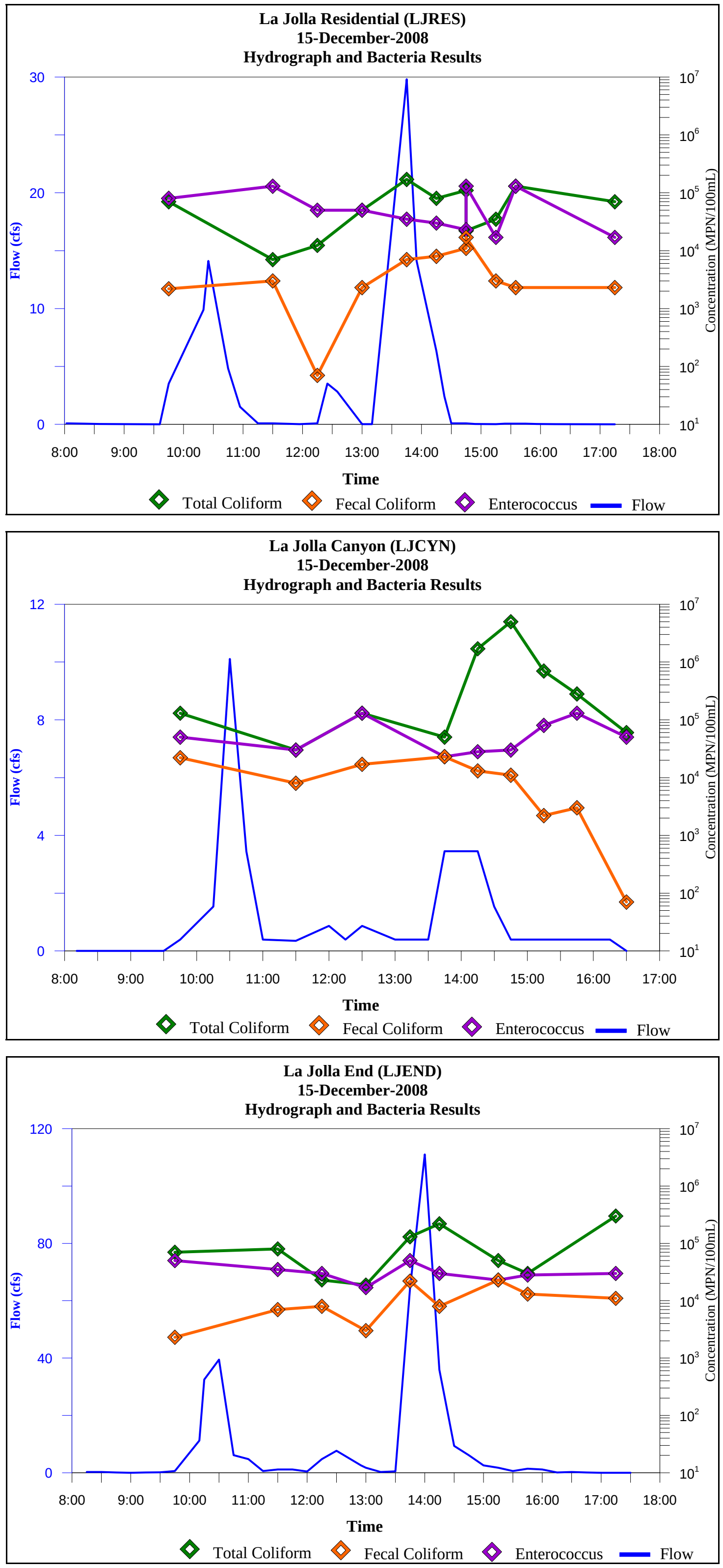



**Figure 3-16. Indicator Bacteria Concentrations over Time at LJ RES (residential land use), LJ CYN (open space land use), and LJ END (mixed land use) – December 15, 2008**

### 3.1.2 Secondary Constituents

#### *3.1.2.1 Dioxins/Furans (expressed as TCDD equivalents)*

***Storm 1 – January 5, 2008***

TCDD equivalents were analyzed in water samples collected from the offshore sampling location. Nearly all of the detected dioxins/furans were comprised of octa-chlorinated and penta-chlorinated dibenzo-p-dioxins (Appendix C). Dioxins are ubiquitous in the environment, primarily formed through combustion of fossil fuels. Their presence in La Jolla may be the result of aerial deposition from wild fires, recreational bonfires, air emissions, and diesel exhaust (Baker and Hites, 2000). The total toxic equivalency quotient (TEQ) of detected dioxins and furans was $1.37\text{x}10^{-9}$ µg/L, which was below the Ocean Plan's criteria of $3.9 \text{ x } 10^{-9}$ µg/L for a 30-day average.

***Storm 2 – December 15, 2008***

Dioxins and furans were not analyzed during Storm 2.

#### *3.1.2.2 Polycyclic Aromatic Hydrocarbons*

***Storm 1 – January 5, 2008***

PAHs were detected in each of the pollutograph samples collected at LJ END (Figure 3-17). There is no WQO listed for PAHs in the San Diego Basin Plan. PAHs exhibited a first flush effect and generally rose and fell with the hydrograph at LJ END. Total PAHs in the offshore water sample were below the Ocean Plan water quality benchmark (Appendix C). PAHs are a group of over 100 different chemicals formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. Sources for PAHs in the La Jolla area include automobile exhaust, used engine oil, asphalt roads, cigarette smoke, recreational bonfires, and other forms of fossil-fuel combustion (e.g., wild fires).

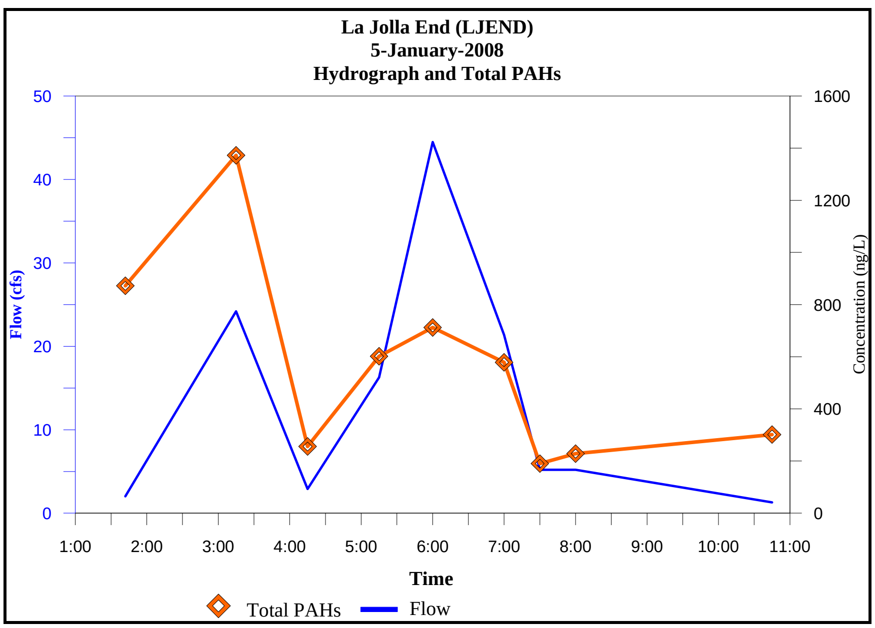



**Figure 3-17. Pollutograph of Polycyclic Aromatic Hydrocarbon Concentration at LJ END on January 5, 2008**

***Storm 2 – December 15, 2008***

PAHs were detected in each of the pollutograph samples collected at LJ END during Storm 2 (Figure 3-18). As in Storm 1, pollutograph results depict elevated PAH concentrations during the storm's first flush. This phenomenon is generally attributed to a buildup of contaminants washed into storm drains from impermeable surfaces (e.g., roadways). After the first flush phenomenon, PAH concentrations rose and fell with the LJ END hydrograph.

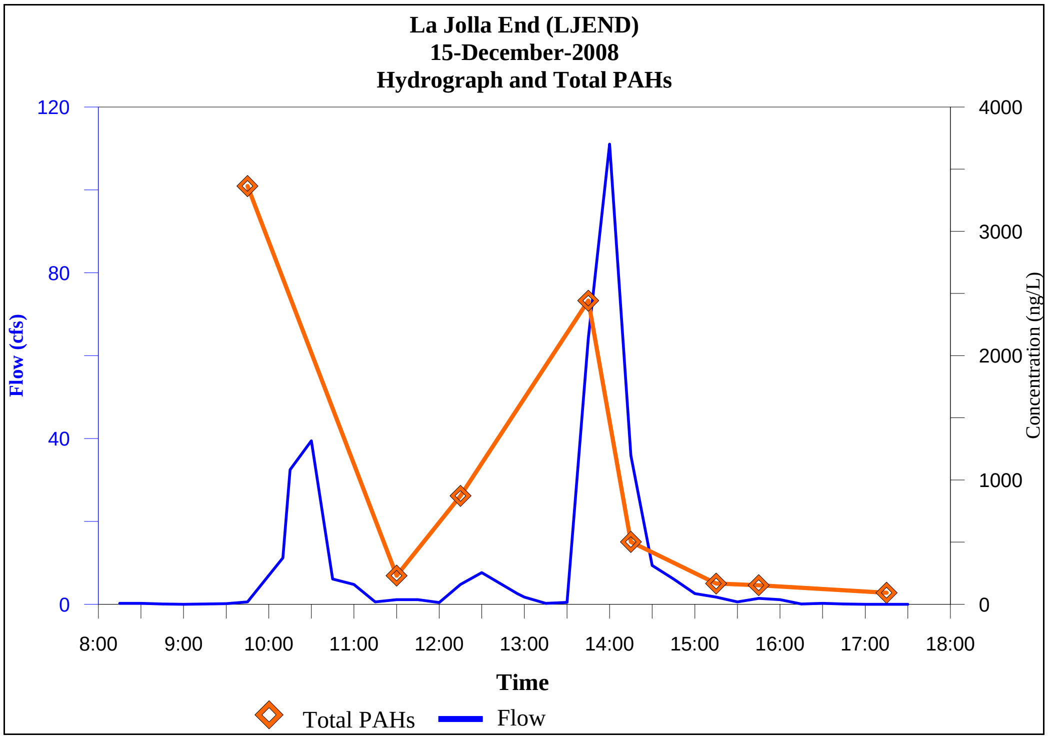



**Figure 3-18. Pollutograph of Polycyclic Aromatic Hydrocarbon concentration at LJ END on December 15, 2008**

### *3.1.2.3 Organophosphorus Pesticides*

***Storm 1 – January 5, 2008***

The OP pesticides, Chlorpyrifos and Malathion, were detected in all samples at LJ END (Appendix C). A first flush effect was exhibited by Malathion (Figure 3-19) and Chlorpyrifos. Subsequent to the initial flush of storm water, Malathion concentrations leveled off and diminished only slightly throughout the storm, whereas Chlorpyrifos concentrations diminished to a greater extent over time. No other OP pesticides (e.g., Diazinon) were detected. Because Diazinon was phased out in 2005, increased concentrations of Chlorpyrifos and Malathion have been detected in storm water runoff within San Diego County (WESTON, 2007c).

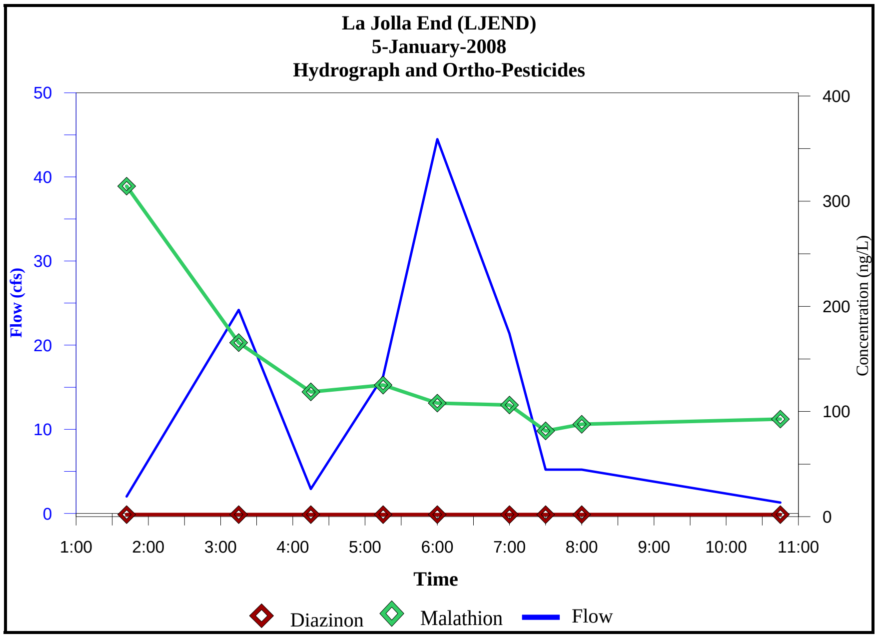



**Figure 3-19. Pollutograph of Diazinon and Malathion Concentrations at LJ END**

***Storm 2 – December 15, 2008***

OP pesticides were detected in all samples at LJ END (Appendix C). Malathion and Diazinon were detected in 88% and 63% of the samples collected, respectively. No other OP pesticides were detected, with the exception of Fenitrothion in one sample. Pollutograph results depict elevated Malathion concentrations during the storm's first flush, and during peak flow.

### *3.1.2.4 Synthetic Pyrethroids*

***Storm 1 – January 5, 2008***

Synthetic pyrethroids were detected in water samples collected from LJ END (Appendix C). Concentrations of synthetic pyrethroids were greatest during the first flush of storm water runoff. After the initial three hours of rain, synthetic pyrethroid concentrations diminished substantially and by the end of the storm event, were nearly all below reporting limits (Figure 3-20). Bifenthrin, Cyfluthrin, and Cypermethrin were among the most commonly detected synthetic pyrethroids. Within the City, synthetic pyrethroids are considered to be emerging contaminants with the potential to be a long-term issue.

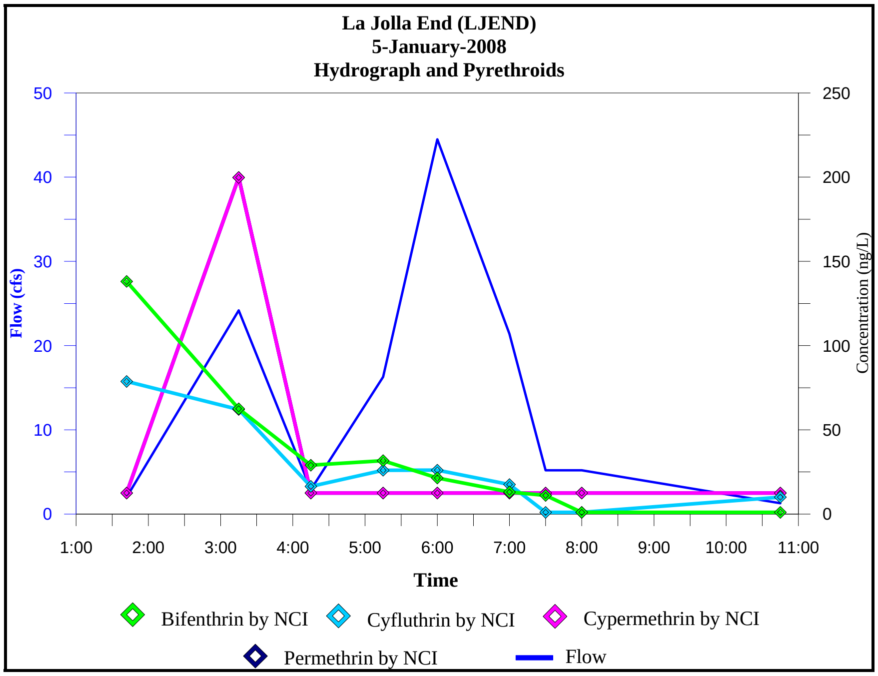



**Figure 3-20. Pollutograph of Synthetic Pyrethroid Concentrations at LJ END**

***Storm 2 – December 15, 2008***

Bifenthrin, Cyfluthrin, and Cypermethrin were the most commonly detected synthetic pyrethroids during Storm 2. Bifenthrin and Cyfluthrin were detected in all samples, whereas Cypermethrin was detected in all but the final two samples. Similar to Storm 1, synthetic pyrethroid concentrations were highest during the first flush. Unlike Storm 1, pyrethroid concentrations during Storm 2 also increased during the time of peak flow.

## 3.2 Particulate Chemistry

Analysis of particulate size classes was performed during Storm 2 to determine which size fractions of suspended particulates were correlated with the majority of the contaminant load and if these fractions varied based upon land use. Stacked bar graphs of the percentage of total copper and total zinc associated with differing grain sizes are shown on Figure 3-21 and Figure 3-22. For both copper and zinc, the grain size associated with the majority of the contaminant load varied somewhat throughout the course of the storm. Initially, at LJ CYN, the copper load was relatively evenly distributed among three size fractions, >35 µm, 5–35 µm, and <0.45 µm (dissolved). At the end of the storm event, however, the <0.45 µm size fraction accounted for over 50% of the suspended sediment-bound (SSB) copper, whereas less than 3% of the SSB copper was associated with grains larger than 35 µm. At LJ RES, the total copper mass was also somewhat evenly distributed across the three size fractions, >35 µm, 5–35 µm, and <0.45 µm. After the second peak in flow, however, the copper was increasing associated with silts and clays (5–35 µm and <0.45 µm size classes, respectively). At the end of the Storm 2, copper bound to LJ RES particulates was almost exclusively associated with particulates smaller than 0.45 µm.

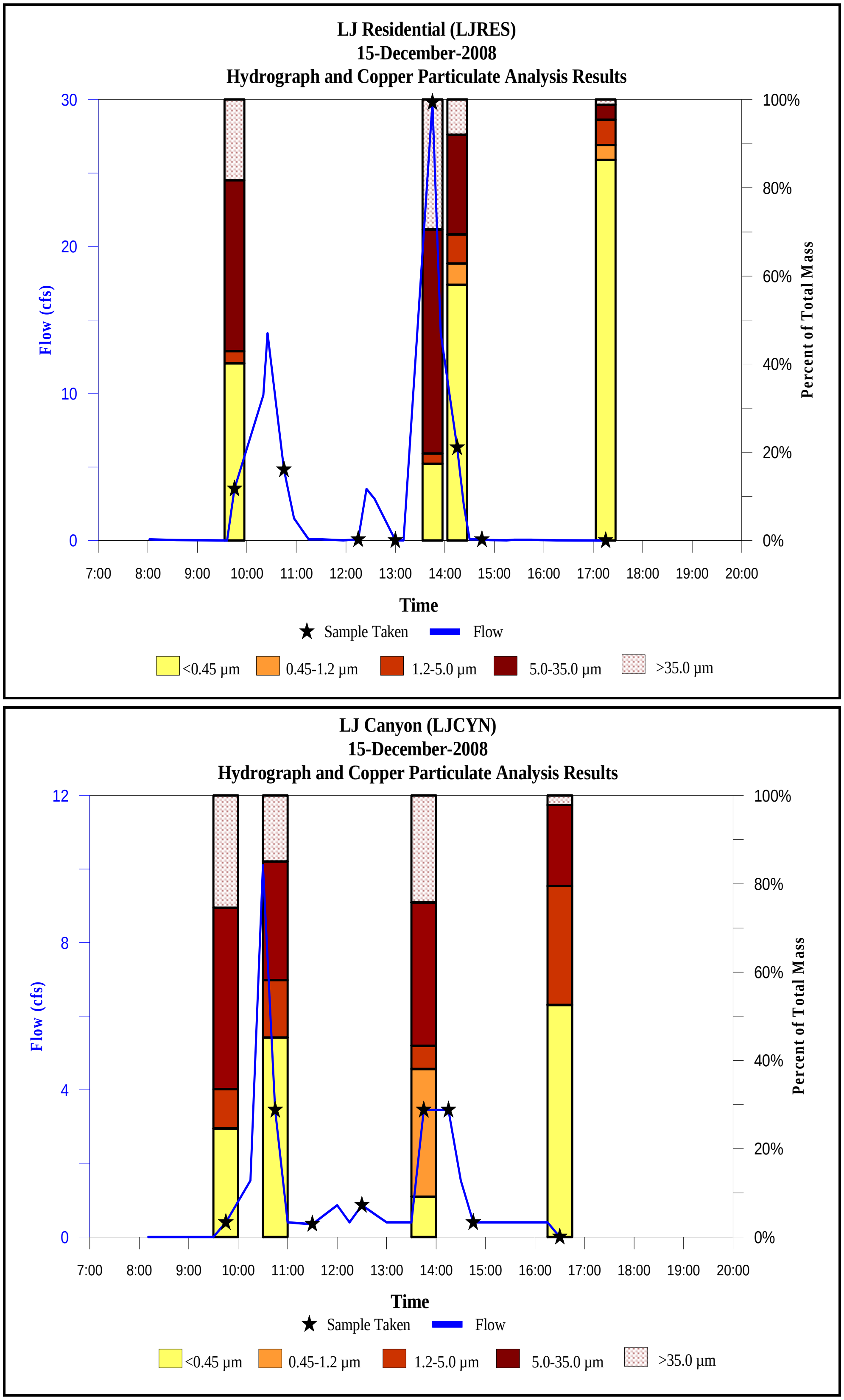



**Figure 3-21. Percentage of Total Copper Associated with Suspended Grains during Storm 2 at LJ RES and LJ CYN**

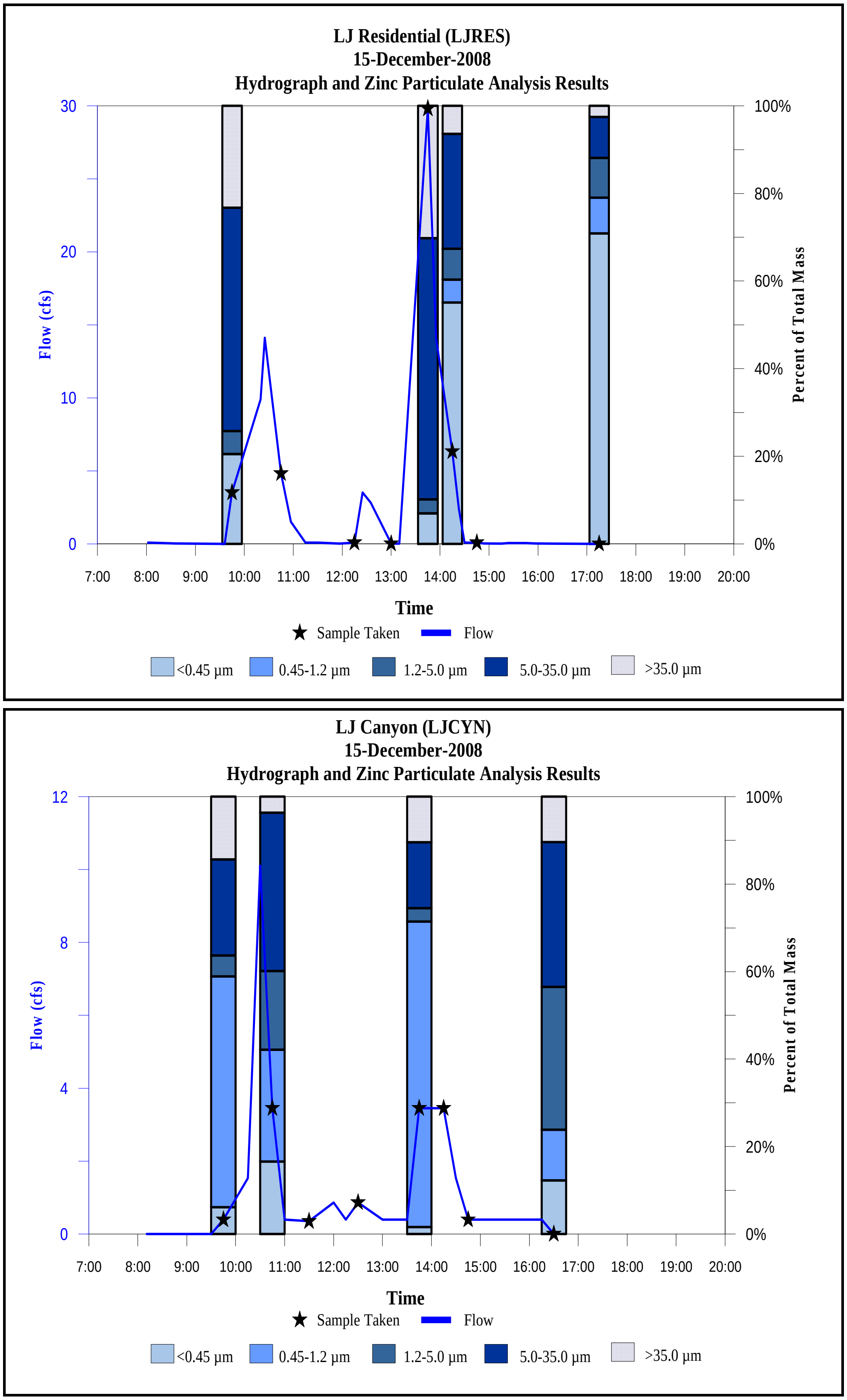



**Figure 3-22. Percentage of Total Zinc Associated with Suspended Grains during Storm 2 at LJ RES and LJ CYN**

At LJ CYN, zinc was associated mostly with fine clays (0.45–1.2 μm) and, to a lesser extent, with silts (5–35 μm) during the initial portion of the storm (Figure 3-22). During peak flow at LJ CYN, nearly 70% of the zinc mass was associated with clay particulates, whereas during lower flows, zinc was predominantly associated with silts and clays. At LJ RES, results of particulate analysis of zinc followed a similar pattern to that of copper; as the storm progressed, zinc became increasing associated with the smaller sized particles. Approximately 70% of the total zinc mass was associated with particulates smaller than 0.45 μm (dissolved phase) at the end of Storm 2.

Lead was associated primarily with silt and sand particulates at LJ CYN during the beginning of Storm 2 and with silt and clay particulates at the end of Storm 2. During peak flow at LJ CYN, lead was evenly distributed among sand, silt, and clay particulates. At LJ RES, lead was almost exclusively found in sand and silt particulates through the middle of Storm 2. At the end of Storm 2, lead was primarily distributed among silts, clays, and particulates smaller than 0.45 μm (dissolved phase).

Sediment bound synthetic pyrethroids were also examined in particulate analyses. LJ CYN particulate samples were largely devoid of synthetic pyrethroids; two samples at LJ CYN contained particulates with esfenvalerate (5–35 μm) and one sample contained Bifenthrin (1.2–5 μm). Cyfluthrin, Bifenthrin, Fluvinate, and Cypermethrin were detected in particulate samples from LJ RES. With the exception of Cyfluthrin, which was associated with sand, silt, and clay particulates, pyrethroids were detected in either silt (5–35 μm) or clay (1.2–5 μm) grain size fractions.

## 3.3 Sediment Chemistry

Sediment chemistry was analyzed following Storm 1. Concentrations of heavy metals in ASBS sediment samples were low and all were below established Effects Range – Low toxicity values. In addition to metals, chemical analyses of ammonia, cyanide, organotins, PAHs, polychlorinated biphenyl (PCB) aroclors and congeners, organochlorine (OC) and OP pesticides, synthetic pyrethroids, volatiles, and semi-volatiles were also performed. With the exception of ammonia, none of the analytes within any of these groups were above laboratory detection limits, indicating that exposure to sediments collected immediately offshore from the Avenida de la Playa MS4 would not be expected to result in toxic effects to marine organisms.

## 3.4 Toxicity Testing of Offshore Sediment

Toxicity testing was performed using sediment collected from a site located directly offshore from the Avenida de la Playa storm drain in La Jolla Shores. A marine amphipod species (*Eohaustorius estuarius*) was tested to help determine biological impacts from sediment and contaminants carried in storm water runoff to species living within the ASBS marine ecosystem sediment. Bioassay testing of one sediment sample was preformed concurrently with the testing of one laboratory control sample. Interstitial and overlying ammonia levels were monitored at the beginning and end of the test. A cadmium chloride reference toxicant test was also performed to ensure proper sensitivity of the test species. A summary of test results is provided in Table 3-1.

Mean percent survival of *E. estuarius* exposed to La Jolla Shores test sediment was 96%, whereas mean percent survival in the control sediment was 93%, indicating that no toxicity was observed. The cadmium chloride reference toxicant test indicated that the sensitivity of *E. estuarius* used in the assessment of test sediments fell within the normal range.

**Table 3-1. Results of Solid Phase Toxicity Test Using *Eohaustorius estuarius***

| Composite Area ID | Amphipods (*Eohaustorius estuarius*) | | | | |
|---|---|---|---|---|---|
| | Overlying Total Ammonia Concentration (mg/L) | | Interstitial Total Ammonia Concentration (mg/L) | | % Survival |
| | Initial | Day 10 | Initial | Day 10 | |
| Control | <0.500 | <0.500 | <0.500 | <0.500 | 93.0 |
| LJ-ASBS | 0.940 | 5.34 | 4.27 | 6.45 | 96.0 |

| Cadmium chloride reference toxicant test | | | |
|---|---|---|---|
| | Concentration (mg/L) | % Survival | $LC_{50}$ (mg/L) |
| | Control | 93.3 | 2.50 |
| | 2.50 | 46.7 | |
| | 5.00 | 16.7 | |
| | 10.0 | 3.30 | |
| | 20.0 | 0.00 | |
| | 40.0 | 0.00 | |

## 3.5 Post-Storm Toxicity Testing of Offshore Water

Toxicity testing was performed using water collected during post-storm sampling of Storm 1. Water was collected directly offshore from the Avenida de la Playa storm drain. Three approved ocean species (i.e., mysid shrimp, giant kelp, and purple sea urchins) were tested to help determine biological impacts from storm water runoff to species living within the ASBS marine ecosystem. The toxicity testing included both acute and chronic bioassays. Acute testing was performed on mysid shrimp, whereas chronic testing was performed on giant kelp, mysid shrimp, and purple sea urchins. The rationale for performing both acute and chronic testing was that acute testing represents short-term conditions (e.g., storm water entering the ASBS) and examines acute impacts (e.g., mortality) from short-term exposures to storm water effluent and its receiving water. Chronic testing, on the other hand, focuses on longer-term exposures that may be more typical of ocean samples and examines both lethal (mortality) and sublethal endpoints (growth and reproduction) in test species.

No-observed-effect concentration (NOEC) and lowest-observed-effect concentration (LOEC) values were 100% for all test species, indicating the samples were not toxic to the test organisms. Results of bioassay tests are provided in Table 3-2.

**Table 3-2. Acute and Chronic Toxicity Results for Giant Kelp, Mysid Shrimp, and Sea Urchins Exposed to Post-Storm Offshore Water Samples Collected January 7, 2008**

| Test Species | Test Type | Endpoint | NOEC (%) | LOEC (%) | EC50 (%) | TUc |
|---|---|---|---|---|---|---|
| *Mysidopsis bahia* (Mysid shrimp) | Acute | 96-hour survival | 100 | >100 | >100 | TUa = 0.51 |
| | Chronic | 7-day survival | 100 | >100 | >100 | 1 |
| | | 7-day combined endpoint | 100 | >100 | >100 | 1 |
| *Macrocystis pyrifera* (Giant kelp) | Chronic | Proportion germinated | 100 | >100 | >100 | 1 |
| | | Growth-length | 100 | >100 | >100 | 1 |
| *Strongylocentrotus purpuratus* (Purple sea urchin) | Chronic | Proportion fertilized | 100 | >100 | >100 | 1 |

# 4.0 FLOW AND LOADING

The relatively small size of the watershed, steep canyon areas, soil types, and impervious surfaces within La Jolla Shores Coastal Watershed accelerate its ability to drain quickly. As a result, flows within this watershed are typically highly responsive to the onset and termination of rainfall events. Flow at LJ END could not be monitored using a flowmeter due to the steep pipe bed slope (0.016 ft/ft). A flowmeter was installed prior to a storm on December 7, 2007, but the high velocities tore out the sensor. Therefore, an alternative flow assessment methodology had to be developed.

Flow depth in the vault that connects the upstream and downstream pipes of LJ END was measured using a tape-down methodology. Field staff obtained these depth measurements from street level (12.25 ft above the floor of the vault) using a weighted tape measure and flashlight. Tape-down measurements were collected on January 5, 2008 and December 15, 2008, during sampling. For safety reasons, field staff was unable to enter the vault to obtain velocity measurements during these storms. Field observations indicated high velocities, a hydraulic jump within the vault no greater than 2 inches (noted during the December 2008 storm event), and ineffective areas (dead water) along the sides of the vault.

Flow assessment using these tape-down measurements underwent a lengthy and iterative process. First, flow was modeled in the upstream pipe using Manning's Equation (n=0.013) and the pipe dimensions measured during site reconnaissance. The hydraulic radius and area was calculated using the assumption that water depths in the vault were directly translatable to the depths in the upstream pipe (1:1 ratio). Second, the Manning's flow model was set aside, because during the quality assurance (QA) / quality control (QC) review prior to the December 2008 storm event, WESTON hydrologists hypothesized that the abrupt change in bed slope at the vault entrance would result in a significant hydraulic jump, invalidating the assumptions underlying the Manning's calculation. Flow at LJ END was modeled using HEC-RAS. The HEC-RAS model comprised of an inlet pipe (6-ft diameter, 0.016 ft/ft) and an outlet pipe (6-ft diameter, 0.020 ft/ft) placed on center around a 4-ft by 7-ft, flat bottom, concrete vault. Two 0.5-ft ineffective flow areas, set on either side of the 6-ft pipe along the full length of the vault, were incorporated into the HEC-RAS model. A rating curve was developed downstream of the hydraulic jump in the vault. Although the HEC-RAS model for the vault produced flows that were feasible, further analysis using the rational method, standard pipe nomographs, and other QA/QC checks indicated that these flows were not reasonable for the following reasons:

- Inherent inaccuracies in the tape-down measurement process.
- The 0% bed slope of the vault dissipated a significant amount of energy, but the model overestimated the hydraulic jump. Storm flow profiles produced by the model include hydraulic jumps two to six times larger than those actually observed, resulting in an underestimation of storm flows.
- The hydraulic jump caused the velocities through the vault to be significantly smaller than observed (based on best professional judgment).

It was again assumed that the flows modeled in the upstream pipe would be more accurate than flows in the vault. Using the water surface elevations presented in the profile function of HEC-RAS, a rating curve was manually created for the upstream pipe, 3.3 ft upstream of the entrance to the vault. The tape-downs for the vault were again assumed to equate to depths in the upstream pipe at a 1:1 ratio. As shown in Table 4-1, the outputs for the upstream pipe were comparable to the Manning's Equation output. These flows also more closely resemble the nomograph data for pipe diameter, discharge, and $D_{critical}/D_{full}$ ratios than the original modeled flows.

**Table 4-1. Calculated Flows for January 5, 2008 Storm at LJ END Using Three Different Methods**

| Site | Stage | Manning's Upstream Pipe Method | HEC-RAS Vault Method | HEC-RAS Upstream Pipe Method |
|---|---|---|---|---|
| **LJ END** | 1.17 in | 44.48 cfs | 11.03 cfs | 36.25 cfs |

***Storm 1 – January 5, 2008***

Flow among the three sampling locations varied considerably. Flow at LJ RES peaked during the first several hours of rain before quickly returning to near base-flow conditions (Figure 4-1). In contrast, flow at LJ CYN remained near base-flow conditions for the first several hours of rainfall then gradually peaked around 07:30 before quickly returning back to base flow conditions. At Site LJ END, which drains a much larger area of the watershed than either LJ RES or LJ CYN (Figure 2-1), flow was bimodal with an initial peak at 03:15 followed by a larger peak at 06:00.

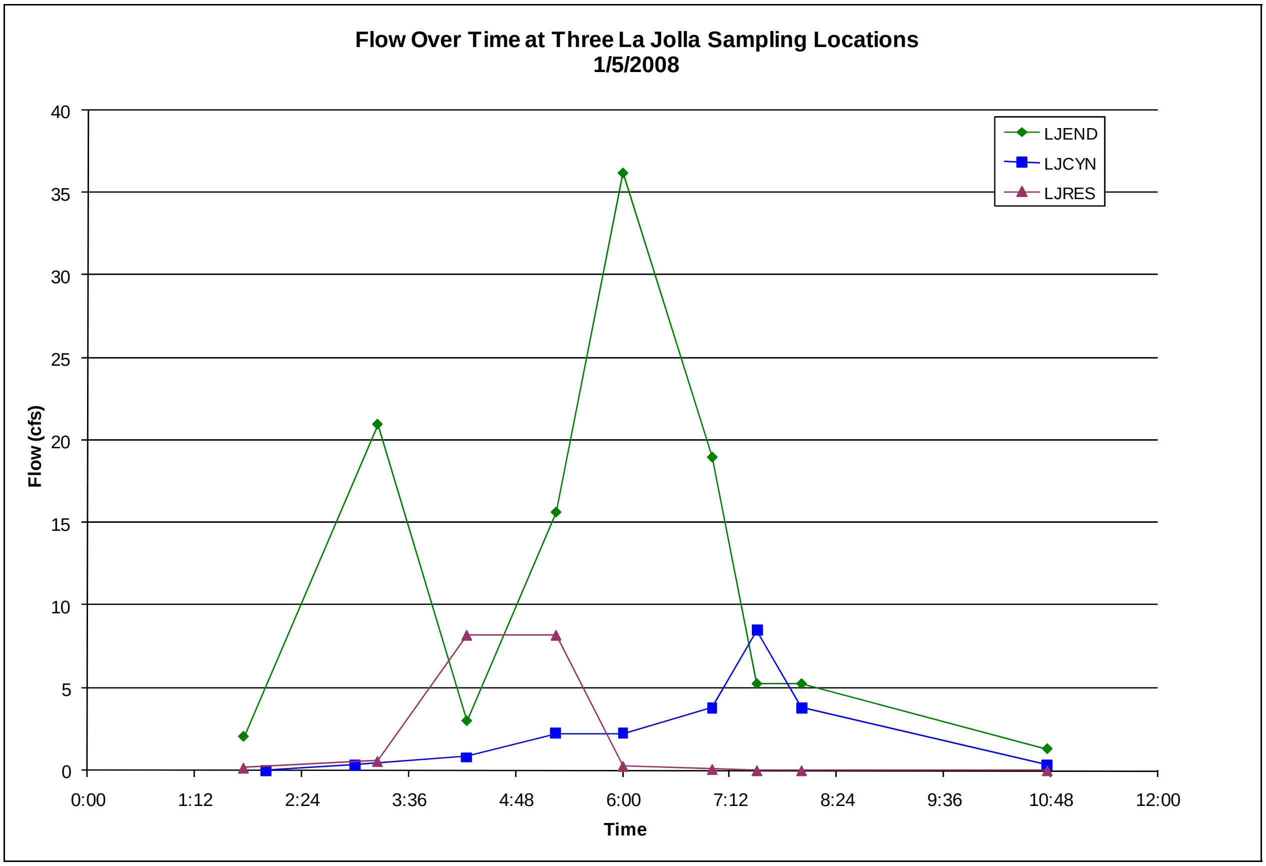



**Figure 4-1. Flow over Time at LJ RES (residential land use), LJ CYN (open space land use), and LJ END (mixed land use) – January 5, 2008**

Total loads over the course of the monitored storm event were calculated for TSS and for total and dissolved concentrations of copper, lead, and zinc (Figure 4-2 and Figure 4-3). Manning's Equation was used to calculate loads based on measured flows and measured analyte concentrations (Table 4-2). Overall, the TSS load at LJ END was 2.7 times greater than at LJ CYN and over 46 times greater than at LJ RES. Instantaneous TSS loads (i.e., the calculated load at the time of sampling) over the course of the storm generally mirrored the hydrograph and were reflective of the influence of flow on the load calculation.

**Table 4-2. Total Constituent Loads at Three Sites from the January 5, 2008 Storm Event**

| Site | Drainage Area (acres) | TSS (g) | Copper (g) | | Lead (g) | | Zinc (g) | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| LJ CYN | 66.7 | 1,139,056 | 10 | 3.4 | 10 | 0.1 | 117 | 3.4 |
| LJ RES | 105.7 | 65,855 | 40 | 22 | 6.5 | 0.5 | 183 | 56 |
| LJ END | 785.1 | 3,081,911 | 226 | 113 | 73 | 3.3 | 740 | 108 |

There are significant size differences between the subwatersheds monitored in this study. To account for this, loads for each sampling location were divided by the acreage of the drainage area (Table 4-3) to yield load per acre of watershed, also known as flux. The TSS load per acre was highest at LJ CYN, followed by LJ END and LJ RES. LJ CYN had a TSS per acre load that was over four times greater than LJ END and over 27 times greater than LJ RES. This suggests that residential land use and mixed land uses in La Jolla contribute much smaller proportions of TSS to the receiving waters on a per acre basis. This is likely due to the larger proportion of impervious soil in residential and mixed land uses compared with open space land use (LJ CYN).

**Table 4-3. Constituent Loads per Acre at Three Sites from the January 5, 2008 Storm Event**

| Site | Drainage Area (acres) | TSS (g/acre) | Copper (g/acre) | | Lead (g/acre) | | Zinc (g/acre) | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| LJ CYN | 66.7 | 17,077 | 0.15 | 0.05 | 0.15 | 0.00 | 1.8 | 0.05 |
| LJ RES | 105.7 | 623 | 0.38 | 0.21 | 0.06 | 0.00 | 1.7 | 0.53 |
| LJ END | 785.1 | 3,926 | 0.29 | 0.14 | 0.09 | 0.00 | 0.94 | 0.14 |

Total and dissolved loads of copper, lead, and zinc were greater at LJ END than at either LJ RES or LJ CYN (Table 4-2). This is likely attributable to the much larger drainage area for LJ END (785.1 acres) than at either LJ RES (105.7 acres) or at LJ CYN (66.7 acres), resulting in greater flows at LJ END (Figure 4-1). On a per acre basis (i.e., flux), the open space subwatershed (LJ CYN) had the lowest yield per acre for total and dissolved copper and dissolved zinc. Total zinc per acre was similar at LJ RES and LJ CYN, whereas total lead per acre was greater at LJ CYN than at either LJ RES or LJ END. Dissolved copper and zinc loads per acre were lowest at LJ CYN and were highest at LJ RES. The higher TSS loads present at LJ CYN and LJ END may be responsible for reducing dissolved metal loads by providing a substrate to which they can bind.

Copper, lead, and zinc are known to be associated with anthropogenic inputs, such as automobile emissions. Although these metals may be found in greater concentrations near transportation corridors and industrial facilities, their presence is somewhat ubiquitous throughout the watershed as a result of wind dispersion and aerial deposition. Instantaneous copper loads are shown on Figure 4-3, instantaneous loads of lead and zinc were similar to those for copper and are not shown here. As with TSS, instantaneous loads of copper (as well as lead and zinc) mirrored the hydrograph.

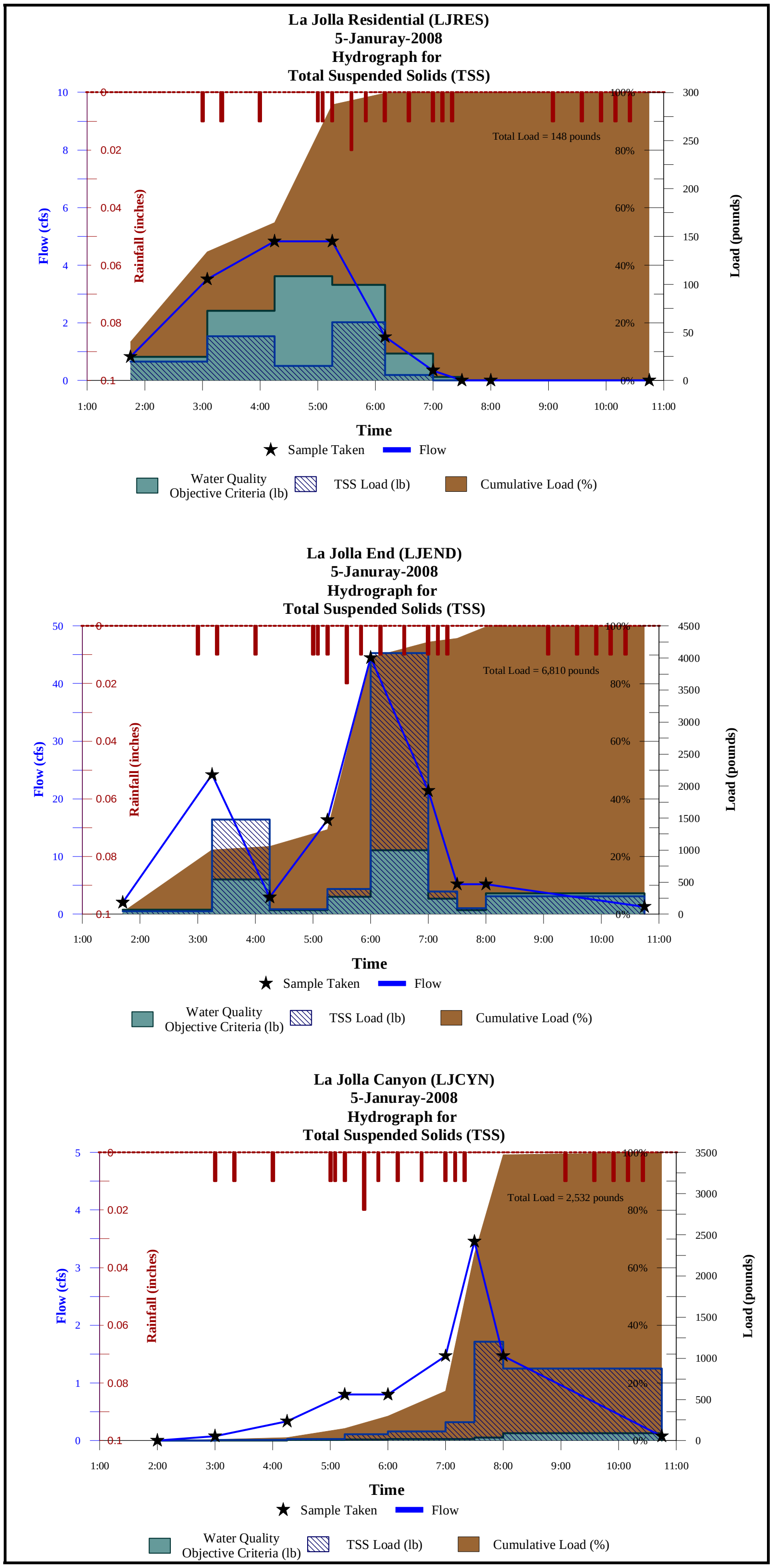



**Figure 4-2. Instantaneous Total Suspended Solids Load over Time at LJ RES, LJ CYN, and LJ END – January 5, 2008**

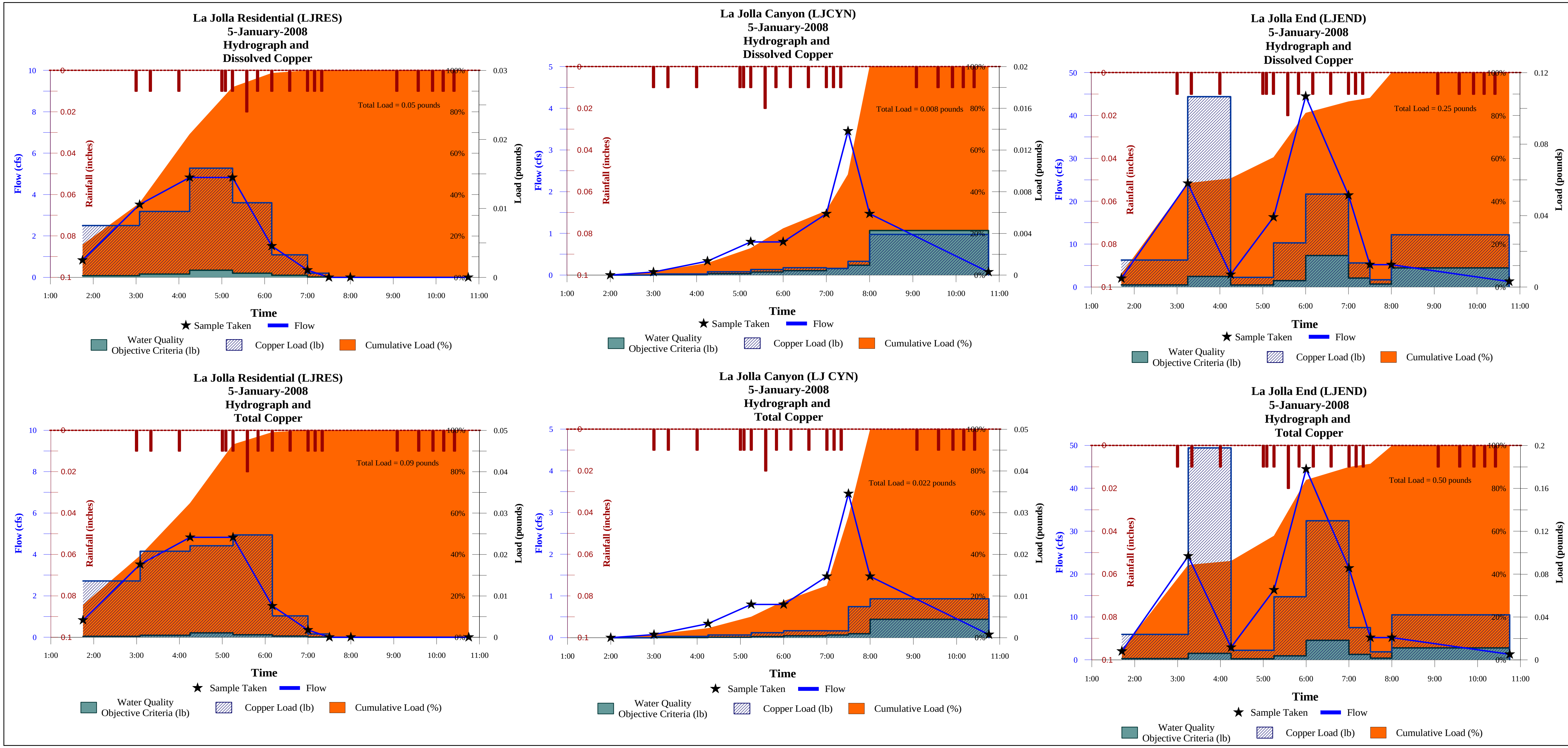



**Figure 4-3. Instantaneous Copper Load at LJ RES, LJ CYN, and LJ END – January 5, 2008**

## Storm 2

Storm 2 flow varied substantially among the three sampling locations. Overland runoff began flowing into the MS4 sampling locations at approximately 09:30 during the onset of storm. Storm flow was more or less bimodal across each sampling location; an initial peak corresponded to the first band of rain moving through the area, whereas a second peak occurred approximately four hours later when a second band of heavy rain moved through La Jolla. Flow at LJ RES and LJ CYN peaked during the first several hours of rain before quickly returning to near base-flow conditions (Figure 4-4). A second peak in storm water flow occurred simultaneously at all of the sites. Peak flow at LJ END was approximately four times the peak flow of either LJ CYN or LJ RES.

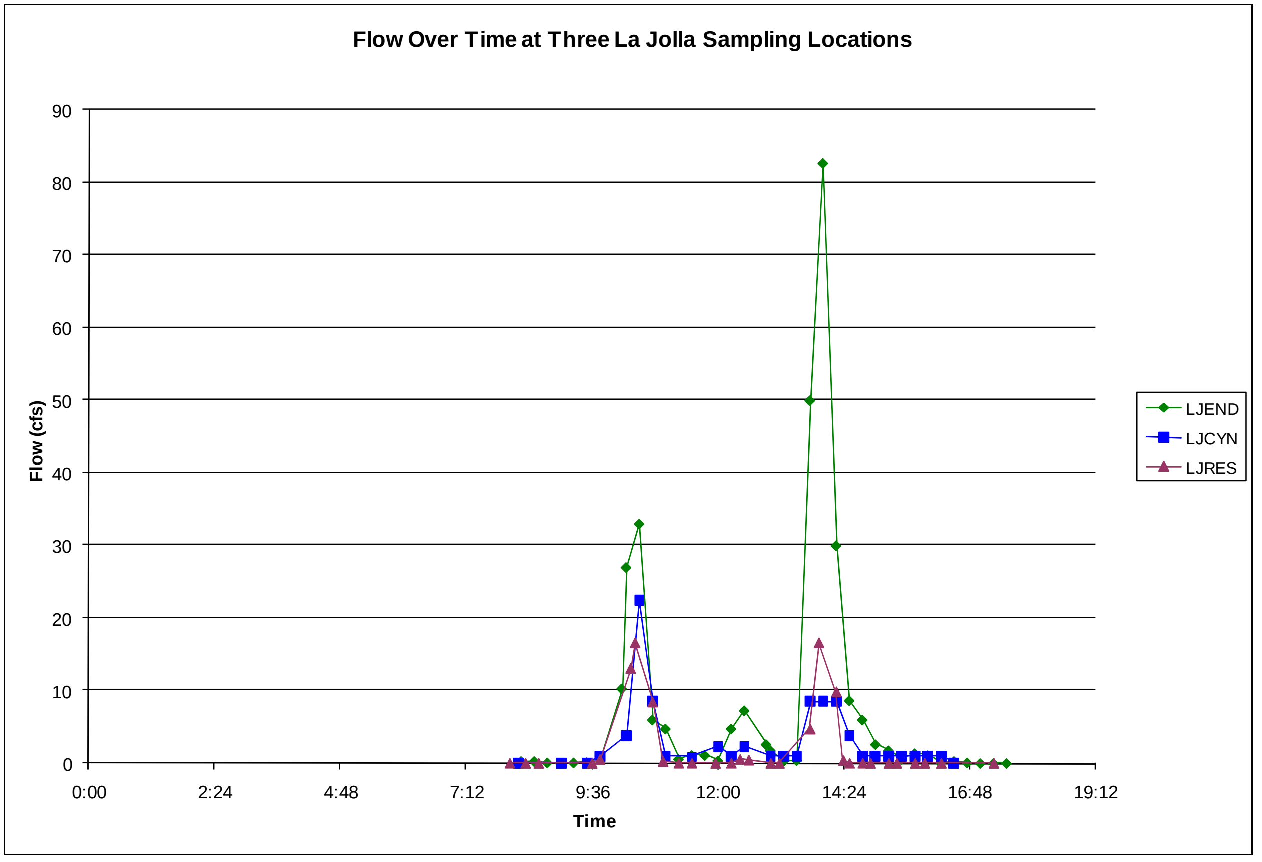



**Figure 4-4. Hydrograph of Storm 2 at LJ RES, LJ CYN, and LJ END- December 15, 2008**

Using Manning's Equation, total loads were calculated for TSS and for total and dissolved concentrations of copper, lead, and zinc over the course of Storm 2. Calculated loads were based on measured flows and measured analyte concentrations from each sampling location (Table 4-4). Similar to Storm 1, the TSS load at LJ END during Storm 2 was approximately three times greater than the TSS load at LJ CYN. The TSS load at LJ RES was approximately 1/16$^{th}$ that of LJ END and 1/5$^{th}$ that of LJ CYN during Storm 2. Instantaneous TSS loads (i.e., the calculated load at the time of sampling) over the course of the storm closely followed the hydrograph at each site.

**Table 4-4. Total Constituent Loads at Three Sites from the December 15, 2008 Storm Event**

| Site | Drainage Area (acres) | TSS (g) | Copper (g) | | Lead (g) | | Zinc (g) | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| LJ CYN | 66.7 | 2,016,777 | 35.2 | 7.09 | 23.8 | 0.07 | 280 | 12.0 |
| LJ RES | 105.7 | 384,305 | 215 | 66.9 | 27.4 | 1.46 | 417 | 82.0 |
| LJ END | 785.1 | 6,232,256 | 373 | 52.6 | 209 | 1.69 | 1555 | 63.0 |

Loads for each sampling location were divided by the acreage of the drainage area (Table 4-5) to account for size differences among the subwatersheds. TSS fluxes for Storm 2 were approximately two times those calculated for Storm 1 at LJ END and LJ CYN and were six times those calculated at LJ RES. Similar to Storm 1, TSS flux during Storm 2 was highest at LJ CYN, followed by LJ END and LJ RES. LJ CYN had a TSS per acre load approximately three times greater than LJ END and approximately over eight times greater than LJ RES.

**Table 4-5. Constituent Loads per Acre at Three Sites from the December 15, 2008 Storm Event**

| Site | Drainage Area (acres) | TSS (g/acre) | Copper (g/acre) | | Lead (g/acre) | | Zinc (g/acre) | |
|---|---|---|---|---|---|---|---|---|
| | | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| LJ CYN | 66.7 | 30,237 | 0.53 | 0.11 | 0.36 | 0.00 | 4.20 | 0.18 |
| LJ RES | 105.7 | 3,636 | 2.03 | 0.63 | 0.26 | 0.01 | 3.94 | 0.78 |
| LJ END | 785.1 | 7,938 | 0.48 | 0.07 | 0.27 | 0.00 | 1.98 | 0.08 |

Total and dissolved loads of copper and total loads of lead and zinc were greater at LJ END than at either LJ RES or LJ CYN, whereas dissolved loads of copper and zinc were greater at LJ RES than at LJ CYN and LJ END (Table 4-4). LJ RES had the highest yield per acre for total and dissolved copper and dissolved lead and zinc among the three land use sites. The two sites with the highest TSS per acre (LJ CYN and LJ END) also had the lowest dissolved metals per acre. This pattern was also seen in Storm 1, as higher TSS loads present at LJ CYN and LJ END likely reduced dissolved metal loads by providing a substrate to which they can bind. In Storm 2, as with Storm 1, LJ CYN had the highest total lead per acre among the sites. Increased lead flux at LJ CYN may result from the canyon's erosive soils containing historical fallout from lead-based gasoline use. This lead signature would not likely be present to the same degree in the developed residential and mixed use drainage areas due to its burial beneath asphalt and housing structures. Open canyons exposed to wind and rain, however, are likely to continue to erode lead-bound soil particles.

Total zinc flux was highest at LJ RES and LJ CYN, whereas dissolved zinc flux was highest at LJ RES. Dissolved copper and zinc loads per acre were lowest at LJ CYN and were highest at LJ RES.

Copper, lead, and zinc are known to be associated with anthropogenic inputs, such as automobile exhaust and break pad dust. Although these metals may be found in greater concentrations near transportation corridors and industrial facilities, their presence is likely ubiquitous throughout the watershed as a result of wind dispersion and aerial deposition. Instantaneous copper loads are shown on Figure 4-3; instantaneous loads of lead and zinc were similar to those for copper and are not shown here. As with TSS, instantaneous loads of copper (as well as lead and zinc) mirrored the hydrograph.

# 5.0 SUMMARY AND CONCLUSIONS

Storm water sampling, offshore water sampling, and offshore sediment sampling was conducted in 2008 and 2009 to answer six key questions regarding land use, ASBS sediment loading, grain size, water quality, and sediment quality. The goals of this study are to provide a greater understanding of the fate and effect of mobilized pollutant loads during a large storm event in the La Jolla Shores Coastal Watershed and to enable the City to establish a baseline by which to measure the effectiveness of future management actions. Information provided in this study will enable the City to prioritize BMP strategies aimed at reducing pollutant loading to the La Jolla Shores ASBS. The key questions for this study, and the findings that addressed these questions, are provided below.

1. **During storm events, how does land use influence sediment loading?**

Based on results from this study, land use influenced sediment loading during storm events in several ways. The quantity of TSS generated during storm events as well as the size of suspended grains and the sediment-bound contaminant levels in runoff appear to be impacted by land use. The open space Site LJ CYN delivered significantly more sediment to the receiving water on a per acre basis than the residential (LJ RES) or mixed use (LJ END) sites. During Storm 1 and Storm 2, LJ CYN had a TSS load per acre three to four times higher than the TSS load at LJ END and eight to 27 times higher than the TSS load at LJ RES. Although open space canyons within the watershed may represent only 20% of the total drainage area, based upon Storm 1 and Storm 2 TSS load calculations, the canyons are responsible for contributing between 67–87% of the total sediment load. Overall, the total TSS load was highest at the mixed land use site (LJ END) as a result of its significantly larger drainage area among the three monitoring sites.

Land use within the La Jolla Coastal Watershed was also correlated with grain size differences in TSS. TSS grain size fractions at LJ RES were substantially larger (primarily sands and silts) than TSS grain sizes at LJ CYN and LJ END (primarily silts and clays). In contrast to results from LJ CYN and LJ END, median grain size at LJ RES varied considerably throughout Storm 2. The median grain size at LJ RES was generally inversely proportional to flow; median grain sizes were smallest during periods of high flow in the middle of the storm event and were largest at the beginning and end of the storm event when flows were reduced. Median grain size at LJ CYN was lowest among the three sites and varied little throughout both storm events, ranging from 2–18 μm in Storm 2. Median grain size at LJ END was consistent between Storm 1 and Storm 2, varying little after the initial flush of storm water runoff. In Storm 2, approximately 90% of the total TSS volume was generated during the second peak in flow and was largely associated with silts and clays from LJ CYN and LJ END.

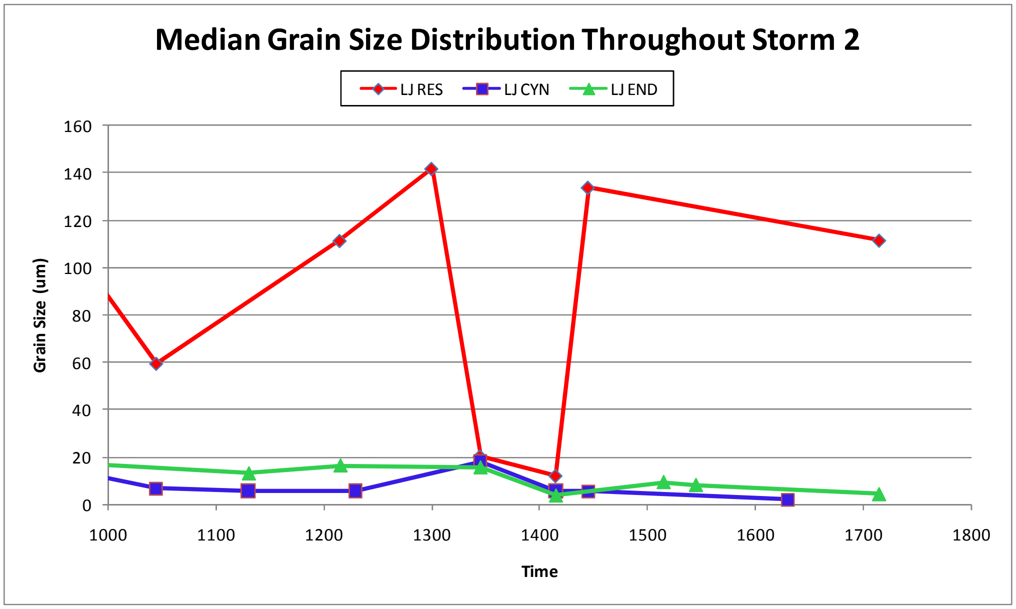



**Figure 5-1. Median Grain Size over Time at LJ RES, LJ CYN, and LJ END- December 15, 2008**

Trace metal concentrations within storm water runoff were associated with differences in land use. In both Storm 1 and Storm 2, LJ CYN had the highest total lead flux among the three sites. A higher concentration of total lead at LJ CYN may result from the erosion of canyon soils that likely contain historical fallout from lead-based gasoline use. Since developed areas are more effective in burying the historical leaded gasoline signature beneath asphalt and housing structures, runoff through erosive canyon and open space areas may carry a higher concentration of lead-bound soil particles. Confounding factors, such as significant sources of lead in the open space areas or differences in soil composition among the sites, are not believed to be present, but cannot necessarily be ruled out.

Residential land use had substantially higher yields per acre for total and dissolved copper than open space or mixed land use sites. The total copper load per acre at LJ RES was approximately two to four times higher than the load from LJ CYN and LJ END, whereas dissolved copper loads per acre at LJ RES were approximately four to six times higher than loads at LJ CYN and were two to nine times higher than loads at LJ END. Total zinc concentrations were similar between LJ RES and LJ CYN, whereas dissolved zinc was substantially higher at LJ RES. The zinc load per acre at LJ END was approximately 50% less than that of LJ CYN and LJ RES. Likely sources of copper within the La Jolla Coastal Watershed include brake pads, copper pipes, cooling systems, and copper-based root control systems, whereas likely sources of zinc within the watershed include vehicle tires, galvanized building materials, and paint.

2. **Do sediment loading patterns or the relative grain size proportions change throughout a storm hydrograph?**

Current data support the statement that sediment loading patterns and grain size both appear to change throughout a storm's hydrograph. Land use may significantly alter the loading of a particular constituent (e.g., total copper) (Figure 5-2). In this example from Storm 1, more than

80% of the total copper load had been mobilized for LJ RES in the first 3.5 hours of the storm event, whereas only approximately 10% had been mobilized for LJ CYN. The final stages of the storm event produced nearly 80% of the total copper at LJ CYN and less than 20% of the total copper at LJ RES and LJ END. Similar loading patterns were observed for total lead and zinc and dissolved copper, lead, and zinc.

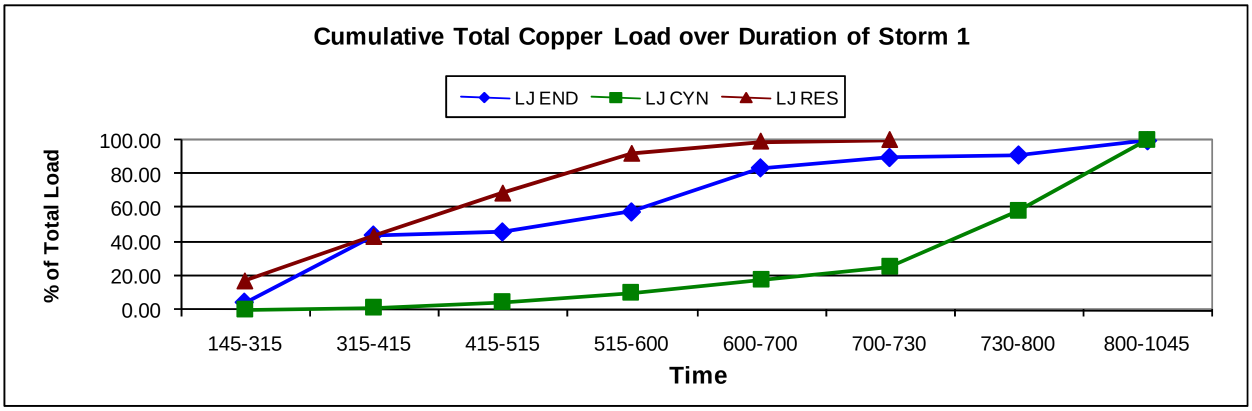



**Figure 5-2. Percentage of Total Copper Load Released over Time during Storm 1- January 5, 2008**

Although average grain size varied somewhat throughout the storm event, an overall decreasing trend was evident at the open space (LJ CYN) and mixed use (LJ END) sites. Median grain size at these sites was largest during the initial stages of the storm. A slight decrease in grain size was observed during the middle and latter portion of the storm at LJ CYN and LJ END. At LJ RES, the median grain size was substantially larger (89 µm) than at LJ CYN (8 µm) or LJ END (11 µm). The grain size at LJ RES was larger at the beginning and end of the storm than it was during times of peak flow. It remains unclear why the storm runoff from the residential drainage area was comprised mostly of sand, whereas the canyon drainage area consisted mostly of silts and clays. One possible explanation for this is that localized construction/denuding activities within the fully built-out residential drainage area were occurring at the time of Storm 2, coupled with different lithological characteristics between the sites, onshore winds blowing beach sands into the residential drainage area, and humans and vehicles tracking sand a short distance inland from the beach.

**3. What is the estimated sediment and pollutant load entering the ASBS during a large storm event?**

It is difficult to assess the total pollutant and sediment load entering the ASBS during a storm event since only 54% of the watershed is captured by the sampling points used in this study. However, if it is assumed that the uncaptured water carries a similar pollutant and sediment load as the captured water, an extrapolation of the existing data can be made to derive an estimated load for the entire watershed. Calculated loads for the captured portion of the watershed and for the total watershed are provided in Table 5-1. Based on flow measurements and analytical data from Storm 1 and Storm 2, the average sediment load in the form of TSS that is representative of the captured portion of the watershed—54% of the watershed's drainage area was captured in this study—was 4,883 kg (Table 5-1). Extrapolating the calculated average sediment load to the entire watershed predicts a total TSS load of 9,043 kg, based on TSS measurements. Estimated total metal loads for the entire watershed were 427 g of copper, 158 g of lead, and 1,448 g of zinc. Estimated dissolved metal loads for the watershed were 128 g of copper, 6.5 g of lead, and 291 g of zinc.

To derive the TSS value, the calculated TSS loads from LJ END and LJ RES were added together for each storm event; since LJ CYN drains to LJ END, it was not included in the total load calculation. An average TSS load was then calculated from the Storm 1 and Storm 2 TSS loads. The average loads for the captured portion of the watershed (54%) were then extrapolated to the entire watershed by dividing the average load of the captured portion of the watershed by 0.54.

**Table 5-1. Sediment and Metals Loading Estimates for La Jolla Shores Coastal Watershed**

| Watershed Area | Storm Event | Drainage Area (acres) | TSS (kg) | Copper (g) | | Lead (g) | | Zinc (g) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | Dissolved | Total | Dissolved | Total | Dissolved |
| Captured portion of watershed (54%) | Storm 1 | 891 | 3,149 | 266 | 135 | 79.5 | 3.8 | 923 | 164 |
| | Storm 2 | | 6,617 | 588 | 120 | 236 | 3.2 | 1,972 | 145 |
| | Average load of Storm 1 and Storm 2 | 891 | 4,883 | 427 | 128 | 158 | 3.5 | 1,448 | 157 |
| Total watershed (100%) | Total load for watershed based on average load | 1,646 | 9,043 | 791 | 237 | 293 | 6.5 | 2,681 | 291 |

4. **What are the water quality and sediment conditions in the ASBS receiving water?**

Within approximately 48 hours following a storm event, water quality and sediment conditions within the ASBS appeared to be close to prestorm conditions. Water samples collected just beyond the surf zone two days after a storm event had detectable concentrations of heavy metals and trace amounts of PAHs. No detectable concentrations of PCBs (aroclors or individual PCB congeners), pesticides, organotins, synthetic pyrethroids, volatiles, or semi-volatile compounds were present in offshore water samples. Exposure to offshore water collected two days following a storm event did not produce acute or chronic toxicity to mysid shrimp and did not produce chronic toxicity to giant kelp or sea urchins.

Sediment within the ASBS did not contain any detectable concentrations of PAHs, PCBs (aroclors or individual PCB congeners), pesticides, organotins, synthetic pyrethroids, volatiles, or semi-volatile compounds. Concentrations of heavy metals were detected but all were below established levels in which toxic effects to benthic infauna would be expected (Effects Range – Low criteria). Mean percent survival of *E. estuarius* exposed to La Jolla Shores' test sediment was 96%, whereas mean percent survival in the control sediment was 93%, indicating that no toxicity was observed.

**5. Are concentrations of constituents in runoff correlated with specific sediment loads or grain size fractions?**

Chemical analyses performed on pollutograph samples collected at LJ RES and LJ CYN indicated that sediment-bound copper, lead, and zinc concentrations at both sites were proportionally highest in grains that were between 5–35 µm (i.e., particles that passed through a 35 µm filter but were retained on a 5 µm filter). Particulate chemistry was not performed on LJ END samples. During the initial part of the storm, suspended grains from LJ CYN consisted of approximately 20% sand, 45% silt, and 35% clay, whereas near the end of the storm, the suspended grains became progressively smaller (2% sand, 35% silt, and 63% clay). In contrast, LJ RES was comprised of approximately 75% sand, 18% silt, and 7% sand at the beginning of the storm and approximately 85% sand, 7% silt, and 8 % clay at the end of the storm. Despite the low proportion of suspended grains that were 35 µm or smaller (silts and clays) at LJ RES, the >35 µm grain size fraction at LJ RES contained approximately 87% of the particulate-bound copper load, 82% of the particulate-bound lead load, and 82% of the particulate-bound zinc load. Similarly, the silt and clay fraction of the suspended sediment from LJ CYN also contained the vast majority of the sediment-bound contaminant load. At LJ CYN, however, silts and clays comprised greater than 80% of the suspended sediment.

Dissolved metal concentrations were shown to be correlated with TSS. Pollutograph sampling demonstrated that the initial flush of storm water runoff mobilized high concentrations of metals in both the total and dissolved phase. As runoff and TSS decreased, however, total metal concentrations decreased, whereas dissolved metal concentrations generally increased. Since metals have a propensity to bind to fine particulates, high TSS concentrations can correspond with a lowering of the ratio between dissolved metals and total metals. Similarly, when low TSS concentrations are present, a greater fraction of total metals may enter into their typically more toxic liquid phase. Aside from TSS concentrations, other properties that may influence dissolved metal concentrations include water temperature, pH, hardness, and concentrations of metal binding sites (e.g., DOC) (USEPA, 1996).

**6. What potential BMP solutions are available, applicable, and feasible for implementation in the La Jolla Shores Watershed based upon the data compiled in this study?**

Recommendations for potential BMP solutions that are available, applicable, and feasible for implementation within the La Jolla Shores Coastal Watershed are assessed in the La Jolla Shores Water Quality Compliance Study. The Compliance Study focuses on water quality conditions within the ASBS receiving water.

# 6.0 KEY RECOMMENDATIONS

This Phase II Source Study identifies Tier I, Tier II and Tier III BMPs to reduce sediment and contaminant loads. Key recommendations that may be considered include the following:

- Tier I – Develop and implement a Data Management System to consolidate data, track activities, load reductions and effectiveness of storm water program efforts.
- Tier I – Conduct education and outreach programs to keep the public informed about protecting the ASBS.
- Tier II – Continue to assess aggressive street sweeping as a means of reducing loads to the ASBS and consider other source controls such as a runoff reduction program.
- Tier II – Develop a pollutant loading model and load reduction calculations for the La Jolla Shores Coastal Watershed.
- Tier III – Pursue existing plans to implement a dry weather diversion structure at Avenida de la Playa to eliminate dry weather flows as required by the permit.

# 7.0 REFERENCES

ASTM (American Society for Testing and Materials). 2006. *ASTM Standard E1367-03*.

Baker, J.I. and R.A. Hites. 2000. "Is Combustion the Major Source of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans to the Environment? A Mass Balance Investigation." In *Environmental Science and Technology*. (34)2879–2886.

Krone, U.E., R.K. Thauer, and H.P.C. Hogenkamp. 1989. "Reductive Dechlorination of Chlorinated C1-Hydrocarbons Mediated by Corrinoids." In *Biochemistry*. (28)4908–4914.

SIO (Scripps Institution of Oceanography), University of California San Diego, City of San Diego, and San Diego Coastkeeper. 2008. *The La Jolla Shores Coastal Watershed Management Plan*.

USEPA (United States Environmental Protection Agency). 1994. *Methods for Assessing Toxicity of Sediment-Associated Contaminants with Estuarine and Marine Amphipods*.

USEPA (United States Environmental Protection Agency). 1996. *The Metals Translator: Guidance for Calculating a Total Recoverable Permit Limit from a Dissolved Criterion*. EPA/823-B-96-007).

WESTON (Weston Solutions, Inc.). 2007a. *Strategic Plan for Watershed Activity Implementation.* November 2007.

WESTON (Weston Solutions, Inc.). 2007b. *Quality Assurance Project Plan, Areas of Special Biological Significance, Monitoring of La Jolla Shores Coastal Watershed for San Diego Marine Life Refuge and La Jolla Ecological Reserve*. September 2007.

WESTON (Weston Solutions, Inc.). 2007b. *San Diego County Municipal Copermittees 2005–2006 Urban Runoff Monitoring*. Prepared for the County of San Diego January 2007.