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Aquatic Macroinvertebrates and Water Quality in Sandia Canyon

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AQUATIC MACROINVERTEBRATES AND WATER QUALITY IN SANDIA CANYON

by

Kathryn Bennett

ABSTRACT

In 1990, field studies of water quality and stream macroinvertebrate communities were initiated in Sandia Canyon at Los Alamos National Laboratory. The studies were designed to establish baseline data and to determine the effects of routine discharges of industrial and sanitary waste. Water quality measurements were taken and aquatic macroinvertebrates sampled at three permanent stations within the canyon. Two of the three sample stations are located where the stream regularly receives industrial and sanitary waste effluents. These stations exhibited a low diversity of macroinvertebrates and slightly degraded water quality. The last sample station, located approximately 0.4 km (0.25 mi) downstream from the nearest waste-water outfall, appears to be in a zone of recovery where water quality parameters more closely resemble those found in natural streams in the Los Alamos area. A large increase in macroinvertebrate diversity was also observed at the third station. These results indicate that effluents discharged into Sandia Canyon have a marked effect on water quality and aquatic macroinvertebrate communities.

1. INTRODUCTION

During the early summer of 1990, 3785-5300 liters (1000-1400 gallons) of sulfuric acid spilled from the TA-3 Power Plant Environmental Tank to the cattail-dominated wetland in Sandia Canyon. As a result of this incident, the Biological Resources Evaluation Team (BRET) was asked to review the impact of the spill on the downstream wetland. The study was subsequently extended to acquire baseline information on aquatic macroinvertebrate communities of Sandia Canyon at Los Alamos National Laboratory (LANL) and to determine if these communities are affected by routine industrial and sanitary waste discharges. This report summarizes the first three years of data from the study.

Data on macroinvertebrate species composition and diversity and on water quality were gathered over the three years (1990, 1991, and 1992) of field study. Standard water quality parameters—temperature, pH, dissolved oxygen, and conductivity—were used to broadly evaluate water quality. Aquatic macroinvertebrates were also sampled at each station and were identified to genus, when possible, in the laboratory.

Water temperature is significant because it governs physiological functions in organisms and acts directly or indirectly in combination with other water quality characteristics to strongly affect aquatic life (Canter and Hill 1979). The pH of natural waters is also important to aquatic organisms and is an indicator of water quality. Some aquatic macroinvertebrates and other aquatic organisms are sensitive to low pH, and pollution problems such as accidental acid spills or acid rain deposition can significantly lower pH values. The pH range of natural surface water is 6.5–9.0 (Canter and Hill 1979). In Los Alamos Canyon, the pH of natural surface water ranges between 7.8 and 8.2 (LANL 1990).

Dissolved oxygen (DO) is an extremely important element in aquatic ecosystems and is probably the most frequently measured water quality parameter. The critical range of DO for virtually all freshwater fish species is 3-6 mg/l (Canter and Hill 1979). The importance of DO to aquatic macroinvertebrates is indicated by a study done by Nebeker (1972), which suggests that low oxygen concentrations dramatically affect the survival and emergence of aquatic macroinvertebrate larvae. Depressed oxygen environments are often indicative of the presence of organic waste.

Conductivity is a measure of the ability of water to carry an electrical current and reflects the concentration of ionized elements in water. The conductivity of potable water in the U.S. ranges from 50 to 1500 μohms/cm, while the conductivity of industrial waste may be as high as 10 000 μohms/cm. Conductivity is also a reflection of the concentration of total dissolved solids (TDS) in water. A rough approximation of the TDS of freshwater can be obtained by multiplying the conductivity by 0.66. The upper limit of TDS that most fish and other aquatic organisms can tolerate ranges from 5000 to 10 000 mg/l (Battelle 1972).

The literature on freshwater ecology suggests that aquatic macroinvertebrate communities are very good indicators of the presence of environmental pollutants (Pederson and Perkins 1986; Gaufin and Tarzwell 1956; Nebeker 1972; Wurtz 1955; Patrick 1950; Resh and Unzicker 1975; Weber 1973). Aquatic macroinvertebrates are suitable for studies of water quality because they are very sensitive to physical and chemical stress, they lack the mobility to escape areas of pollution, and they have relatively long life spans.

As a general rule, monitoring only the physical and chemical characteristics of water can provide very little insight into conditions prior to the time that a water sample is taken. In contrast, monitoring changes in macroinvertebrate communities can give some indication of water quality over a much longer period of time. Shifts in the relative numbers of individuals and the species composition in a macroinvertebrate community can result from infrequent discharges of waste that could remain undetected by monitoring physical characteristics alone (Weber 1973).

2. ENVIRONMENTAL SETTING

2.1. General Setting

Sandia Canyon is located within the boundaries of Los Alamos National Laboratory (LANL). The Laboratory is located in north-central New Mexico on the Pajarito Plateau, approximately 120 km (80 mi) north of Albuquerque and 40 km (25 mi) west of Santa Fe (Fig. 1). The plateau is an apron of volcanic rock stretching 33-40 km (20-25 mi) in a north-south direction and 8-16 km (5-10 mi) from east to west. The average elevation of the plateau is 2286 m (7500 ft). It slopes gradually eastward from the edge of the Jemez Mountains, a complex pile of volcanic rock situated along the northwest margin of the Rio Grande rift. From an elevation of approximately 1890 meters (6200 ft) at White Rock, the plateau scarp drops to 1646 meters (5400 ft) at the Rio Grande. Intermittent streams flowing southeastward have dissected the plateau into a number of finger-like, narrow mesas separated by deep, narrow canyons. The bedrock

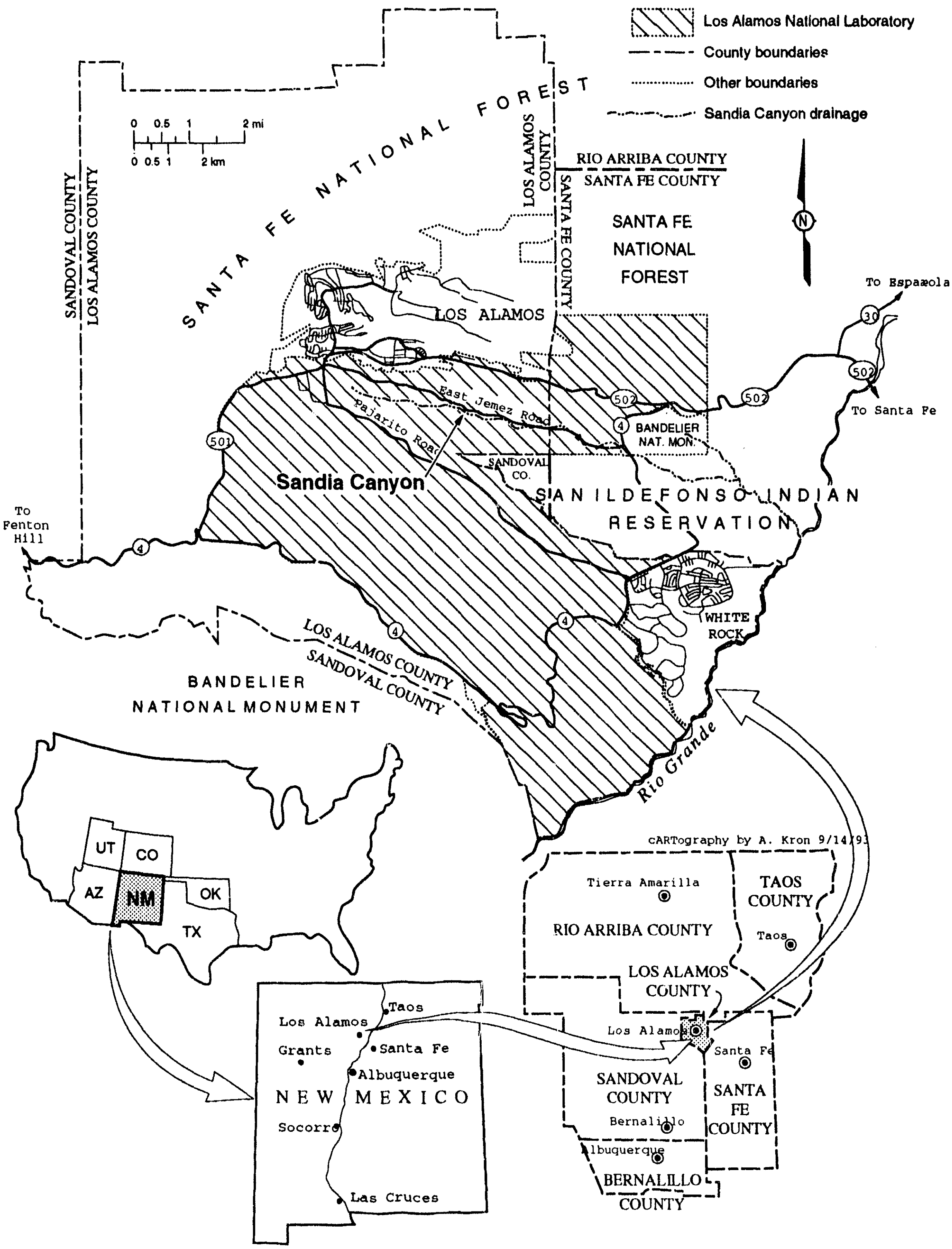

Fig. 1. Location of Sandia Canyon at LANL.

consists of Bandelier tuff that erupted from the Jemez Mountains about 1.1 to 1.4 million years ago. The tuff overlaps other volcanics that in turn overlay the Puye Formation conglomerate (LANL 1988). This conglomerate intermixes with Chino Mesa basalts along the Rio Grande.

The LANL area is characterized by a semiarid, temperate mountain climate. In the summer months, temperatures typically range from a daily low of around 10° C (50° F) to a high of 27° C (80° F) (Bowen 1990). Winter temperatures generally range from near -10° C (15° F) to about 10°C (50° F) during a 24-h period. Annual precipitation varies from 33 to 46 cm (13 to 18 in.), with most of it falling as rain in July and August.

2.1.1. Description of Sandia Canyon

The head of Sandia Canyon is near the University House in Technical Area 3 (TA-3) and the canyon extends southeastward to the Rio Grande. The area of the drainage basin is approximately 13.5 km^2 (5.6 mi^2). Industrial effluents from LANL activities maintain the stream flow in Sandia Canyon year-round.

The National Wetlands Inventory conducted by the US Fish and Wildlife Service shows three types of wetlands or water systems in Sandia Canyon. This research effort was concentrated in the uppermost wetland area, a "persistent, artificially flooded, palustrine wetland" (Cowardin 1979). Situated below TA-3, this wetland receives effluent from the TA-3 steam plant, a sewage treatment plant, and an asphalt plant. Storm water runoff and snow melt also contribute to the stream seasonally. LANL has discharged effluents to the stream since the early 1950s.

Farther downstream where the stream meets East Jemez Road, the wetland area changes to a "temporarily flooded palustrine wetland" type, and the lower section of the stream is an "intermittent, temporarily flooded, riverine stream bed" (Cowardin 1979). The National Wetland Inventory Map of Sandia Canyon is shown in Fig. 2. The three LANL outfalls collectively discharge 1 639 000 l/d (432 864 gal/d) into

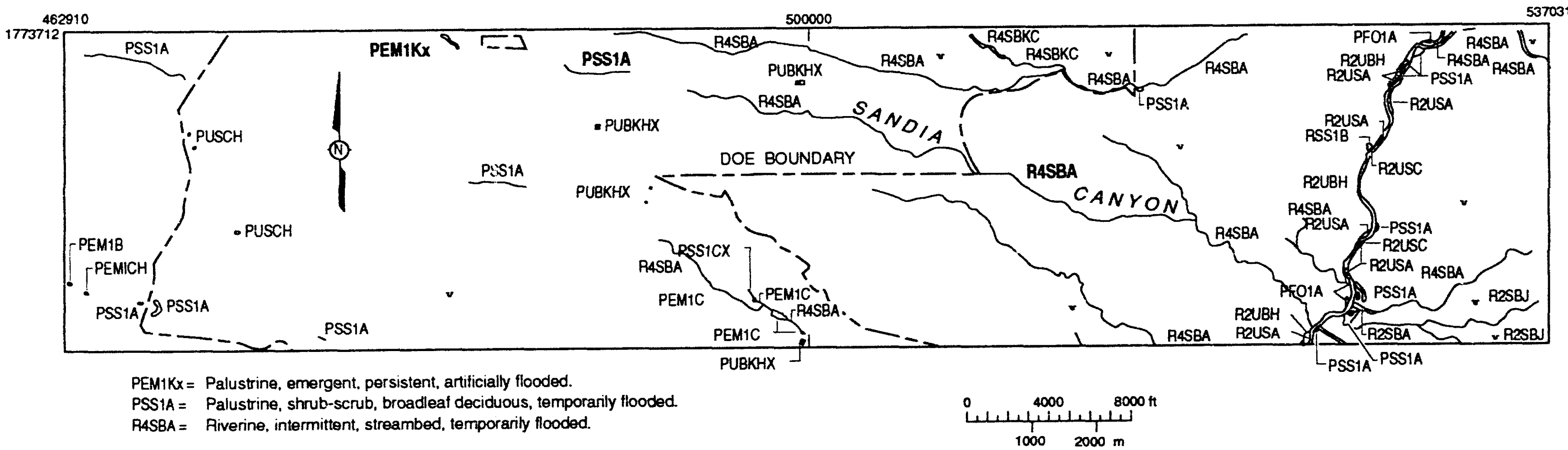

Fig. 2. National Wetland Inventory Map for Sandia Canyon, Los Alamos County, New Mexico (developed by the US Fish and Wildlife Service).

Sandia Canyon.

2.1.2. Description of the Study Site

Three permanent sample stations were placed in the artificially flooded, palustrine wetland in Sandia Canyon. Station SC1, located beneath the rubble landfill and immediately below the effluent culvert, receives effluent from the steam plant and the asphalt plant. The streamside vegetation in this section consists of bluegrass (*Poa* spp.) and cattails (*Typha latifolia*) on the south side and predominantly cattails on the north side of the water course. The stream bed is composed of coarse gravel and sand and there is little or no emergent vegetation within the stream channel (Fig. 3). The water flow is variable at this station due to erratic releases from the asphalt plant. When the plant discharges effluent, the greatly increased flow disturbs the stream bed substrate and redeposits portions downstream. The water and stream channel usually have no odor at this station.

Station SC2, located approximately 0.4 km (0.25 mi) downstream from Station SC1, receives additional effluent from the sewage treatment plant. The vegetation in this area is characterized by bluegrass on the south side of the stream channel and cattails on the north side. The stream bed substrate consists of silts and sands containing a large quantity of humus (Fig. 4). The water and substrate at this station generally give off a slight to obvious chlorine odor. Water flow is much more stable at this station than at Station SC1.

Station SC3 is located approximately 0.4 km (0.25 mi) downstream from Station SC2. The vegetation here includes fewer cattails than the other stations, and bluegrass, willows (*Salix* spp.), and Gambel oak (*Quercus gambelii*) are more common. The stream substrate consists of sand and gravel deposited onto bedrock except in a large pool in the stream, where the substrate is composed of sand and silt deposited on top of rock (Figure 5). Immediately east of the pool, the stream narrows and forms riffles where the stream bed is littered with rocks as large as 20 cm (8 in.) in diameter. There is usually no odor associated with this station.

Fig. 3. Station SC1 in Sandia Canyon

Fig. 4. Station SC2 in Sandia Canyon

Figure 5: The large pool at Station SC3 in Sandia Canyon

3. HISTORICAL DISTURBANCES IN SANDIA CANYON

In addition to the impacts of routine effluent discharges, the hydrology of Sandia Canyon has been affected by the rubble landfill, the county sanitary landfill, and accidental chemical spills.

3.1. Rubble Landfill

The rubble landfill was started in 1986 as an alternative disposal site for clean rubble. Presently, the landfill bridges the canyon and will be extended with further rubble to the northeast. Large amounts of fill and sediments erode into the wetland during heavy storms and snow melt. In the past two years, attempts have been made to stabilize the landfill and prevent eroding materials from entering the stream channel and wetland.

3.2. County Landfill

The County Landfill is located to the north of Sandia Canyon and extends 1.2 km (0.75 mi) along the top of Los Alamos Mesa. The landfill receives Los Alamos County business and residential refuse as well as sanitary refuse from LANL. Fill material erodes off the landfill and into the wetland, and paper trash and other debris fall or blow into the canyon.

3.3. Accidental Spills

This study was initiated in response to a sulfuric acid spill into Sandia Canyon in 1990, which is described above. Initially, no macroinvertebrates were found at any of the sample locations, but within a month communities began to reestablish. Station 3 was the first station where recovery was observed.

Another spill occurred during mid summer of 1992, sending a discharge of chlorine from the sewage treatment plant into Sandia Canyon. Investigation showed that there was a significant decline in the number of macroinvertebrates in the stream. However, by the end of the summer, the relative numbers of macroinvertebrates were nearly back to normal.

4. METHODOLOGY

Three sampling stations, designated SC1, SC2, and SC3, were established in Sandia Canyon. Samples were taken at least once a month to measure temperature, pH, DO, and conductivity. Three samples were taken at each site on each visit. All measurements were taken with calibrated meters in accordance with the manufacturer's specifications. Estimates of total dissolved solids were obtained by multiplying the conductivity readings by 0.66 (Battelle 1972).

Aquatic macroinvertebrates were sampled at the same time that water quality characteristics were measured. Most aquatic macroinvertebrate sampling occurred during the months of April through October. The substrate was sampled at the pools and riffles at each station. A large, D-frame dip net

(11.5 cm [4.5 in] in diameter at its widest point) was placed at the bottom of the stream channel and water was allowed to flow freely through the net for 30 seconds. The net was vigorously scraped against the bottom of the stream bed for one minute and then carefully removed from the water. All aquatic invertebrates were collected and taken to the BRET lab for identification.

In addition to the above samples, quantitative samples were taken during 1992. A Surber square-foot sampler was used in the shallow riffle areas and Hester-Dendy multiple plate samplers were placed in pool areas. Specimens collected were preserved in 70% ethanol and identified to genus when possible. All data from each station were pooled and a diversity index was calculated using the equation discussed by Wilhm (1967):

$$D=(S-1) / \ln N$$

where:

D= the taxa diversity index
S = the number of taxa
N = the number of individuals

5. RESULTS AND DISCUSSION

5.1. Macroinvertebrate Sampling

The taxa of aquatic macroinvertebrates found within the three sample locations in Sandia Canyon are listed in Table 1 and the number of taxa found at each station is shown in Fig. 6. Station SC3 had the highest number of taxa (25) collected. Five taxa were collected at each of the other two sites (SC1 and SC2).

In general terms, larvae in the orders Ephemeroptera, Odonata, Plectoptera, and Trichoptera are intolerant of highly degraded waters and their presence is an indication of good water quality (Weber 1973). These macroinvertebrates are gilled and are sensitive to depressed oxygen environments and environmental pollutants. Figure 7 illustrates the percentage of the species found from these orders at each station. Station SC3 had the highest percentage and station SC2 had the lowest percentage of these species.

Diversity indices were prepared from the relative numbers of individuals collected and the number of different taxa found at each of the sample stations (Fig. 8). The greatest biodiversity of aquatic macroinvertebrates (3.74) was found at SC3, while the lowest biodiversity (1.09) was found at SC2 .

5.2. Water Quality Measurements

5.2.1. Temperature

Figure 9 shows the temperatures recorded at each sample station in 1990, 1991, and 1992. Temperatures were measured in degrees Celsius. In 1990, water temperature measurements were only taken during the summer months. Of the three sample stations, SC1 had the highest water temperature, and SC3 had the lowest. SC1 receives effluent from the steam plant at TA-3 that is normally discharged at a temperature higher than the natural stream temperature.

5.2.2. pH

Figure 10 shows average monthly pH readings from the three sample stations. In 1990, pH was only taken during the summer months. The highest pH was regularly measured at SC1. This is probably due to the influence of the steam plant effluent, which has a pH higher than the natural waters of the area. (The LANL National Pollutant Discharge and Elimination System [NPDES] permit, issued by the Environmental Protection Agency, allows a maximum allowable pH of 9.0 at this outfall.) The lowest pH occurred at SC2, which receives effluent discharges from the sewage treatment plant. This effluent is generally discharged at a neutral pH (7) and the average pH at this station was approximately 7.5. The pH of the water at SC3 was usually within the pH range of natural water in this area (7.8–8.2).

Figure 11 presents a functional curve developed by Battelle (1972) to rate water quality based on pH alone. Even though SC1 had an average pH (8.5) that is slightly higher than the natural pH of area waters, the station's Environmental Water Quality Index based on pH is in the excellent range. This is also true of SC2 and SC3

5.2.3. Dissolved Oxygen

Figure 12 shows the monthly DO concentrations (in mg/l) taken from the three sample stations. During the year 1990, measurements were only taken during the summer months. Figure 13 shows the percent of dissolved oxygen saturation in water samples taken at the stations in Sandia Canyon for the year 1992. DO concentration was usually highest at SC3, but the percent saturation was found to be the highest at station SC1. The difference between the concentration and the percent saturation of dissolved oxygen is due to water temperature differences at the stations. The dissolved oxygen concentration and the percent saturation were the lowest at SC2, which receives a large amount of organic (sanitary) waste. The depression in dissolved oxygen concentration/saturation at this station is probably a consequence of a high microorganism population, which feeds on the organic waste and consumes oxygen.

A functional curve relating the percent of dissolved oxygen saturation to an Environmental Quality Index is shown in Fig.14 (Battelle 1972). Based on dissolved oxygen saturation alone, SC1 and SC3 fall within the excellent range, but SC2 is in the fair range.

5.2.4. Conductivity and Total Dissolved Solids (TDS)

Monthly conductivity readings in µohms/cm are shown in Fig.15. The highest readings were recorded at SC1 during the winter months, when conductivity values were as high as 2450 µohms/cm. This elevation in conductivity can probably be attributed to an influx of ions from road salting activities during the winter. Because of the high winter readings, the highest average conductivity (774 µohms/cm) was also measured at SC1. Average conductivity at stations SC2 and SC3 was 674 and 690 µohms/cm, respectively.

Figure 15 illustrates estimated monthly TDS concentrations from the three stations. The average TDS concentrations of all three stations fall within the excellent range of the Environmental Quality Index developed by Battelle (1972) (Fig.16). During the winter months, TDS values fall into the good to fair range at all three stations. However, aquatic organisms can generally tolerate TDS concentrations as high as 5000 mg/l—a concentration much higher than any calculated for the three sample stations.

6. CONCLUSION

The results of this study indicate that of the three stations sampled, station SC3 has the greatest number of and diversity of aquatic macroinvertebrate taxa. This suggests that there is a marked improvement in water quality progressing downstream from station SC1 to SC3. This conclusion is supported by water quality data obtained simultaneously with the macroinvertebrate data. Measured water quality parameters indicate progressively improved water quality from station SC1 to SC3. Station SC1 is affected greatly by fluctuations in water flow, which inhibit aquatic macroinvertebrate colonization. In addition, SC1 receives effluents directly from several industrial wastewater outfalls that exert a strong influence on stream conditions, especially following accidental spills. The fact that pH and temperature at SC1 are slightly higher than expected in natural waters of the area is also probably attributable to an influx of pollutants from these outfalls. Station SC2 receives a large input of effluents from the sewage treatment plant, which is probably responsible for the low levels of dissolved oxygen content at this station. The aquatic macroinvertebrate community at this station is comprised almost entirely of various Diptera (fly) larvae or adult aquatic beetles. The Diptera larvae found (mainly red chironomid larvae) are very well adapted to low oxygen environments (Pennak 1978).

Station SC3 appears to be in a zone of recovery from the influence of the upstream outfalls. Dissolved oxygen concentration here is higher than at the other stations and pH and water temperature values are similar to those of natural waters. Trichoptera (caddis fly) larvae and Ephemeroptera (mayfly) nymphs—orders that are typical of zones of recovery (Pennak 1978; Wetzel 1983)—are commonly found at SC3 and are absent from SC1 or SC2.

This initial three-year study has established baseline aquatic macroinvertebrate data and compared this data to broad water quality parameters. Future studies will be designed to determine aquatic macroinvertebrate densities and species composition in relation to the physical and chemical characteristics of the stream. Additional sample stations, including a control site outside of LANL, will be established for data comparison, and a wider variety of water quality parameters will be measured.

7. ACKNOWLEDGMENTS

The Water Quality Section of the Environmental Protection Group (ESH-8) at Los Alamos National Laboratory provided funding for this study and also provided data on outfall discharge volumes.
The study was directed by Teralene Foxx, Project Ecologist for BRET in the Environmental Assessments and Resource Evaluations section of ESH-8 at LANL.

Field personnel included Kathryn Bennett (Field Leader and Environmental Scientist), Teralene Foxx (Botanist), Brenda Edeskuty (Ecologist), Tim Haarmann (Entomologist), Saul Cross (Botanist), and Mary Salisbury (Field Technician). Kathryn Bennett, Saul Cross and Tim Haarmann identified the aquatic macroinvertebrates collected in this study. Kathryn Bennett analyzed the data and compiled the manuscript. Don Usner edited the final manuscript.

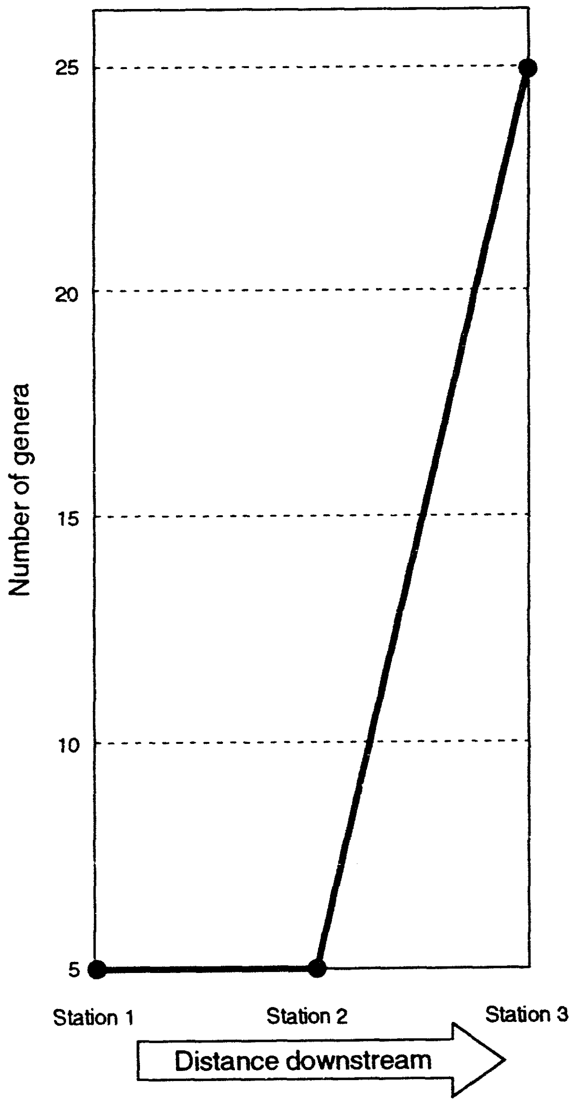

Fig. 6. Number of taxa identified at three sample stations within Sandia Canyon.

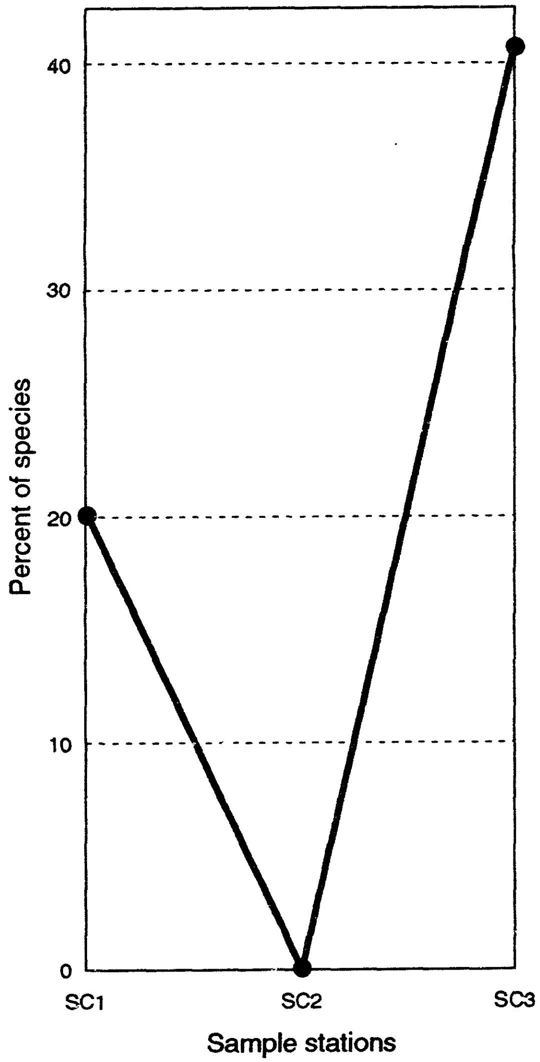

Fig. 7. Percent of taxa found at each sample station in Sandia Canyon that are considered good water quality indicators or intolerant of highly degraded waters.

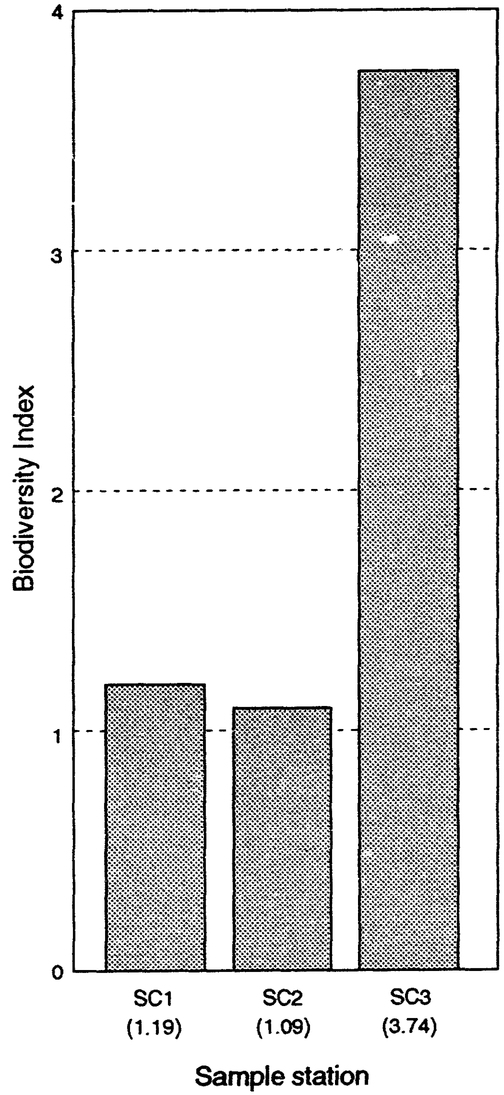

Fig. 8. Biodiversity indices for three sample stations in Sandia Canyon.

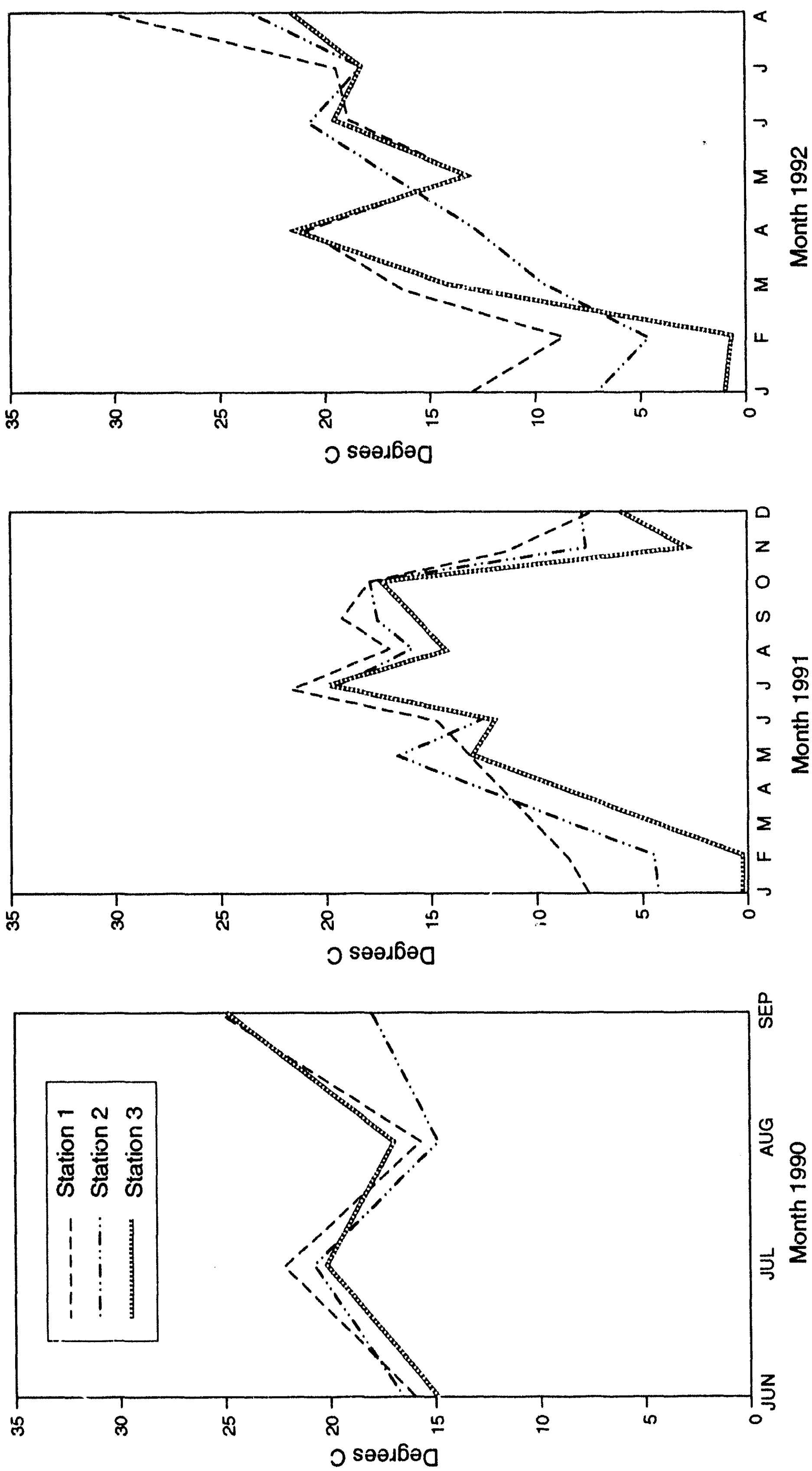

Fig. 9. Average monthly water temperature in degrees Celsius for three sample stations in Sandia Canyon.

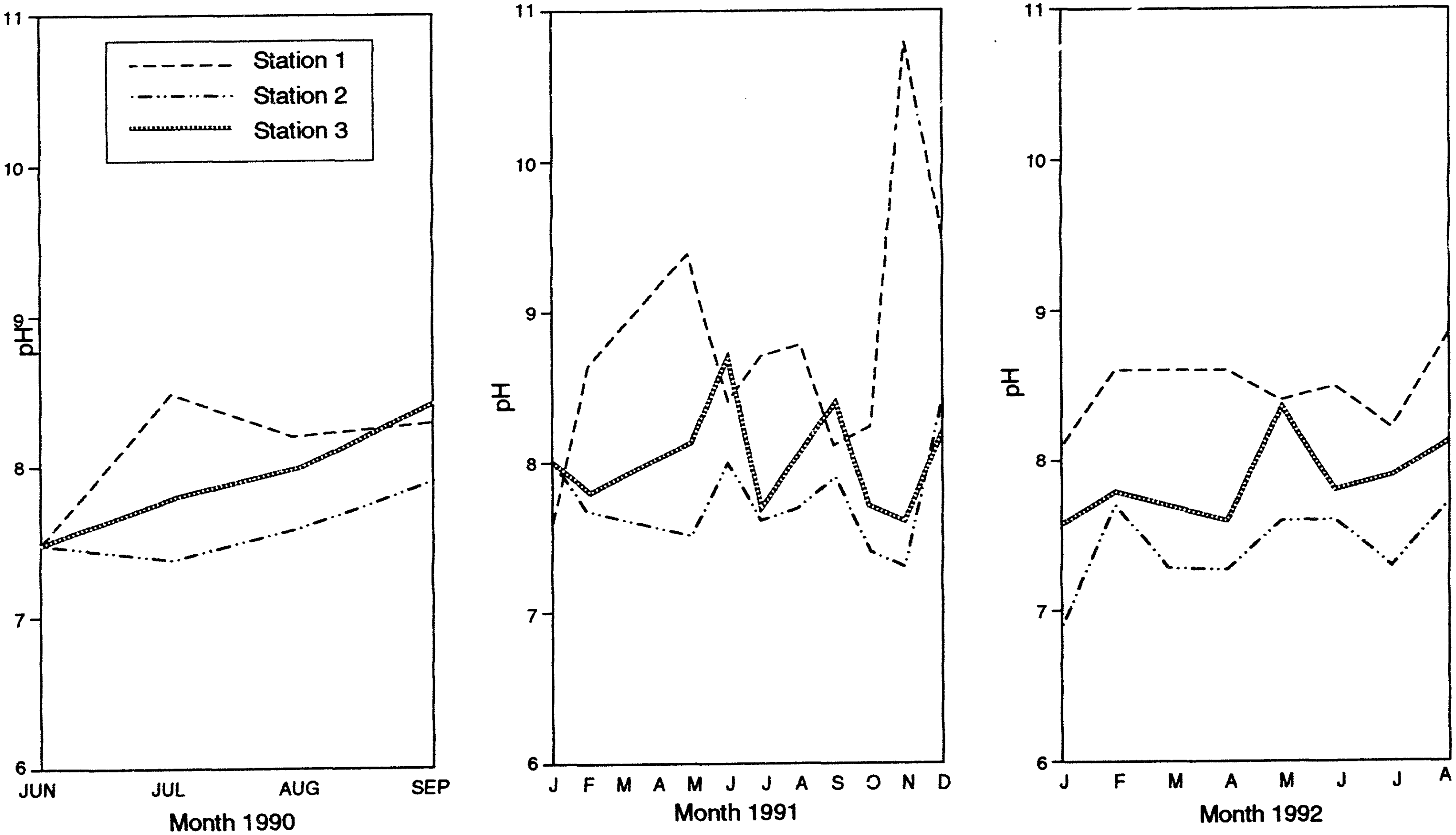

Fig. 10. Average monthly pH readings for three sample stations in Sandia Canyon.

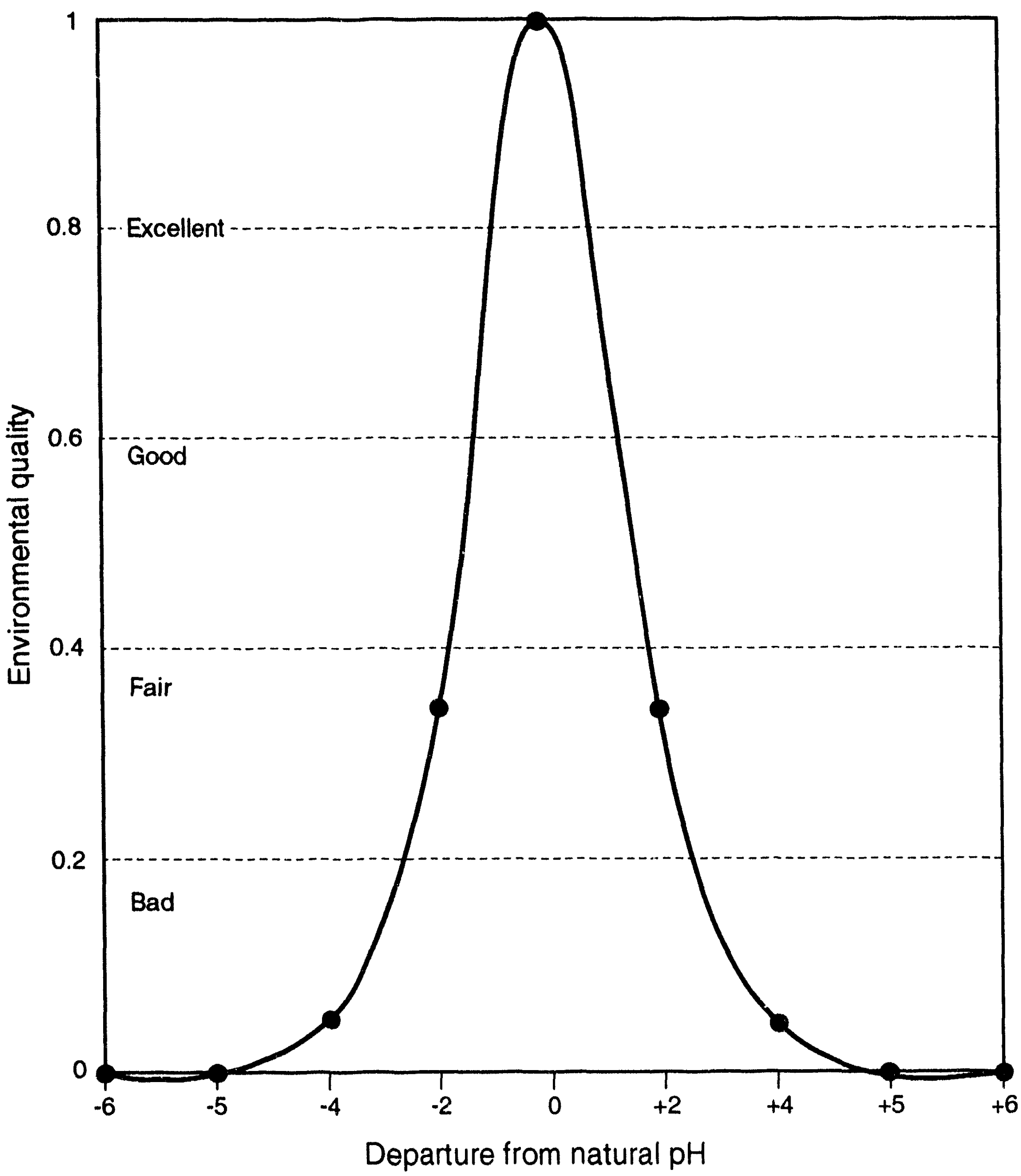

Fig. 11. Departure from natural pH versus an Environmental Quality Index. Natural pH for the area is 7.8 to 8.2. Index developed by Battelle (1972).

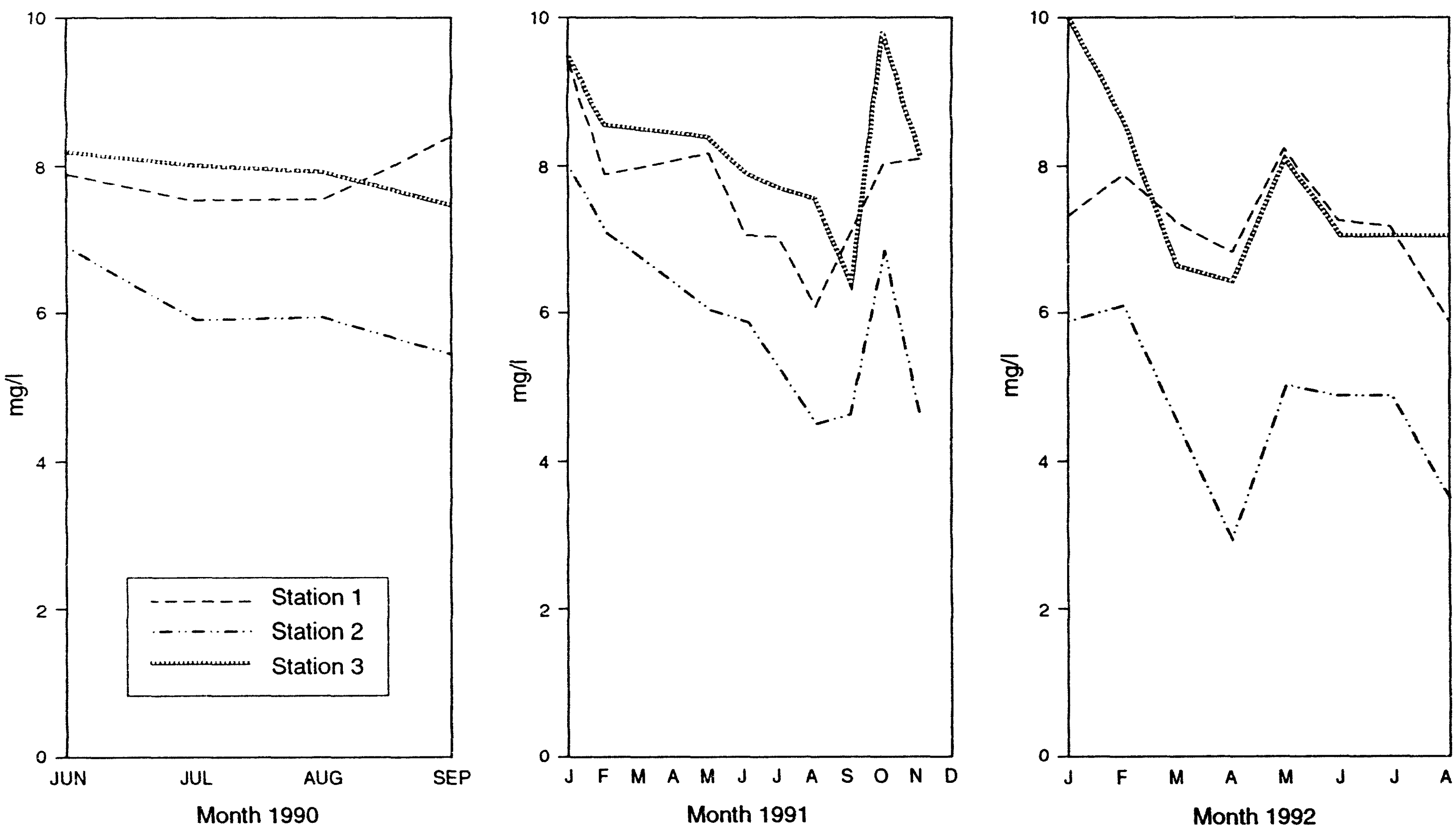

Fig. 12. Average monthly dissolved oxygen concentrations in mg/l for three sample stations in Sandia Canyon.

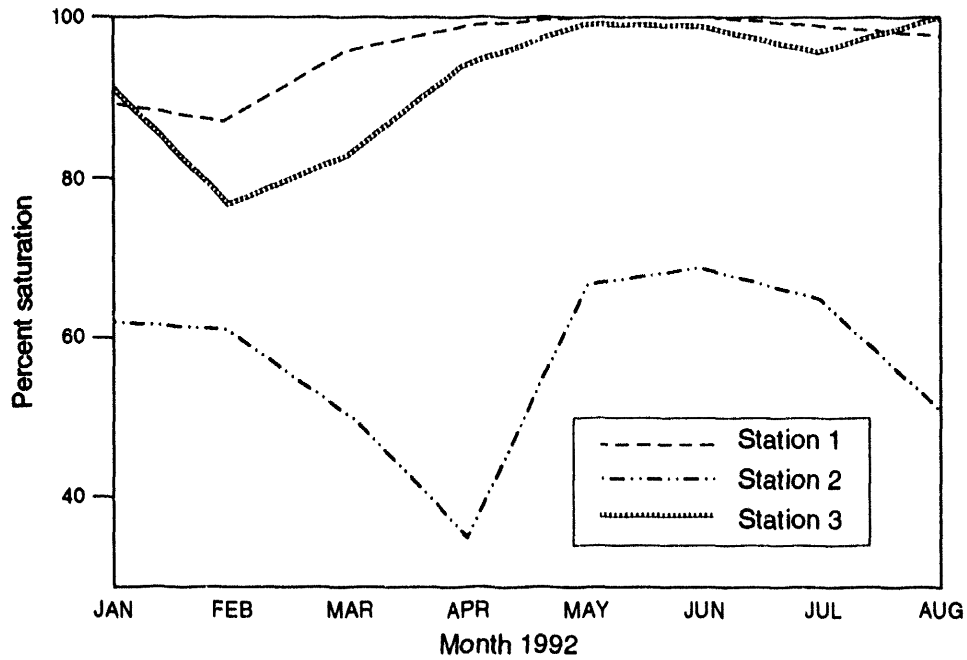

Fig. 13. Average monthly percent saturation of dissolved oxygen for three sample stations in Sandia Canyon (1992).

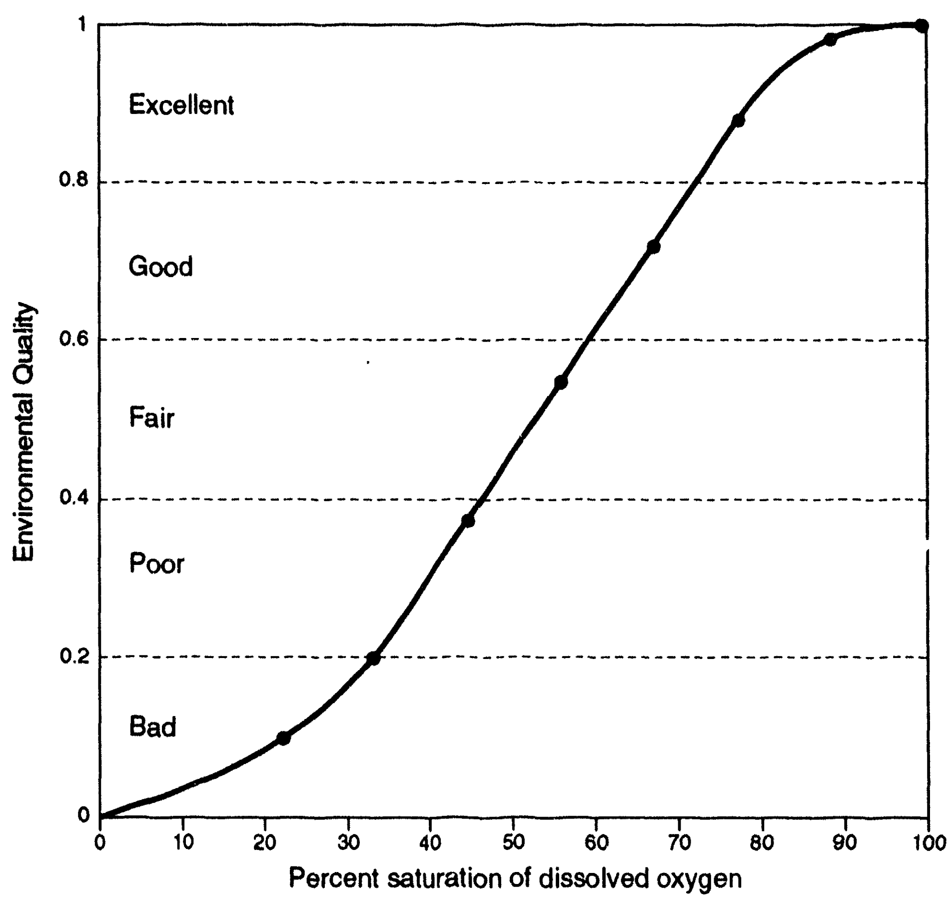

Fig. 14. Percent dissolved oxygen saturation versus an Environmental Quality Index. Index developed by Battelle (1972).

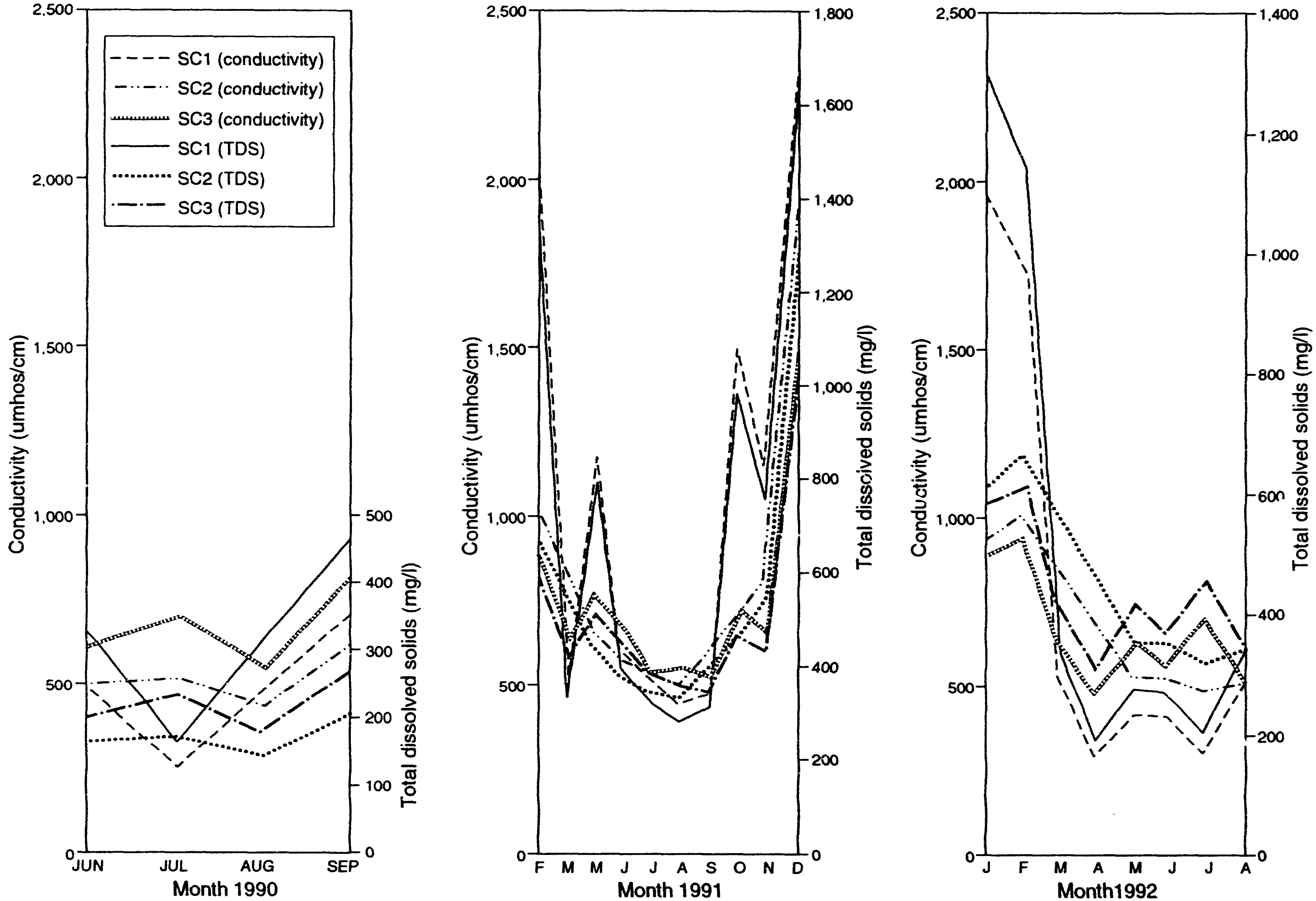

Fig. 15. Average monthly conductivity readings (µohms/cm) and estimated TDS (mg/l) for three sample stations in Sandia Canyon.

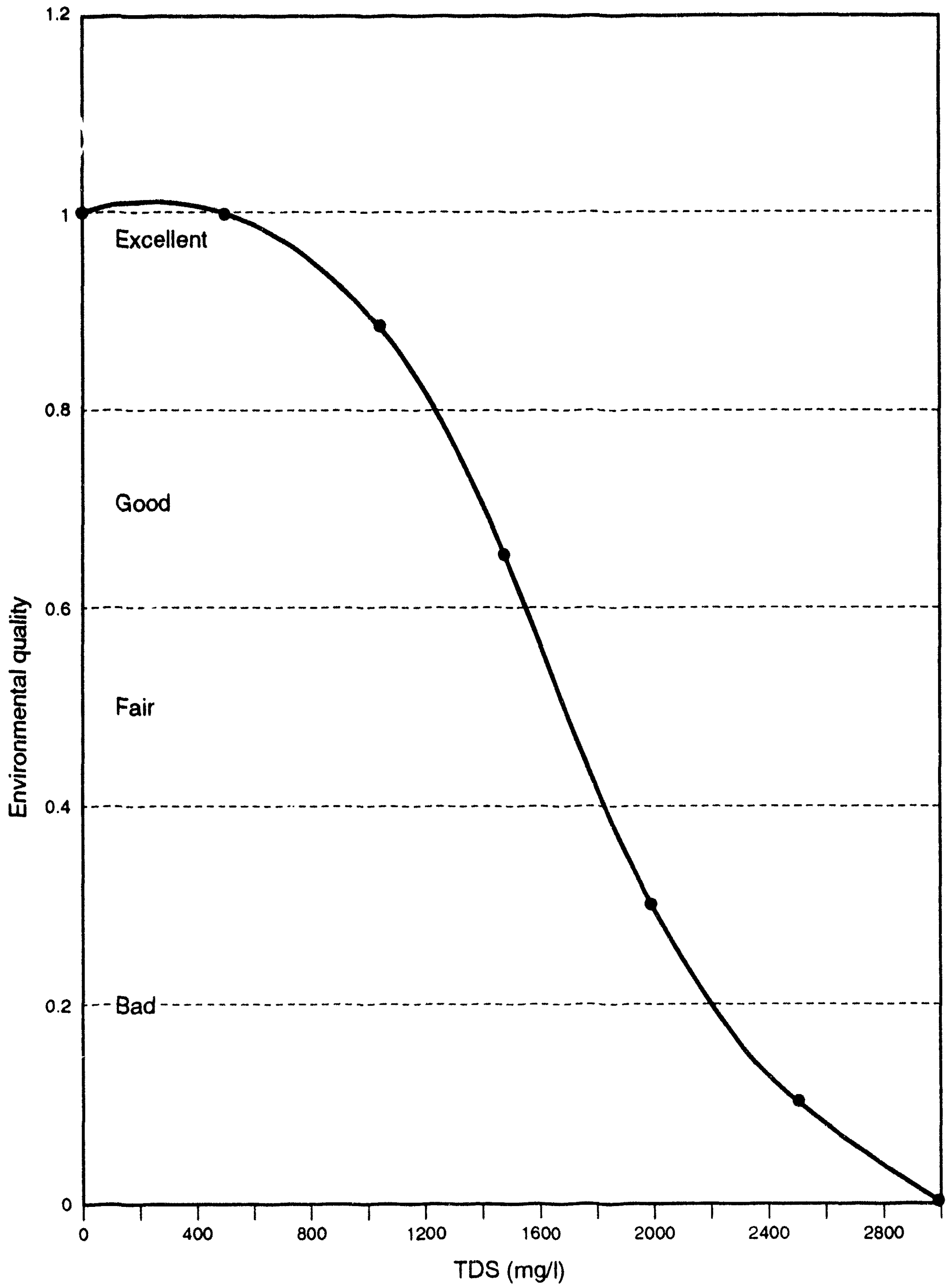

Fig. 16. Total dissolved solids TDS (mg/l) versus an Environmental Quality Index developed by Battelle (1972).

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