Chapter 2

THE EFFECT OF SURFACE RUNOFF ON RECREATION-USE WATERS

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Introduction

A casual glance at the Berkeley waterfront might indicate that the area is not living up to its recreational and commercial potential. However, a closer look reveals an intensive, albeit sporadic, usage of the area as shown by Judy Drexler's report (this volume). One can find people fishing, jogging or walking along the rocky shore between University and Ashby Avenues in all but the worst of weather. Offshore, boaters and windsurfers enjoy typical San Francisco Bay activities.

With an even closer look one will find that the waters in which we play are not safe, particularly after a rainstorm. However, even during dry conditions, debris enters the bay via storm drains and brings with it levels of pathogenic bacteria that far exceed the objectives of the California Regional Water Quality Control Board (RWQCB) for water contact and non-contact recreation. If recreational activities are to remain an integral part of the waterfront experience, the problem of contaminated surface runoff must be addressed and solved.

This report gives an indication of the levels of bacterial contamination being discharged from city storm drains into the bay and adds to the present data base for water quality along the Berkeley shoreline. In addition, I will compare the results of my study to studies done previously in an effort to determine any yearly variation in contamination levels.

Background

For many people the primary use of the waterfront is for recreation, such as jogging, walking, or windsurfing. Some community and special interest groups have called for a dramatic increase in the use of the Berkeley waterfront, including a significant increase in primary water contact forms of recreation (i.e., swimming and bathing). Among the proposals are the restoration of the beach at Fleming Point and the creation of two new beaches, one north of the Ashby Spit and the other along the North Basin Strip (Manning, 1979). Increasing the use of the waterfront for recreation increases the number of people exposed to the risk of contracting such water-borne diseases as typhoid fever, salmonellosis, bacillary dysentery and infectious hepatitis.

The major intermittent source of bacteria entering waterways is stormwater (Geldreich, 1966). Surface runoff flowing down the streets and hills of Berkeley cleans the streets and gutters but also carries with it high levels of enteric bacteria originating primarily, it is believed, from domestic pets and sewage overflow (ABAG, 1977). The bacteria most prevalent in surface runoff belong to the genera Salmonella, Shigella, Mycobacterium, and Leptospira (Geldreich, 1966).

Because of the difficulty and expense of isolating and enumerating pathogenic bacteria in waste water, the presence of bacterial contamination is estimated by the presence of indicator organisms. The indicator most frequently used is a group of microorganisms classified as coliforms. Coliforms exhibit qualities similar to those of pathogenic bacteria and thus make a good indicator of the sanitary quality of polluted waters.

Various state and federal water quality agencies have recommended standards for coliforms in order to reduce the incidence of exposure to water contaminated with bacteria. It is required that the median number of total coliforms in primary contact waters not exceed 240 organisms per 100 ml sample with no sample to exceed 10,000 (RWQCB, 1982).

Past Studies

The profile of the water quality along the Berkeley shoreline extends back to 1965. Two studies have been done since then pertaining to the surface runoff discharged from storm drains. The study periods covered by the two studies represent, coincidentally, two extremes in Berkeley weather, thereby providing data for very dry (1976-77) and very wet weather (1983).

In the most significant of the earlier studies, bacteriological water quality was monitored monthly at eight locations along the shoreline from June 1976 through May 1977 (Sharpe, 1977).

Teresa Simonitch, a U.C. Berkeley student, tested water quality with respect to stormwater runoff at the North Basin storm drains (Simonitch, 1983).

These studies are in general agreement. Sharpe's data suggest that coliform densities are far above the standards year-round at storm drain locations, whereas densities at non-outfall locations are highest during the rainy season. Simonitch also found total coliform densities to be greater than the standards at outfalls. In addition, she recorded an increase in total coliform numbers during rainstorms.

Methods

The four storm drains along the Berkeley waterfront constituted the study area for my research. They are located at Gilman Street, Virginia Street, Strawberry Creek and Potter Street (Figure 1).

The conditions under which samples were collected varied from February to March. February 27 sampling took place at midday, under clear and windy weather conditions. Outfall streams were approximately one to two feet deep, and tidal charts indicate that sampling was done near low tide. March 26 samples were also taken at low tide and from outfall streams less than two feet deep; however, sampling took place during morning hours under a light drizzle and moderate winds. The intensity of the rain had increased appreciably by the time samples from Virginia and Gilman Streets were taken.

Samples were collected in 100 ml bottles held immediately below the surface of the outfall stream and as near the center as possible. In some cases, stream bank instability led to samples being taken from stream portions away from the center.

Tests for the presence of the coliform group were carried out by the multiple-tube fermentation method using three fermentation tubes for each of four dilutions (10^{-1} to 10^{-4}), and coliform densities were calculated by the Most Probable Number (MPN) method (APHA, 1980, pp. 802-804). Due to the lack of comparable data from other studies, I did not attempt to determine the levels of fecal coliforms, thereby precluding the identification of the source of contamination (which is commonly ascertained by the ratio of fecal to total coliforms).

The use of this technique will produce results that are subject to errors. Inaccuracy could result from the collection of unrepresentative samples or from procedural errors. It should be noted that each sample represents one moment in time and therefore is representative of only that moment. Because things in nature are not distributed in a log-normal fashion, the probability of a sample not being near the mean population density increases with a decreasing number of samples. In short, the accuracy of the findings could be suspect due to the small number of samples taken. Further sources of error include the fact that if grab samples are collected from shallow discharge streams, total coliform densities might be influenced by high coliform densities in the underlying mud, where densities commonly are 100 to 1,000 times greater than in the overlying water (Geldreich, 1970). Further, if the sample is taken in a relatively stagnant part of the outfall stream, the results could be unrepresentatively high (APHA, 1980).

Finally, mistakes stemming from procedural error could include insufficient or excessive dilutions, or simple human error.

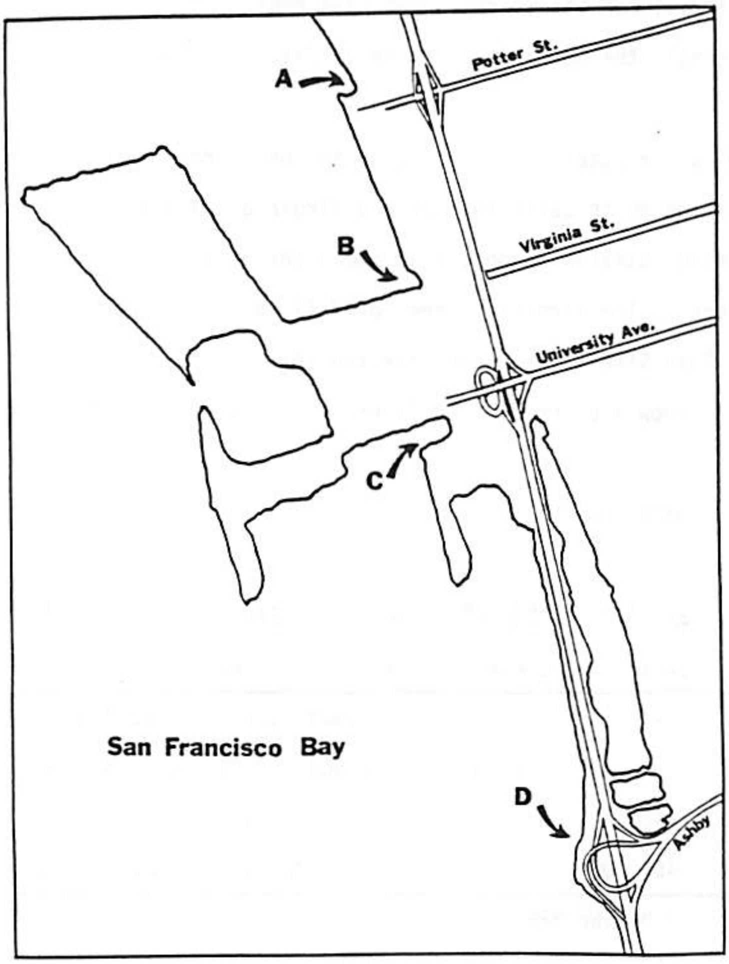

Figure 1. Berkeley Storm Drains Emptying into the San Francisco Bay: A, Gilman Street; B, Virginia Street; C, Strawberry Creek; D, Potter Street.
Source: After Simonitch (1983).

Results

The results of storm drain sampling are presented in Table 1. Total coliform densities for February 27 range from 2.3×10^3 to $>2,400 \times 10^3$ organisms per 100 ml sample -- levels 10 to 10,000 times higher than RWQCB standards. The Potter Street drain, with an MPN greater than $2,400 \times 10^3$/100 ml, has the highest coliform count of any site sampled. The Gilman and Strawberry Creek outfalls also show a high concentration of coliforms, $1,100 \times 10^3$/100 ml and 460×10^3/100 ml, respectively. The Virginia outfall shows a coliform density of 2.3×10^3/ 100 ml, making discharge water from this site the "cleanest" from February sampling. However, Virginia Street coliform levels are still ten times accepted standards. In general, the water discharged from outfalls south of University Avenue as a whole bear a higher coliform burden than do the North Basin outfalls.

March sampling reveals MPNs ranging from 24×10^3 to $>2,400 \times 10^3$ organisms per 100 ml. These values correspond to contamination levels 100 to 10,000 times the standard. The Gilman and Potter Street outfalls display MPNs four orders of magnitude greater than the standard; that is, in excess of one million organisms per 100 ml sample. Virginia Street and Strawberry Creek have MPNs 10 to 100 times smaller than those from the other two sites. In general, the North Basin outfalls discharged water containing the highest levels of coliforms in March.

The general trend from February 27 to March 26 is characterized by a change in the degree of contamination with respect to the two sampling regions, the North Basin (Gilman and Virginia outfalls) and the region south of University Avenue. North Basin outfalls changed from being the least contaminated in February to the most contaminated in March. The Virginia Street outfall levels increased by two orders of magnitude whereas the outfall at Gilman Street increased only two-fold. Conversely, samples taken from each outfall south of the landfill show a decrease in coliform numbers. Strawberry

MPN (10^3/100 ml)

Sample Site	2/26/76[a] Weather Not Given	3/23/76[a] Weather Not Given	2/8/77[a] Rain	3/9/77[a] Clear	3/22/77[a] Clear	2/25-3/3/83[b] Rain	2/27/85[c] Clear	3/26/85[c] Drizzle
Gilman Street	9,300	4,600	120,000	-	-	63,000*	1,100,000	>2,400,000
Virginia Street	4,300	>240,000	9,300	-	23,000	76,000*	2,300	460,000
Strawberry Creek	7,500	46,000	93,000	-	-	-	460,000	24,000
Potter Street	>240,000	>240,000	-	460,000	-	-	>2,400,000	>2,400,000

Source

* Median MPN

a. Sharpe, 1977

b. Simonitch, 1983

c. Reed, 1985

Table 1. Compilation of Results from Storm Drain Sampling.

Creek outfall, with a one order of magnitude reduction, became the cleanest site. The Potter Street outfall decreased by one-half in March.

Discussion

All samples have coliform levels far above standards for primary contact recreation. Although the sources of the high coliforms cannot be positively identified, I speculate that the elevated levels are dependent on a combination of the following factors: quantity of surface debris, antecedent rainfall, stream path, and discharge quantity. Because the streets of Berkeley are swept upon residents' request, the streets could have remained unswept for years prior to the 1985 sampling period. Assuming that storm runoff is not perfectly efficient in removing coliform sources, the absence of street sweeping might allow the sources of coliforms, specifically fecal material from domestic animals, to build to quantities large enough to affect coliform levels in the discharge water. Because both sampling dates were preceded by two to three weeks of dry weather (that continued for another week after February 27), neither flushing process would be in effect, thereby increasing the accumulated coliform sources even further than if it had rained. These coliforms would then be flushed from the hills and streets in a short period of time by the next rain, thus dramatically increasing coliform numbers. This probably accounts for the high coliform levels in the North Basin stormdrains on March 23, when sampling conditions changed from a light drizzle to heavy rain. The path of creeks and the area from which the runoff is collected may also influence coliform levels. The consistently high levels at Potter Street may be due to its path being largely through highly populated residential areas, thereby increasing coliform sources and finally coliform numbers. The high degree of contamination of outfalls south of the landfill in February could be a result of the uphill areas being predominantly residential. Finally, small quantities of discharge water present during sampling may have served to concentrate the coliforms. The samples would then appear more contaminated than a sample from an "average" size discharge stream, given a comparable load of coliforms.

The results for February for Virginia Street cannot be readily explained. Coliform densities are 100 to 1,000 times smaller than at the other sites sampled. In addition, one month later levels increased by a factor of 200. Given these large discrepancies, experimental error seems the likely cause.

My results indicate that the water flowing from Berkeley's stormwater outfalls is more contaminated in the late winter months than it was in the 1976 and 1977 dry weather sampling period. Coliform densities in February and March of 1976 and 1977 range from 4.3×10^3 to 450×10^3 organisms per 100 ml sample (Sharpe, 1977). The range of 1985 densities, on the other hand, has an upper limit ten times higher. Further, in most cases individual samples from 1985 are 10 to 100 times more contaminated than samples from 1976 and 1977. Sharpe's data from each site in February 1976 varies considerably from my February results. Sharpe found water samples from Gilman Street, Virginia Street, and Strawberry Creek to have coliform densities only one order of magnitude greater than the standard, whereas I found densities at both Gilman Street and Strawberry Creek exceeding the standard by over three orders of magnitude. Despite the difference in magnitudes of water contamination from site to site and from study to study, all samples taken from February and March were consistently above RWQCB standards. In addition, data strongly suggest the occurrence of "hot spots" along the waterfront. Potter and Gilman Streets showed the highest coliform counts in 80% of the February and March samples.

Dry weather data from 1985 reveal coliform levels far higher than wet weather data from the 1983 study by Simonitch. In 1983 water quality tests, total coliform densities range from 7.0×10^3/100 ml to 170×10^3/100 ml (Simonitch, 1983). 1985 results are higher than this study by a factor of 100. Again, despite the differences in the magnitude of contamination between studies, all samples exceed RWQCB standards.

I am unable to explain the disparity between magnitudes of contamination from each study period, because of the large number of variables involved. I will, however, speculate that the cause of the disparity is related to the quantity of water flowing through the creeks and storm drains. Flow may effectively concentrate or dilute the discharge water that is to be sampled. The very low flow of the 1976-1977 sampling period and the low to moderate flow of the 1985 sampling period may have concentrated the samples, thereby erroneously indicating high water contamination. Conversely, the very high flow during 1983 (the wettest season on record) may have diluted the samples, thus revealing low coliform densities.

Conclusions and Recommendations

My results and the results of previous studies of water quality at Berkeley storm drains indicate that water samples taken from these outfalls contain large numbers of coliform organisms. Because these organisms are indicators of the presence of pathogenic bacteria, it can be assumed that the outfall discharges are highly contaminated with harmful bacteria. Highly contaminated water can, in turn, be expected to increase exposure of bathers and others pursuing primary contact activities to potentially dangerous diseases such as salmonellosis and bacillary dysentery. Further, because levels of contamination show little seasonal variation, as illustrated by the relative agreement of studies conducted under a variety of weather conditions, one can expect the water to be contaminated regardless of variation in yearly precipitation. The water, in failing to meet the standards set for primary contact waters, must be deemed non-conducive to this kind of activity.

The proposed recreational plans for the Berkeley waterfront, such as the creation of beaches and a North Basin swimming area, should not be implemented with the levels of bacterial contamination now present in surface runoff. This fact should be addressed by the planners of the waterfront and solved by pinpointing and eliminating the source or sources of contamination.

Strategies for abatement of contaminated surface runoff might include street sweeping, leash laws, or the filtering of storm drain discharge. A complete and extensive presentation of abatement possibilities together with their economic implications can be found in a surface runoff brief by the Association of Bay Area Governments (ABAG, 1977).

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