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# LAKELINE

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## Stormwater Management



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# LAKELINE

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# Contaminants in Urban Runoff:
## *Looking at Southern Nevada*

*Xiaoping Zhou*, *Kimberly S. Zikmund*, *Peggy Roefer*, and *James F. LaBounty*

**Introduction**

Las Vegas Wash (Wash) flows into Boulder Basin of Lake Mead. It serves as the sole drainage channel for the entire 1600 square mile Las Vegas Valley Hydrographic Basin with a population of 1.7 million. Flows in the Wash include urban runoff from tributaries, treated wastewater effluents from the Valley's wastewater treatment plants, intercepted shallow groundwater, and stormwater. Although the Wash provides only about 1.5 percent of the total water inflow to Lake Mead, it is a critical element in the overall environmental and water resource challenge facing southern Nevada. Lake Mead is the largest reservoir on the Colorado River system and provides water to Southern Nevada, Arizona, southern California, and Mexico.

Discharge of the Wash into Lake Mead presents potential concerns due to the presence of certain chemical and biological constituents typical of urban influence. The Urban Runoff Water Quality Monitoring Project was designed to provide data that are helpful in managing urban flows. Six sampling locations were chosen. Each site was sampled quarterly for chemical and biological constituents.

As a first-time systematic study, the tributary monitoring program, which began in 2000, provided a baseline of water quality data from urban runoff during non-storm (dry) weather conditions. Chemical loadings from the tributaries and their relative contributions to Lake Mead were also calculated (LVWCC 2003; Zhou, Roefer, and Zikmund 2004). This investigation, along with other water quality investigations of the Wash and Lake Mead, improves our ability to manage the Las Vegas Valley watershed.

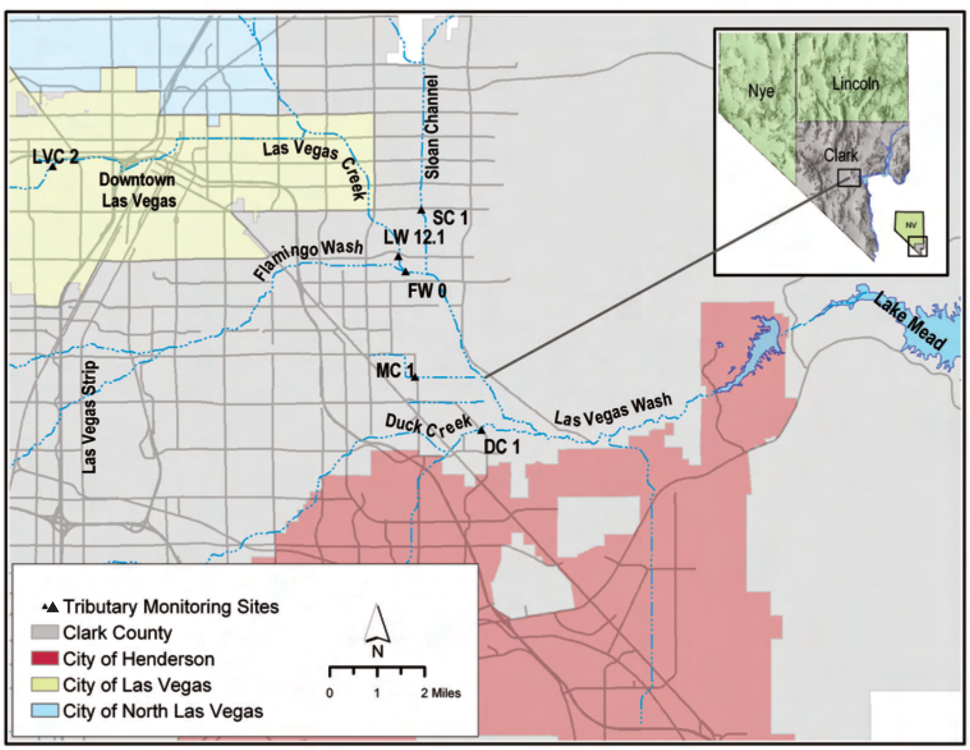
**Methods**

*In situ* physical parameters and water samples were collected from the six tributaries quarterly beginning in October 2000. The six tributaries are: Alta Channel at Meadows Detention Basin (LVC_2), Sloan Channel (SC_1), Las Vegas Creek (LW12.1), Flamingo Wash (FW_0), Monson Channel (MC_1), and Duck Creek (DC_1) (Figure 1). Samples were collected only when there was dry weather. EPA-certified protocols were strictly followed. We monitored the following field parameters: water temperature, dissolved oxygen, pH, specific conductance, and turbidity using a multi-parameter probe (Hydrolab Corporation Model Surveyor® 4). Water samples were analyzed for major ions, heavy metals, plant nutrients, and a full suite of organic constituents (derived from drinking water standards) in order for us to fully evaluate water quality of the Las Vegas Wash and its environmental impacts on drinking water in Lake Mead.

**Water Chemistry**

*Field Parameters:* Waters in all tributaries to the Las Vegas Wash were alkaline, with pH ranging from 8.2 to 8.6. Water temperature in the tributaries varied with seasons with a range between 1°C and 30°C. Dissolved oxygen concentrations were always saturated or supersaturated, ranging from 9 mg/L to 12 mg/L. Specific

*Figure 1. Location map showing major tributaries to the Las Vegas Wash in the Las Vegas Valley and six sample sites (▲) for the tributary water quality monitoring program.*



conductance was lower in Alta Channel (1900 µS/cm) and Sloan Channel (2350 µS/cm) and much higher at Duck Creek (5900 mS/cm), Monson Channel (4600 µS/cm), Flamingo Wash (3700 µS/cm), and Las Vegas Creek (3600 µS/cm). In general, higher specific conductance was found in the tributaries with a longer flow path and/or shallow groundwater inputs.

Interestingly, there is a large range in the relationship of specific conductance and total dissolved solids (TDS) in the urban tributaries. Specific conductance is a measurement of the ability of a substance to conduct an electrical current. The presence of charged ionic species (dissolved solids) in water makes the water conductive. As dissolved solid concentrations increase, conductance of the water increases; therefore, the specific conductance measurement provides an indication of total dissolved solid (TDS) concentration in water. TDS can be calculated based on the specific conductance. Among six tributaries, Duck Creek, Flamingo Wash, Las Vegas Creek, and Monson Channel have higher total dissolved solids (TDS) (ranging from 3246 mg/L to 5048 mg/L), whereas Sloan Channel and Alta Channel have lower TDS concentrations (approximately 1720 mg/L and 1413 mg/L, respectively) (Table 1).

*Major Ions:* Waters in all tributaries to the Las Vegas Wash are the Mg-Ca-Na-$SO_4$-Cl type. The dominant cations are calcium ($Ca^{+2}$) ranging from 122 to 505 mg/L, magnesium ($Mg^{+2}$) from 103 to 321 mg/L, and sodium ($Na^{+}$) from 157 to 566 mg/L. The dominant anions are sulfate ($SO_4^{-2}$) ranging from 608 to 2526 mg/L, chloride ($Cl^{-}$) from 160 to 839 mg/L, and bicarbonate ($HCO_3^{-}$) from 224 to 282 mg/L (Table1). Additionally, potassium ($K^{+}$) and silica ($SiO_2$) concentrations range from 16 to 63 mg/L and from 21 to 57 mg/L, respectively. Carbonate ($CO_3^{-2}$) concentration ranges from 2 mg/L to 10 mg/L. Bromide ($Br^{-}$) and Fluoride ($F^{-}$) concentrations are very low in all tributaries, less than 1.5 mg/L. Major ion (salt) concentrations from the tributaries to the Wash are generally high due to high evaporation rates and contacts with surface soils that are naturally saline in the arid environment. Salts in the surface soils can readily be dissolved by irrigation water and leached into the tributaries.

*Heavy Metals:* Seventeen heavy metals were analyzed. Concentrations of 11 metals from six tributaries are in Table 1. The metals not included in Table 1 were below detection limits. Average concentrations of aluminum, iron, and manganese varied from 5.3 mg/L to 386.7 mg/L. Concentrations of other trace metals, including arsenic,

**Table 1. Average Chemistry Data of Water Samples from the Tributaries to the Las Vegas Wash, Nevada**

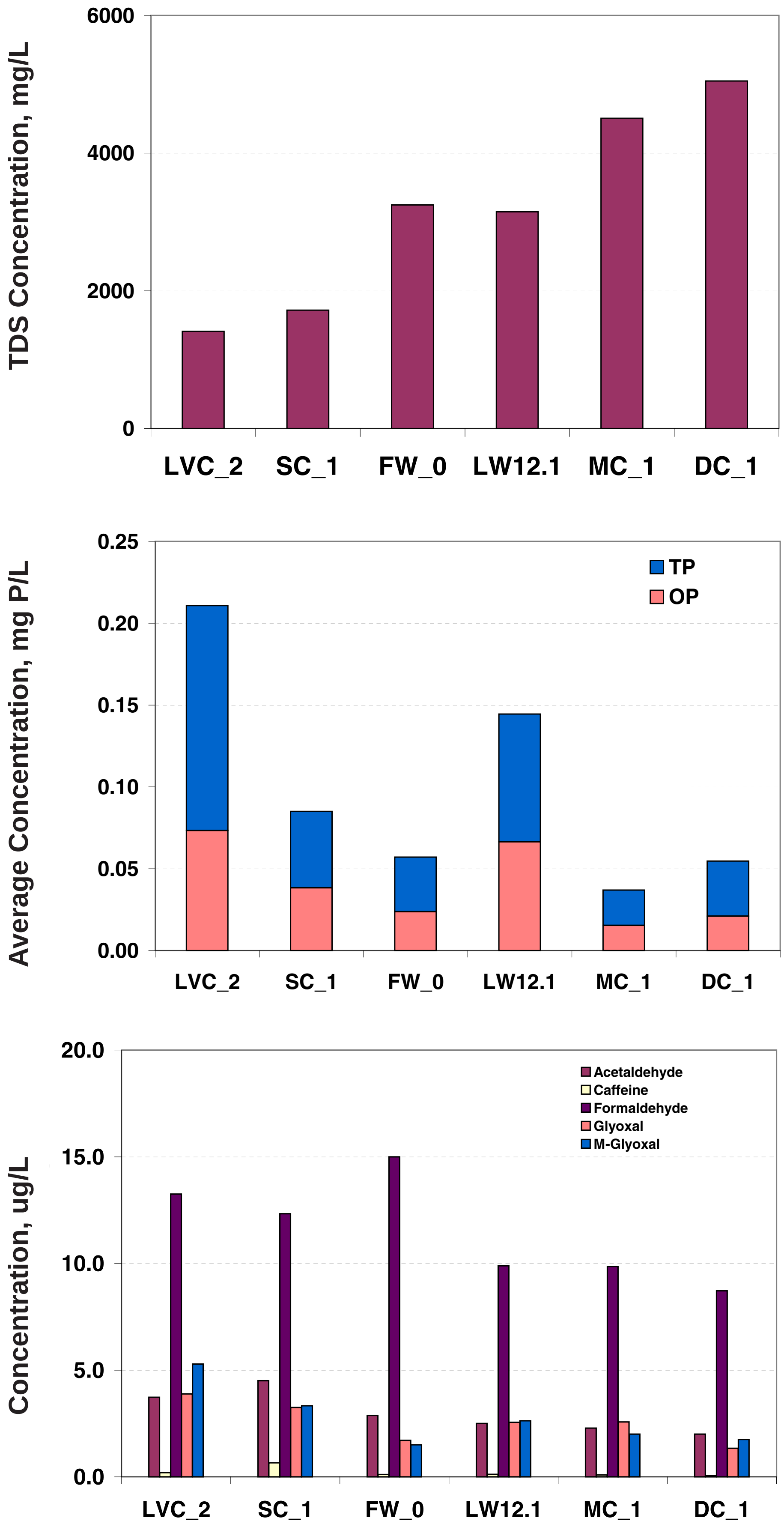
| | Parameters | DC_1 | FW_0 | LW12.1 | LVC_2 | MC_1 | SC_1 |
|---|---|---|---|---|---|---|---|
| Major Ions (mg/L) | Calcium | 505 | 328 | 233 | 122 | 435 | 122 |
| | Magnesium | 287 | 225 | 255 | 103 | 321 | 151 |
| | Sodium | 566 | 289 | 293 | 157 | 425 | 169 |
| | Potassium | 63 | 32 | 55 | 18 | 32 | 16 |
| | Bicarbonate | 225 | 236 | 260 | 282 | 227 | 224 |
| | Carbonate | 1.9 | 3.0 | 4.8 | 10 | 3.5 | 5.0 |
| | Sulfate | 2469 | 1743 | 1715 | 608 | 2526 | 763 |
| | Chloride | 839 | 303 | 278 | 160 | 414 | 212 |
| | Bromide | 1.0 | 0.8 | 0.7 | 0.3 | 1.1 | 0.8 |
| | Fluoride | 1.3 | 0.6 | 0.5 | 0.5 | 0.7 | 1.1 |
| | Silica | 53 | 31 | 31 | 21 | 43 | 57 |
| | Total Dissolved Solids (TDS) | 5048 | 3246 | 3147 | 1413 | 4505 | 1720 |
| Metals (ug/L) | Aluminum | 167.9 | 54.8 | 77.0 | 105.0 | 74.9 | 167.1 |
| | Arsenic | 50.5 | 6.6 | 5.5 | 3.7 | 16.8 | 21.4 |
| | Barium | 28.9 | 35.9 | 36.8 | 43.9 | 26.1 | 61.7 |
| | Chromium | 2.0 | 2.4 | 2.3 | 2.3 | 2.3 | 4.5 |
| | Copper | 10.8 | 8.7 | 7.3 | 6.9 | 8.7 | 5.5 |
| | Iron | 307.5 | 340.0 | 263.3 | 260.0 | 250.0 | 386.7 |
| | Lead | 0.6 | 0.8 | 0.9 | 1.0 | 1.0 | 0.7 |
| | Manganese | 31.7 | 8.7 | 11.4 | 10.2 | 5.3 | 43.8 |
| | Nickel | 21.1 | 12.6 | 10.2 | 6.7 | 15.6 | 6.3 |
| | Zinc | 15.2 | 16.6 | 18.7 | 19.7 | 13.6 | 12.4 |
| | Selenium | 23.3 | 15.0 | 11.0 | 5.0 | 22.6 | 6.6 |
| Organics (ug/L) | Acetaldehyde | 2.00 | 2.88 | 2.50 | 3.73 | 2.29 | 4.50 |
| | Caffeine | 0.06 | 0.11 | 0.12 | 0.20 | 0.08 | 0.66 |
| | Formaldehyde | 8.71 | 15.00 | 9.89 | 13.25 | 9.86 | 12.33 |
| | Glyoxal | 1.33 | 1.71 | 2.56 | 3.89 | 2.57 | 3.25 |
| | M-Glyoxal | 1.75 | 1.50 | 2.63 | 5.29 | 2.00 | 3.33 |
| **Perchlorate** | $ClO_4$, _g/L | 19.87 | 10.52 | 11.13 | 11.06 | 17.01 | 8.65 |
| Nutrients | $NH_4$, _g N/L | 96 | 89 | 94 | 222 | 91 | 188 |
| | $NO_2$, _g N/L | 80 | 80 | 119 | 89 | 95 | 93 |
| | $NO_3$, _g N/L | 4799 | 4075 | 2977 | 2346 | 4326 | 2448 |
| | $NO_2 + NO_3$, _g N/L | 4823 | 4091 | 3032 | 2491 | 4375 | 2498 |
| | TKN, _g N/L | 467 | 467 | 983 | 1817 | 833 | 975 |
| | OP, _g P/L | 21 | 24 | 66 | 73 | 15 | 38 |
| | TP, _g P/L | 34 | 33 | 78 | 137 | 22 | 47 |

barium, chromium, copper, lead, manganese, zinc, and selenium, were lower or much lower than the maximum contamination level (MCL) for the primary standards and the secondary standards for drinking water. Of the six tributaries, Duck Creek has relatively higher concentrations of aluminum (167.9 µg/L), iron (307.5 µg/L), manganese (31.7 µg/L), arsenic (50.5 µg/L), nickel (21.1 µg/L), and selenium (23.3 µg/L). Monson Channel also has a higher selenium concentration (22.6 µg/L).

As one of those metalloids that have a potential to be bioaccumulated in aquatic environment, selenium can be toxic to some animals at elevated concentrations. The EPA selenium criterium for wildlife in freshwater is 5 µg/L. Selenium is widely distributed in nature and abundant with sulfide minerals of various metals, such as iron, lead, and copper. Weathering of rocks, including volcanic and sedimentary rocks, is the major source of environmental selenium. These types of rocks are common in southern Nevada and around the Las Vegas valley.

*Plant Nutrients:* Analysis for nitrogen and phosphorus included ammonia ($NH_4$-N), nitrite ($NO_2$-N), nitrate ($NO_3$-N), total Kjeldahl nitrogen (TKN), orthophosphorus ($OP_4$-P), and total phosphorus (TP) (Table 1, Figure 2). Ammonia concentrations in most tributaries were lower than the detection limit (80 µg N/L). The exceptions were Alta Channel at Meadows Detention Basin and Sloan Channel, in which average ammonia concentrations were 222 and 188 µg N/L, respectively. As an unstable species of nitrogen in aerated water, nitrite concentrations were generally below the detection limit in all tributaries. Nitrate nitrogen, as a stable species in natural water, was always detected in all tributaries in high concentrations. Nitrate concentrations in the tributaries ranged from 2346 µg N/L to 4799 µg N/L. The average TKN concentrations varied from 467 µg N/L to 1817 µg N/L, with some high concentrations (1200 – 1600 µg N/L) in Alta Channel at Meadows Detention Basin, Monson Channel, and Sloan Channel. Both orthophosphorus and

*Figure 2. Average concentrations of total dissolved solids (TDS), phosphorus nutrients, and five organic pollutants in water from six tributaries.*



total phosphorus concentrations in the tributaries ranged from 15 µg P/L to 137 µg P/L.

*Organic Compounds:* One hundred and seventy-seven priority organic compounds were analyzed for all collected samples. Most of these compounds were below the analytical detection limits. However, five organic compounds were detected from all tributaries and 35 organic compounds were detected at least once. Twenty-one compounds were detected from only one sample site. There were 15 compounds detected at Meadows Detention Basin (LVC_2), 12 at Sloan Channel (SC_1), 11 at Monson Channel, 9 at Flamingo Wash (FW_0), and 7 at Duck Creek (DC_1) and Las Vegas Creek (LW12.1), respectively. The five most common organic compounds detected were acetaldehyde, caffeine, formaldehyde, glyoxal, and M-glyoxal (pyruvic aldehyde). They were detected at all six tributaries (Table 1, Figure 2). Concentrations of caffeine were less than 1 µg/L and concentrations of acetaldehyde, formaldehyde, glyoxal, and M-glyoxal (pyruvic aldehyde) were less than 15 µg/L. Less common organic compounds, such as di(2-ethylhexyl) phthalate, propanal, and 2,4-D, were also found at most sample sites. Acetaldehyde and formaldehyde are hazardous pollutants and toxic at elevated levels. Sources of acetaldehyde and formaldehyde include emission from combustion processes, building materials, food preservative, tobacco smoke, paper mills, crude oil and natural gas mining, and petroleum refining.

**Flows in the Tributaries**

In order to quantify mass loading rates of different chemical constituents, flow rates of six tributaries were measured monthly since April of 2001. The U.S. Geological Survey (USGS) Parshall flume and the Price pygmy flow meter were used depending on the hydrological conditions of flow channels. The methods for measurement and computation of streamflow developed by USGS (Rantz et al. 1982) were followed.

Based on our measurements, the six tributaries contribute approximately 18 cubic feet per second (approximately12 million gallons per day) of flow to the Wash under dry weather condition. As one of four flow components in the Las Vegas Wash, urban runoff from the Las Vegas Valley contributes more than13,000 acre feet per year (LVWCC, 2003) of water to the Wash, approximately 7% of the total Wash flow (Figure 3). As stated previously, the Las Vegas Wash accounts for 1.5% of the total water inflow to Lake Mead. Therefore, flows from tributaries are equivalent to 0.11% of the total water inflow to Lake Mead.

**Mass Loading from the Tributaries to the Wash**

The daily mass loading rates (lbs/day or tons/day) of TDS, heavy metals, and nutrients from each tributary were calculated using the average concentrations of these chemical constituents and the average flow rate in each tributary. The total daily load (TDL) from all six tributaries to the Las Vegas Wash was obtained by summing the mass loading of each tributary. The relative percentages of the TDL of each chemical constituent from all six tributaries vs. that in the Las Vegas Wash were also computed (Table 2). With approximately 7% of the Wash total flow, six tributaries together contribute approximately 17% of total TDS, 40% of selenium, 15% of arsenic, 2% of total metals, 2% of nitrogen nutrient, and 1% of phosphorus nutrient mass loading to the Wash (Table 2, Figure 4).

**Discussion**

In general, tributary water has higher TDS, higher trace metals (copper, nickel, selenium, and arsenic), and lower nutrients compared with the mainstream Wash water that consists mainly (> 85%) of treated wastewater. This is particularly true for those tributaries that flow through the highly urbanized areas and are located in the lower portion of the Las Vegas Valley. These variations in water quality are most likely due to the high evaporation rates in the Las Vegas Valley, urban activities, and shallow groundwater inputs.

Comparisons of concentrations and mass loading rates of different chemical constituents in the six tributaries showed that Duck Creek (DC_1) and Flamingo Wash (FW_0) are the two major sources of TDS, heavy metals (especially selenium, arsenic, copper, and nickel), organic compounds, and nutrients to the Wash. Recent studies of selenium in the Las Vegas Wash and its tributaries indicated that more than 40% of selenium entering the Wash, and eventually to Lake Mead, comes from Duck Creek. Duck Creek intercepts locally resurfacing shallow groundwater, which is the major source of selenium (Figure 4). Las Vegas Creek (LW12.1) contributes the third greatest mass loading of each chemical constituent.

*Figure 3. Average annual flow (acre feet per year) from each tributary to the Las Vegas Wash.*

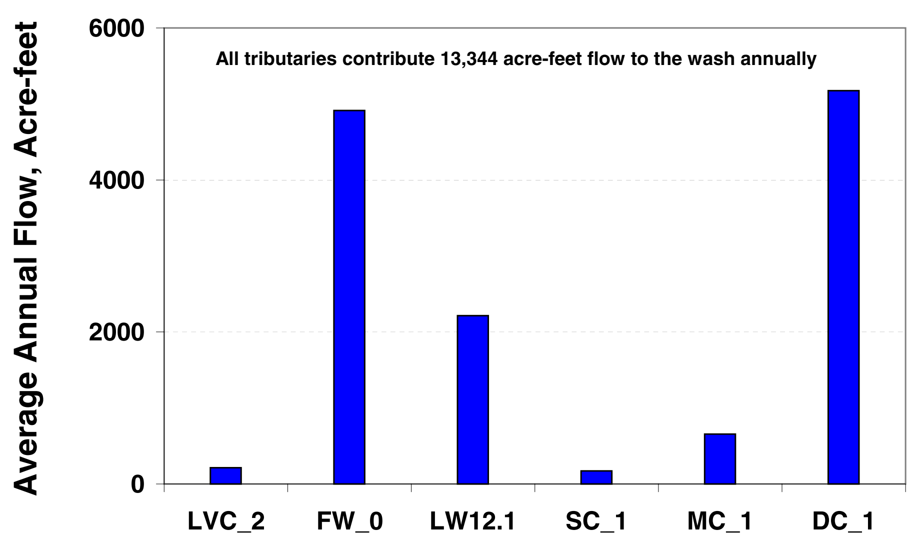


**Table 2. Daily Mass Loading of TDS, Heavy Metals, and Nutrients from Tributaries (TRB) and the Las Vegas Wash (LVW).**

| | Parameter | TRB | LVW | %, TRB vs. LVW |
|---|---|---|---|---|
| TDS (tons/day) | | 186.6 | 1092.7 | 17.1 |
| Heavy Metals (lbs/day) | Aluminum | 8.9 | 863.6 | 1.0 |
| | Arsenic | 2.1 | 14.4 | 14.5 |
| | Barium | 3.3 | 70.4 | 4.7 |
| | Chromium | 0.2 | 110.0 | 0.2 |
| | Copper | 1.1 | 8.3 | 13.2 |
| | Iron | 28.4 | 1281.3 | 2.2 |
| | Manganese | 1.9 | 96.5 | 1.9 |
| | Nickel | 1.6 | 15.2 | 10.3 |
| | Lead | 0.1 | 2.7 | 3.2 |
| | Selenium | 1.6 | 4.1 | 39.7 |
| | Zinc | 2.1 | 52.9 | 3.9 |
| | Total Metals | 51.3 | 2519.4 | 2.0 |
| Nutrients (lbs/day) | $NH_4$ | 8.1 | 142.2 | 5.7 |
| | $NO_2$+$NO_3$ | 378.6 | 20039.2 | 1.9 |
| | TKN | 36.6 | 796.3 | 4.6 |
| | OP | 3.0 | 262.4 | 1.1 |
| | TP | 4.9 | 366.4 | 1.3 |

Tributaries with less flow, such as Sloan Channel, Alta Channel, and Monson Channel, play a very limited role in terms of mass loading of compounds to the Wash.

Almost three dozen organic compounds were detected in tributaries. The organic compounds found generally come from both urban and industrial sources, such as pesticides, herbicides, automobile oils, and chemical spills and wastes. Las Vegas Wash tributaries drain several sub-basin flows that come from streets and roads. Over-watering of lawns, industrial water uses, car washing, pool water draining, and resurfacing shallow groundwater are sources of urban runoff. Water quality and quantity of these tributary flows, like other urbanized areas in the Western United States, are greatly affected by urban development, human activity, water use habit and land use pattern, and local weather and geology. However, there were no severe or massive chemical contaminations to the tributaries, except for an elevated selenium concentration at Duck Creek, Flamingo Wash, and Monson Channel.

## Summary

The long-term monitoring in the tributaries permits characterization of the water quality of urban runoff within the Las Vegas Valley watershed, and it provides us information to quantify potential environmental impacts. Data from this study were used by the Las Vegas Wash Coordination Committee (LVWCC) to evaluate the current state of heath of urban runoff from the tributaries to the Wash, to monitor variations over time in water quality, and to help better manage the Wash and Lake Mead.

As the fastest-growing city in U.S., Las Vegas will continue to face challenges of urban runoff water quality. There are no easy solutions to these complicated problems. The long-term and comprehensive management plans that have been implemented by federal, state, and local government organizations and agencies since the early of 1990s greatly helped maintain or improve water quality in the tributaries, the Las Vegas Wash, and Lake Mead. Specifically, the Best Management Practice (BMP) within the Las Vegas Valley watershed, such as sub-basin and drain maintenance, street sweeping, illegal/illicit connection elimination, hazardous material disposal management, water conservation, and public education, are having positive impacts on water quality in the tributaries, the Wash, and Lake Mead.

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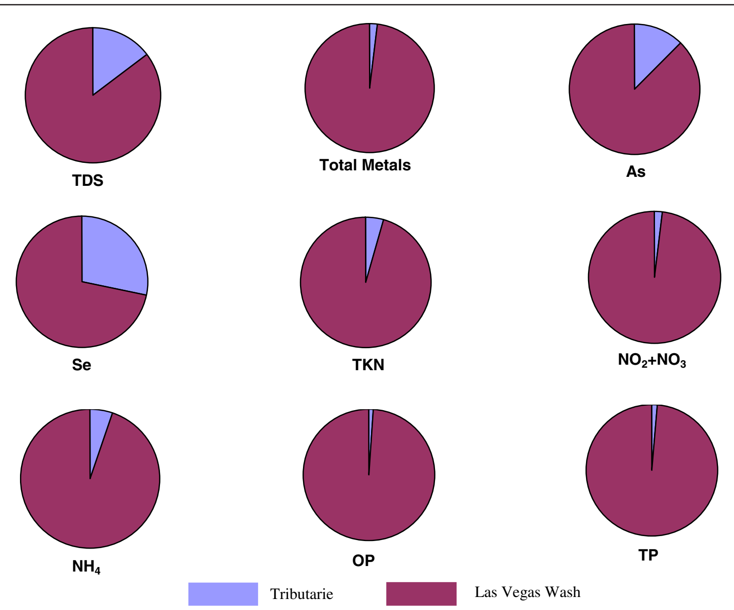


*Figure 4. Pie diagrams showing the relative percentages of the daily mass loadings of different chemical constituents (tributaries vs. Las Vegas Wash).*

U.S. Geological Survey Water-Supply Paper 2175, 284 p.
Zhou, X., Roefer, P., and K. Zikmund, 2004. Las Vegas Wash Monitoring and Characterization Study: Results for Water Quality in the Wash and Tributaries. Final Report to USEPA, Region IX, 42 p.

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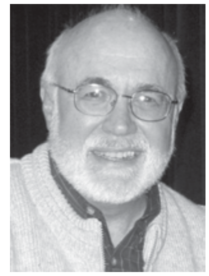

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