2005 PLASTIC DEBRIS CONFERENCE

DEBRIS NETS IN THE SAN GABRIEL RIVER – DESIGN AND PHYSICAL MODELING

RUSSELL H. BOUDREAU, P.E.[1]

ABSTRACT

A major storm event can mobilize waterborne pollutants from throughout our watersheds. Floating debris, including plastics, polystyrene and green waste, finds its way into our tidal waterways and beaches. It degrades the visual amenity, is expensive and time consuming to clean up, and is an environmental threat to wildlife and health. This paper presents information regarding design and physical model testing of innovative debris nets intended for installation in a concrete lined trapezoidal section of the San Gabriel River in Los Angeles County. The nets are designed to intercept debris before it discharges into the tidal sections of the San Gabriel River. The paper will describe the design philosophy behind the nets, the challenges of debris capture in high current velocity regimes and demonstrate the benefits of physical modeling as a key element in the design process. Public safety issues associated with net implementation also played a major role in the ultimate project outcome.

INTRODUCTION

Moffatt & Nichol performed an engineering study for the City of Seal Beach to develop a design for a debris collection system to reduce debris flows within the San Gabriel River watershed that are ultimately discharged at the river mouth. The main goal of the project was to propose an effective design for decreasing the debris load at the mouth of the San Gabriel River, and in particular to decrease the quantity of debris that is washed up onto Seal Beach.

Key steps in the process included identification of types and quantities of debris, assessment of river conditions, development of preliminary design concepts, and refinement of the designs through physical model testing.

ANTICIPATED DEBRIS TYPES

Three types of river-borne debris can be distinguished: green waste (plant material), floating trash, and submerged trash.

---

[1] Associate, Moffatt & Nichol, 3780 Kilroy Airport Way, Suite 600, Long Beach, CA 90806, rboudreau@moffattnichol.com

During the first flush, a large quantity of green waste is typically transported downstream. In our study, the first flush will be considered to be the runoff from the first rainstorm of the fall-winter season with 0.5 inches or more of rain. For example, materials collected at the Los Angeles River are typically two-thirds green waste and one-third trash. At the first rainstorm of the season, as much as 80% of the debris is green waste. Similar proportions are seen at Ballona Creek.

First flush runoff is often considered the worst case for stormwater pollution management, because it transports a large fraction of the pollutants that have built up on impermeable surfaces since the previous storm season. This is the case to a much lesser extent for debris loads, unless the first rainstorm of the season is also a large storm (one to two inches or more of rain). The reason for this is that the debris transported by a rainfall event is most often limited by the quantity of debris that the runoff is able to transport, not by the quantity available to be transported (Allison, Chiew and McMahon, 1997).

By volume, much of the trash transported downstream is floating: uncompacted Styrofoam, paper cups, plastic bottles and other convenience food waste. During large storm events, much larger and heavier trash items can be transported along the bed of the river: tires, shopping carts, and discarded furniture are all commonly found in the Santa Ana River / Delhi Channel. Golf balls, which do not float, are commonly washed up onto Seal Beach.

Debris collection during large storm events can conflict with effective flood control during the same large storm events. A large mass of debris built up at a debris collector can significantly restrict flood flows and pose an upstream flood risk. The same mass of debris suddenly released as the debris collector fails can be a significant downstream hazard. The failure modes of any debris collector must be carefully assessed.

GENERAL RIVER CONDITIONS

The San Gabriel River flows from North to South, from the San Gabriel Mountains and through the eastern portions of Los Angeles and Long Beach, eventually reaching the Pacific Ocean in Seal Beach. Coyote Creek flows from northeast to southwest and passes through a small portion of Long Beach before it outlets into the San Gabriel River. The San Gabriel River is concrete lined for about eight miles; the tidally influenced region and the region upstream of the concrete channel have riprap banks and a soft-bottom channel.

Any debris that reaches the River above the Whittier Narrows Dam (completed in 1957) can be assumed trapped at that dam. Therefore, as a source of debris at the mouth of the River, only the part of the watershed downstream of Whittier Narrows need be considered. Similarly, since Los Cerritos Channel feeds directly into Marine Stadium, the debris from its watershed does not feed into the San Gabriel River, even though this sub-watershed is normally considered part of the San Gabriel River watershed. Figure 1 delineates the lower watershed of the San Gabriel River, showing the sub-watersheds of the San Gabriel River (one sub-watershed between the Whittier Narrows Dam and the confluence with Coyote Creek, and one below the confluence), Coyote Creek and Los Cerritos Channel. The vast majority of this watershed is urban. Approximate drainage areas, based upon USGS gauging station descriptions, are:

- Coyote Creek to the confluence: 150 square miles;
- Whittier Narrows Dam to the San Gabriel River at the confluence: 30 square miles;
- Confluence to the river mouth: 20 square miles.

Much of southern Long Beach is within the watershed of the Los Cerritos Channel, which drains to Alamitos Bay.

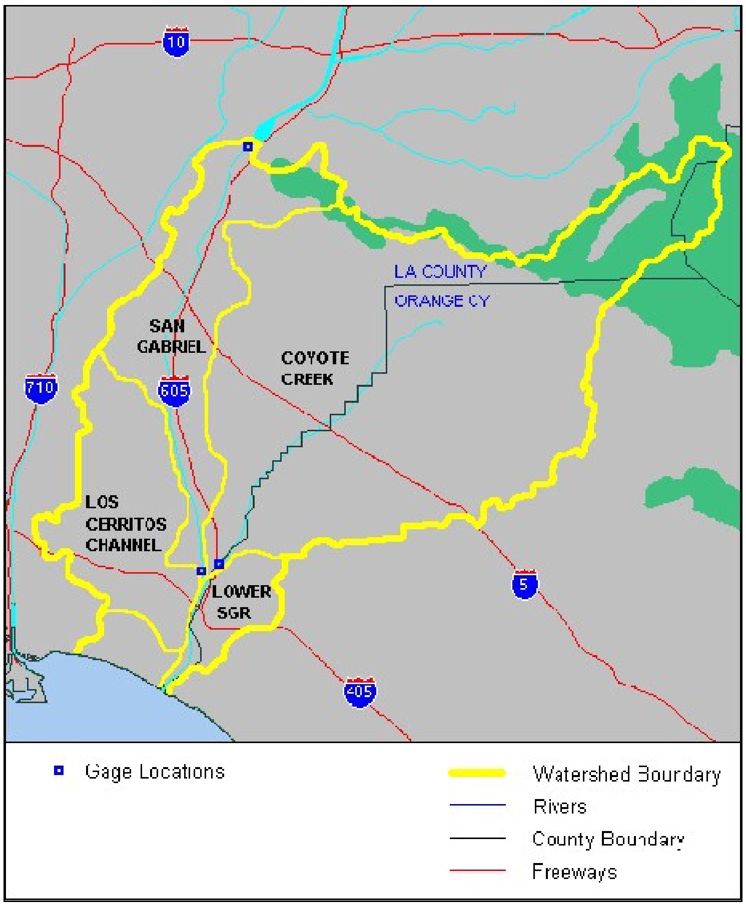

FIGURE 1 – WATERSHED OF THE LOWER SAN GABRIEL RIVER

There are flow gages at three locations below Whittier Narrows Dam: at Pico Rivera just below the Whittier Narrows Dam, on the San Gabriel River at Spring Street in Long Beach, and on Coyote Creek in Los Alamitos. The latter two gage locations lie just upstream of the confluence of the two rivers. Typical and extreme flood flow conditions at these locations are:

- Peak annual flows typically range from 3,000 to 12,000 cubic feet per second for Coyote Creek, and 2,000 to 6,000 cubic feet per second for the San Gabriel River.
- 100-year flood flows are 30,000 cubic feet per second for Coyote Creek, and 14,000 cubic feet per second for the San Gabriel River. Up to an additional 5,000 cubic feet per second may be diverted to the San Gabriel River from the Rio Hondo at peak flows.

The Los Angeles River has much larger flows: typical flows are 10,000 to 70,000 cubic feet per second, with a 100-year flood flow of 180,000 cubic feet per second. The San Gabriel River and Coyote Creek are much more similar to Ballona Creek, with typical flows of 8,000 to 18,000 cubic feet per second, and a 100-year flood flow of 36,000 cubic feet per second.

ANTICIPATED DEBRIS QUANTITIES

Debris quantities in this paper are discussed as volumes, where possible. The volume of debris removed is more important operationally than the weight, because the volume determines the number of truckloads needed to remove the debris from the site and the landfill fees. Very often the debris is uncompacted Styrofoam, paper cups, plastic bottles, and similar trash, which has a very low dry density; operators will compact the debris to some extent while loading the truck. Since the density of debris can vary dramatically according to its source and its degree of compaction, it is not always possible to convert from weight to volume of debris; where references give quantities in tons this value may be used.

One way to estimate the debris load expected in the San Gabriel River is from the debris quantities currently collected from the mouth of the Los Angeles River in Long Beach. Since the San Gabriel and Los Angeles Rivers have similar watersheds, the relative debris quantities in the two rivers are expected to be directly proportional to their relative drainage areas. The Los Angeles River has an urban drainage area of approximately 580 square miles, with a total area of approximately 830 square miles. The City of Long Beach typically collects about 4,000 tons of debris annually from the mouth of the Los Angeles River, corresponding to 8,000 cubic yards as a slightly compacted volume, assuming a debris density of 1,000 pounds per cubic yard.[2] With an urban drainage area (below Whittier Narrows) of 200 square miles, the debris volume at the San Gabriel River can be estimated at 8,000 × 200 / 580 = 2,800 cubic yards per year. Only 10% of this drainage area, or 20 square miles, lies below the confluence of the San Gabriel River and Coyote Creek.

Alternatively, the anticipated quantity of trash (not including green waste) can be estimated from the baseline trash load quoted in the draft trash Total Maximum Daily Load for the Los Angeles River: 640 gallons or 3.2 cubic yards uncompressed trash per square mile per year (California Regional Water Quality Control Board, Los Angeles Region, 2001). A comparable trash load is obtained from Allison, Chiew and McMahon (1997), based on a curve for the dry trash loads as a function of total rainfall in a storm event. This would give 3.2 × 200 = 640 cubic yards per year of trash, or 2,000 cubic yards per year total debris, assuming two-thirds of the debris is green waste. This is comparable to the 2,800 cubic yards per year estimate from the debris collected from the Los Angeles River.

[2] Mixed yard waste has densities between 200 and 750 pounds per cubic yard, depending on the degree of compaction; uncompacted trash has a typical density of 200 pounds per cubic yard (EPA Office of Solid Waste and Emergency Response, 1994). On the other hand, the material retained on bar racks at wastewater intakes has a typical density of 1080 to 1620 pounds per cubic yard (Metcalf and Eddy, 1991).

Debris loads vary dramatically from year to year; figures for the Los Angeles River at Long Beach vary from 3,091 tons in 1998-99 to 9,290 tons in 1997-98. The quantity of trash reaching the river appears to depend more on the runoff volumes available to transport the trash than on the quantity of trash on the city streets (Allison, Chiew and McMahon, 1997).

Based on the above results, this report assumes typical annual debris volumes of approximately 3,000 cubic yards per year and maximum volumes of up to 10,000 cubic yards per year for the mouth of the San Gabriel River.

FLOWS AND DEBRIS LOAD SUMMARY

Table 1 provides estimated peak flow statistics and measured or estimated debris loads for the mouth of the San Gabriel River and for its tributaries at three locations (the two tributaries at its confluence with Coyote Creek and upstream near Fullerton Creek), and for the Los Angeles River and Ballona Creek – both of which have existing trash collection devices.

This table shows that the San Gabriel River has similar flows to Ballona Creek. The debris volumes trapped in the net at Ballona Creek are substantially less than the debris load estimated for the San Gabriel River and based on the load at the Los Angeles River. This may result from a difference in the raw debris loads, in turn arising from the less urbanized watershed for Ballona Creek; more probably, it reflects that only a fraction of the debris is trapped at Ballona Creek.

Table 1: ESTIMATED FLOWS AND DEBRIS LOADS FOR LOCAL RIVERS WITH EXISTING OR POSSIBLE DEBRIS COLLECTION

LOCATION	5-YR FLOOD (CFS)	10-YR FLOOD (CFS)	100-YR FLOOD (CFS)	DRAINAGE AREA (SQ. MI.)	EST. DEBRIS LOAD (CY/YEAR)
LA River Mouth	76,000 [1]	99,000 [1]	180,000 [1]	830	15,000 – 45,000
Ballona Creek	18,000 [2]	22,000 [2]	36,000 [2]	90	(20 – 200) [3]
SGR above confluence with Coyote Creek	7,000 [4]	8,000 [4]	14,000 [4]	30 [5]	500 – 1,500
Coyote Creek above confluence with SGR	14,000 [4]	17,000 [4]	30,000 [4]	150	2,200 – 7,500
Coyote Creek, Coyote Creek North Fork, Fullerton confluence	7,000 [6]	8,000 [6]	15,000 [6]	70	1,100 – 3,700
SGR near mouth	21,000 [7]	25,000 [7]	44,000 [7]	200	3,000 – 10,000

1. Source: Moffatt & Nichol, 1996
2. Source: Moffatt & Nichol, 1999
3. This is the quantity trapped in the net; the total load of the river may be substantially higher
4. Statistical analysis based on USGS and LACDPW peak flow data; note the period of record is only 20-30 years
5. Drainage area below the Whittier Narrows Dam only
6. Estimated as half the flow from Coyote Creek at the SGR, based on estimated relative watershed sizes
7. Estimated as the sum of the values at the confluence

POTENTIAL LOCATIONS

Several potential locations for a debris collection device were identified based on field observations and discussions with personnel from the Cities of Seal Beach and Long Beach, and from Los Angeles County. A single debris collector at or near the mouth of the San Gabriel River could in principle collect all of the trash entering the river throughout the watershed. This approach, while simple, has the disadvantage of providing no backup or redundancy. Additional reasons to prefer locations in the concrete channel portion of the river (at and above the confluence of the San Gabriel River and Coyote Creek) to the soft-bottom, tidally influenced portion of the channel near the mouth of the river or above Westminster Avenue are as follows.

- Recreational navigation is common along the San Gabriel River, throughout the tidally influenced portion of the river. This would impede such navigation, and would make it difficult (although not necessarily impossible) to obtain permits from the USACE to install a net or boom that completely blocked the river. While overlapping booms can be installed without blocking navigation, as has been done at the mouth of the Los Angeles River, for example, this approach increases the complexity and cost of the system, and it is possible for floating trash to work its way around a system of this type.

- In the debris net at Ballona Creek, it has been found that collected trash is driven upstream and away from the net during flood tides – trash can only be effectively removed from the net during ebb tides. This is a significant operational constraint for all tidally influenced sites. At the river mouth, this problem would be exacerbated by the common onshore winds, which would tend to blow trash upstream and away from the net.

- Trash tends to get caught in the riprap banks along the tidally influenced portion of the river, making it difficult to clean out. This has been a problem both at Ballona Creek and at the floating boom near the mouth of the Los Angeles River.

- It would be necessary to account for the corrosive effects of seawater in a tidal location.

- During low-flow conditions, it is possible to work directly in the bed of the river in the concrete channel. This makes it much easier to remove large quantities of trash from a net.

For these reasons, the concrete, non-tidal locations were recommended for installation of a debris net. A system near the confluence of the San Gabriel River and Coyote Creek could trap much of the debris entering the river; a second system near the confluence of Fullerton Creek, Coyote Creek and Coyote Creek North could act as a backup, decreasing the total load on the downstream site.

Confluence of the San Gabriel River and Coyote Creek

A pair of pilot debris nets has been installed at this location by Los Angeles County Department of Public Works. Both channels are basically trapezoidal, with a low-flow inset. The estimated levels and flow quantities for this location are given in Table 2. These estimates are based on peak flows from the United States Geological Survey (2001) and Los Angeles County Department of Public Works (2001); together with rating curves provided by Leonard Davidian, LA County Public Works. Since only 20-30 years of measurements are available for each site (since the construction of Whittier Narrows Dam in the case of the San Gabriel River), return periods above 20 years are not considered.

Table 2: FLOOD FLOW RATES AND WATER LEVELS AT THE SGR / COYOTE CREEK CONFLUENCE

Flood return period	Flow rate Q (cfs)	Flow depth (feet)
San Gabriel River above confluence		
2-year	4,000	6.1
5-year	7,000	7.9
10-year	8,000	8.4
20-year	10,000	9.4
Coyote Creek above confluence		
2-year	9,000	5.7
5-year	14,000	7.2
10-year	17,000	8.1
20-year	21,000	9.2

Confluence of Fullerton Creek, Coyote Creek and Coyote Creek North

These potential sites are located about 7 miles further upstream, at the boundary between Buena Park in Orange County and Cerritos in Los Angeles County. Coyote Creek and Coyote Creek North are not gauged near this location. For the purposes of a conceptual design, these channels can be considered comparable to the San Gabriel River channel just above its confluence with Coyote Creek; the cross-sections are similar, and based on the relative watershed areas the flood flows are expected to be similar. The San Gabriel River location has been used in this report as the design example for a trapezoidal channel.

DEBRIS NET DESIGN

Two net designs are described in this section: Figure 2 illustrated the first design comprising cylindrical buoys supporting a net extending above the water surface and up to four-feet below the water surface in typical rain flows. Figure 3 shows a tetrahedral buoy system with a longer net that traps debris throughout the water column for flows up to the two-year flood (approximately 6-feet depth) and up to four feet above the water surface. The greater trapping efficiency of the tetrahedral net is offset by its greater complexity and potentially greater maintenance costs. Another issue that must be addressed in the final design is the potential backwater or damming effect: the more effective a collector is at trapping debris throughout the water column, the greater the tendency it will have to act as a dam, potentially increasing the upstream flood hazard. Each of these issues was investigated in detail in the physical model testing program.

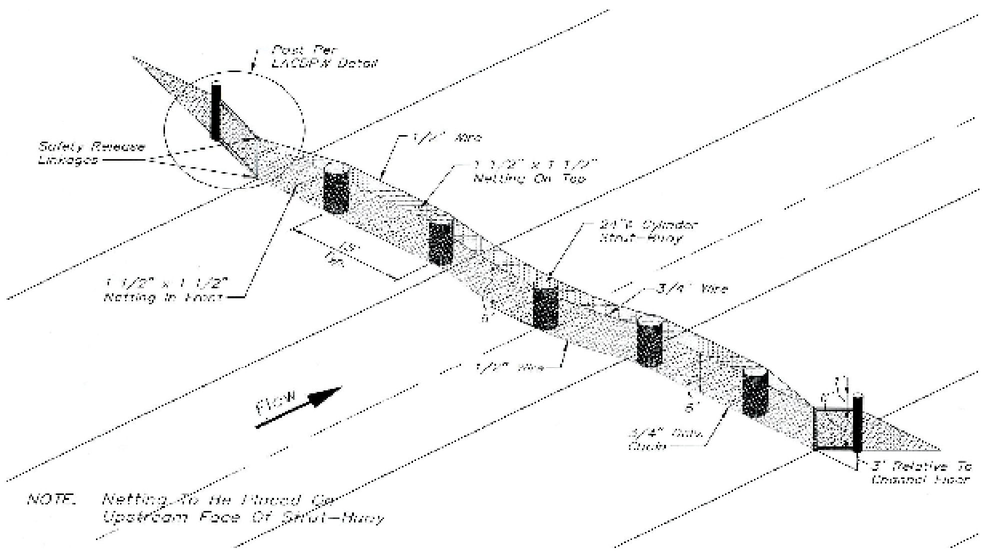

Figure 2 – Cylindrical Buoy Net Design

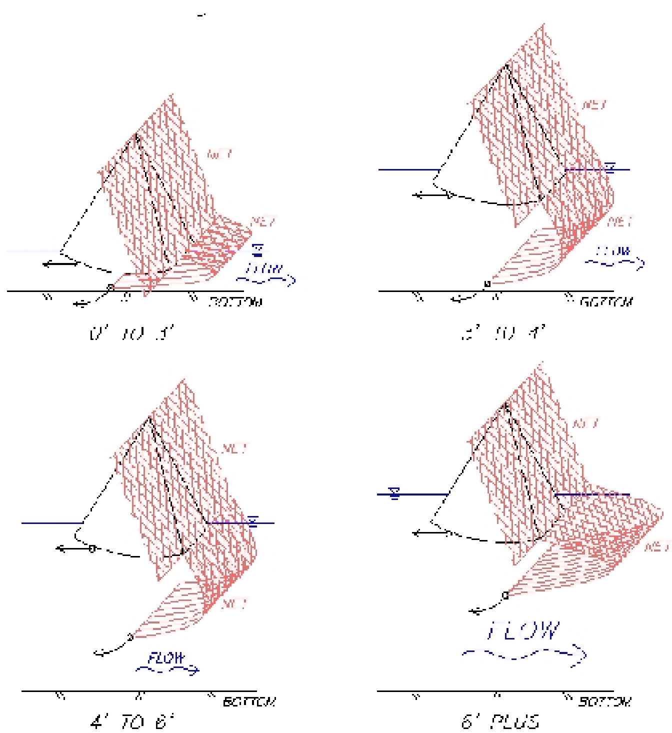

Figure 3 – Tetrahedral Buoy Net

PHYSICAL MODEL TESTING PROGRAM

A physical model study was completed to assess the stability and overall performance of several alternative debris net designs for the San Gabriel River. The physical model study was completed at a scale of 1:14 in the Canadian Hydraulic Centre's High Discharge Flume in Ottawa, Canada. A channel was constructed to match the channel properties of the San Gabriel River at the proposed location for the debris nets to be installed. The debris nets were tested under four flow conditions.

Three debris net buoy designs were tested during the study: spherical buoys (to replicate performance of the pre-existing debris net), cylindrical buoys and tetrahedral buoys. Model scale buoys were designed and fabricated to replicate the geometry, buoyancy, and the mass distribution of the prototype buoys. Styrofoam, masonite and black ABS pipe were used as scaled debris material to represent green waste, floating trash and submerged trash as seen in the prototype channel.

The model study demonstrated that the existing net has a poor capacity to trap debris, allowing debris to pass under medium flows. Visual observations demonstrated that the model scale net acted in a manner similar to the prototype structure, allowing debris to flow overtop of the net at medium flows.

The cylindrical buoys had a good debris trapping capacity. This net design was able to trap and keep debris at high flows. The cylindrical net design was the only net design tested at extreme flow. At the extreme flow values, the cylindrical debris net was not very effective. Most of the debris was washed overtop or underneath the net. For the cylindrical buoy design case, the tension measured in the upper and lower cables under high flows with no debris were significantly lower than the tension values measured under high flow conditions with the existing debris net case.

The tetrahedral net was able to trap debris at high flows; however, once the net became overloaded, the buoys had a tendency to tip, which would release much of the debris that had been captured by the net. The tetrahedral net design was slightly altered and re-tested. The lower chain was moved up by approximately one foot. The tension measured in both cables is approximately half of the tension measured in the previous tetrahedral net design. This is likely due to the net having a smaller capacity to trap debris due to the smaller section of net hanging below the buoys. This design modification resulted in significantly improved hydrodynamic stability and debris collection performance.

PROJECT POSTSCRIPT

The City of Seal Beach was prepared to move forward with implementation of a pilot project to install and manage the cylindrical buoy net design due to its relative simplicity. However, as part of the final review and regulatory compliance process, concern was raised by swift water rescue personnel regarding public safety issues associated with implementation of the net in the proposed channel location. Their main concern was the potential for either a victim or rescuer to be pinned against the net during a storm flow event. As a result, the debris net was not installed.

REFERENCES

Allison R., F. Chiew and T. McMahon (1997). Stormwater Gross Pollutants. Cooperative Research Centre for Catchment Hydrology Industry Report 97/11.

California Regional Water Quality Control Board, Los Angeles Region (2001). Draft Trash Total Maximum Daily Loads for the Los Angeles River Watershed.

EPA Office of Solid Waste and Emergency Response (1994). Waste Prevention, Recycling and Composting Options: Lessons from 30 U.S. Communities. Report EPA 530-R-92-015.

Los Angeles County Department of Public Works, 2001. Water Resources Division Index of Stream Gaging Stations. Available online at ladpw.org/wrd/runoff/index.cfm.

Metcalf & Eddy, Inc. (1991). Wastewater Engineering: Treatment, Disposal, Reuse, and Third Edition. Revised by G. Tchobanoglous and F.L. Burton. McGraw-Hill.

Moffatt & Nichol (1996). Los Angeles River Estuary Navigation Channel Alternatives. Prepared for U.S. Army Corps of Engineers, Los Angeles District. M&NE File Number 3479.

Moffatt & Nichol (1999). Marina Del Rey and Ballona Creek Feasibility Study: Sediment Transport Analysis and Report. Final Submittal. Prepared for U.S. Army Corps of Engineers, Los Angeles District. M&NE File Number 4033-05.

Moffatt & Nichol (2001). Seal Beach / San Gabriel River Floating Debris Collection: Report on Options. Prepared for the City of Seal Beach. M&NE File Number 3874-05.

State of California Resources Agency (2001). Common Ground from the Mountains to the Sea: Watershed and Open Space Plan, San Gabriel and Los Angeles Rivers.

United States Geological Survey, 2001. Surface Water for California. Available online at water.usgs.gov/ca/nwis/sw.