Appendix J

Estimated Annual Illness Burden Resulting from Exposure to CSOs and SSOs at BEACH Survey Beaches

This appendix provides a detailed description of the data and methodology used by EPA to estimate the annual illness burden associated with exposure to CSO and SSO discharges in recreational waters at state-recognized beaches. The analysis does not capture all of the likely annual illnesses attributable to CSOs and SSOs at beaches. EPA believes that CSO and SSO contamination at swimming areas other than those included in this analysis causes additional illnesses in exposed swimmers. A lack of information on these swimming areas, including water quality reporting data, precludes developing a more complete estimate of annual human illness frequency from beach exposure to CSO or SSO contaminants at this time. Moreover, this analysis accounts only for gastrointestinal illnesses.

J.1 National Health Protection Survey of Beaches

EPA's BEACH Survey served as the primary data source for estimating exposure to CSO and SSO discharges to recreational waters, as noted in Section 6.2.1.

BEACH Survey data include beach-specific information on advisories and closings for 3,067 beaches from 274 federal, state, and local agencies; not all beaches provided data for the four-year period. Beaches included in the survey are located in 34 states and the U.S. territories of Guam, Puerto Rico, and the U.S. Virgin Islands. These beaches are primarily marine water beaches, but some freshwater beaches are included. Table J.1 shows the number of beaches covered in the BEACH Survey for each state and the number of beaches with and without pre-emptive actions or monitoring programs.

As shown in Table J.2, California accounts for a significant portion of the total number state-recognized beaches, closure events, and closure events attributed to CSO and SSO discharges. As a result, California may exert a disproportionate influence on illness estimates. There are several possible explanations for this, including that California has a longer swimming and monitoring season and has more rigorous monitoring programs than many other beaches in the nation, resulting in the discovery of more events than at beaches with less frequent monitoring and with an abbreviated swimming season. However, EPA lacks the data to make these comparisons at the time.

Although the BEACH Survey was initiated in 1998 (for the 1997 swim season), only data for the 1999, 2000, 2001, and 2002 swimming seasons were used. Data from the 1997 swimming season were excluded from this analysis because the initial BEACH Survey did not request information from respondents on the source, reason, or cause of advisories or closings. Further, information from the 1998 swimming season was not used due to an error in the data recording procedures.

The BEACH Surveys have been modified over time, including changes to the wording of some questions between 1999 and 2002. Furthermore, the rate of participation by beach authorities has changed somewhat with each BEACH Survey. Nonetheless, EPA believes these differences do not preclude using data from the four most recent surveys.

EPA recognizes the limitations of the BEACH Survey. Specifically, although the data provided by the respondents are reviewed by EPA for potential gross errors, the quality and accuracy of the information may vary significantly with each respondent. In addition, because the BEACH Survey data used in the analysis cover only four years significant climatological events such as La Nina, which caused a severe drought in southern California during 1999, could have a disproportionate affect on the number of CSOs and SSOs reported in the database. Despite these shortcomings, EPA believes that the BEACH Survey is the most accurate and comprehensive source of information on beach contamination and beach authority responses to contamination events. For the purposes

Table J.1. Number of BEACH Survey Beaches and Type of Program by State

State	Number of beaches in BEACH survey[1]	Beaches with pre-emptive actions and/or monitoring	Beaches with no pre-emptive actions or monitoring
Alabama	38	22	16
California	1,078	803	275
Delaware	70	70	0
Florida	962	858	104
Georgia	16	16	0
Guam	160	160	0
Hawaii	288	288	0
Illinois	153	153	0
Indiana	185	185	0
Iowa	102	102	0
Louisiana	16	16	0
Maine	25	18	7
Maryland	200	199	1
Massachusetts	783	748	35
Michigan	812	771	41
Minnesota	74	61	13
Mississippi	9	9	0
New Hampshire	689	689	0
New Jersey	906	906	0
New York	893	837	56
North Carolina	80	80	0
Northern Mariana Islands	3	3	0
Ohio	252	252	0
Pennsylvania	60	60	0
Puerto Rico	47	47	0
Rhode Island	480	480	0
South Carolina	105	105	0
Texas	65	44	21
Vermont	133	132	1
Virgin Islands	145	145	0
Virginia	56	35	21
Washington	202	184	18
Wisconsin	196	138	58
Total	**9,671**	**9,002**	**669**

[1] The number of total beaches include beaches that reported in any of the four years of the BEACH survey used in this analysis: 1999, 2000, 2001, 2002; thus, a beach that reported in all four years would be counted four times.

Table J.2. Comparison of California reporting to all other states in the Beach Survey

	CA	All other states	Total	Percent
1999 Beach Survey				
Number of Beaches	256	1,795	2,051	12.5%
Number of all events	1,277	665	1,942	65.8%
Number of SSO/CSO events	22	102	124	17.7%
2000 Beach Survey				
Number of Beaches	281	2,073	2,354	11.9%
Number of all events	1,545	1,214	2,759	56.0%
Number of SSO/CSO events	61	148	209	29.2%
2001 Beach Survey				
Number of Beaches	272	2,171	2,443	11.1%
Number of all events	1,495	2,184	3,679	40.6%
Number of SSO/CSO events	268	59	327	82.0%
2002 Beach Survey				
Number of Beaches	269	2,554	2,823	9.5%
Number of all events	1,057	2,157	3,214	32.9%
Number of SSO/CSO events	76	196	272	27.9%

of this analysis, EPA contacted a limited number of BEACH Survey respondents to collect additional data on monitoring practices and levels of contamination resulting from SSO events. Other data were obtained from publicly available sources including beach authority websites, where available.

J.2 Methodology for Counting a CSO or SSO Event

In the BEACH Survey, beach authorities were asked to select the sources of pollution that caused any closures or advisories. Respondents could choose the following:

- SSO
- CSO
- CSO/SSO
- POTW
- Septic systems
- Sewer line/blockage/break
- Boat discharge
- Storm water runoff
- Wildlife
- Unknown
- Other (please specify)

For advisories and closings where "SSO" or "sewer line/blockage/break" were identified, the event was classified as an SSO.

J.3 Categorizing BEACH Survey Beaches

Based on the management practices used to address contamination events, each beach authority and its

corresponding beach(es) were assigned to one of the following categories:

(1) Beaches where the sewer authority reports CSO and SSO events to the beach authority.
(2A) Beaches that preemptively initiate advisories or closures due to wet weather events.
(2B) Beaches where advisories or closure decisions are based on monitoring data or preemptive actions due to wet weather events.
(3) Beaches where advisory or closure decisions are made based on beach monitoring alone.
(4) Beaches that have reported advisories and closures, but do not have programs described in Categories 1, 2, and 3.

J.4 Calculation of Swimmer Days

The number of swimmers per typical day at beaches where either a closing or advisory action had been implemented (due to CSOs or SSOs) was estimated by using beach attendance data included in the BEACH Survey. The BEACH Survey contained the following responses to the question on attendance per day:

- Less than 100
- 100 - 499
- 500 - 999
- 1,000 - 9,999
- More than 10,000
- Don't know

Respondents provided answers for weekdays, weekend days and holidays, during the summer season, and during other seasons. Respondents also estimated the length of their swimming season and the percentage of beach visitors that go into the water.

To calculate the number of swimmers per day on weekdays, on weekend days, for the summer season, and for the "other season" category, a midpoint value was selected to represent each numeric response range. For example, 50 was assigned for the "less than 100" response, and 5,500 for the "1,000 - 9,999" response. For a beach where the response was "more than 10,000," EPA assumed an average summer weekday attendance value of 10,000. For a beach where the response was "don't know", the overall average for beaches who supplied data was used.

The difference between the weekday and weekend values was estimated separately for each year of data. For example, the BEACH Survey data for the 2002 BEACH Survey indicated that during the summer, the average weekend attendance levels were on average 62 percent greater than during the weekdays. For the other seasons, weekend attendance was on average 31 percent greater than the weekday.

A daily summer average was estimated by multiplying the summer weekday value by five, multiplying the summer weekend value by two and dividing the sum by seven. This procedure was repeated to estimate the daily average for "other seasons." EPA next calculated a daily average for the year, which consisted of summer and other season daily averages. EPA estimated the proportion of the values for "summer weekday," "summer weekend," "other weekday," and "other weekend" based on the length of the season of the beach. If a beach authority reported that the swim season was six months long, the summer values were counted for six months of the year and the other values were counted for six months of the year. Similarly, if a beach authority noted that the swim season was only three months long, summer values were counted for three months of the year, and other values were counted for nine months of the year.

The percentage of swimmers that enter the water was calculated for each beach, because it was assumed that only the people who actually go in the water are at risk from CSO- and SSO-related contamination. The percentage of swimmers was estimated for each beach based on the beach authority's response to the question: "What percentage of people who use this beach go into the water?" If a beach did not respond to this question the overall

average (calculated for all beaches that answered in that survey year) was substituted. Some beaches responded with a range. In these cases, the midpoint of the range was used. In other cases, beaches responded with either less than or greater than a number. In these cases, the midpoint between the number provided and 0 or 100 was used (e.g., if a beach responded greater than 95 percent, then the value used was 97.5). The percent of swimmers was applied to the attendance for each beach to yield the number of swimmers at each beach.

J.5 Extrapolation Method

This section describes the methods used to extrapolate the exposure estimates for swimmers at BEACH Survey beaches to other state-recognized beaches that did not participate in the BEACH Survey.

From responses to BEACH Survey questions about visitation and the fraction of visitors who swim, EPA estimated that 315 million swimmer days per year occur at the BEACH Survey beaches. The BEACH Survey, however, does not cover all swimming at state-recognized beaches. For example, approximately 13 percent of the beach authorities to whom the survey was mailed did not respond.

To estimate 1) the number of swimmers at state-recognized beaches not accounted for in the BEACH Survey and 2) the number of swimmers not accounted for at beaches where authorities received a survey and did not respond, EPA compared selected BEACH Survey attendance data with corresponding state attendance data estimates reported on the U.S. Life Savers Association and state web sites. A comparison of the Beach Survey data with the other state attendance data is shown in Table J.3. EPA used an adjustment factor of 1.362 to extrapolate the

Table J.3 Attendance Adjustment Calculations

State	Estimated Attendance in BEACH Survey	Total Attendance Including Alternate Sources
California	143,283,136	171,146,608
Delaware	2,479,627	6,000,000
Hawaii	9,462,739	17,285,810
Illinois	5,399,233	24,885,197
Maryland	3,353,142	4,000,000
Total	**163,977,877**	**223,317,615**
Adjustment factor		**1.362**

number of swimmer days from the BEACH Survey beaches to all state-recognized beaches in the United States.

EPA applied an approach based on attendance to estimate the fraction of all beach swimmer days represented by BEACH Survey respondents. The Agency did not have sufficient data to support the assumption that visitation and swimmer days are proportional to mileage of beaches. EPA believes that heavily-used beaches are more likely to be surveyed by and respond to the BEACH Survey than are lightly-attended beaches. EPA also assumes that BEACH Survey beaches likely account for a substantially larger fraction of total beach visitation than the fraction of total beach mileage accounted for by these beaches. Using the attendance-based approach, EPA estimated that BEACH Survey beaches account for 73 percent of total national visitation and swimmer days at all state-recognized beaches.

This approach resulted in the following estimated distribution of the estimated 429 million days per year of outdoor non-pool swimming:

- 315 million swimmer days at BEACH Survey beaches
- 114 million swimmer days at other formal beaches that either were not sent or did not respond to the BEACH Survey

These swimmer days are distributed among categories as shown in Table J.4.

Table J.4 Number of Swimmer Days Per Year, by Category

Number of Swimmers/Year	Category 1	Category 2A	Category 2B	Category 3	Category 4	Total
BEACH Survey beaches	135,049,677	3,674,342	41,754,509	114,619,121	19,763,032	314,860,682
Beaches not in Survey	48,871,303	1,319,658	15,109,975	41,477,965	7,151,776	113,940,677
Total	48,871,303	1,319,658	15,109,975	156,097,086	26,914,808	428,801,359

J.6 Exposure/Noncompliance Rates

It is important to note that each jurisdiction has its own definition of an advisory. EPA defines an advisory as "a recommendation to the public to avoid swimming in water that has exceeded applicable water quality standards to reduce the potential of contracting a swimming related illness." Although each jurisdiction's definition may vary, most authorities use an advisory to recommend that visitors not swim in the water. Closures, on the other hand, usually require that visitors do not enter the water or beach area. The degree to which a closure is enforced, however, can vary widely.

Different jurisdictions also have different policies regarding when they issue a closure or an advisory. South Carolina, for example, issues advisories only and does not issue closures. California generally issues an advisory on a preemptive basis when there is heavy rain; posts a beach warning when monitoring indicates a standard is exceeded, but there is no known source of human sewage; and closes a beach when there is a CSO, SSO, or repeated exceedances of standards. The State of New Jersey issues closures only. And, in many states, individual communities have policies on advisories and closures that can differ from the state's policy regarding state-owned beaches.

For this analysis, EPA found it was not feasible to standardize the BEACH Survey data and adjust for differences in how jurisdictions define and use advisories and closures. Instead, EPA aggregated advisories and closures and refers to them collectively as "actions." Among the "actions" taken by beach authorities in response to CSO or SSO events, 63 percent were denoted as closures and 37 percent were denoted as advisories.

Effectiveness of actions was estimated by requesting information on the actual effectiveness of beach closures and advisories in preventing swimming from several local lifeguard offices. There was consensus that closures are typically well enforced and effective in preventing swimming. Based on this input, EPA assumes that 95 percent of potential swimmers at a closed beach would comply. The effectiveness of advisories estimate was based on information in the report, *Coastal Beach Water Quality and Public Health: Preliminary Steps Toward Improving Public Notification in Wisconsin Under the Federal Beach Act* (Vail, 2002). It reports results from a social survey conducted at Wisconsin's public beaches in 2002, in which survey respondents were shown a sign stating "Alert, Elevated Bacteria Levels, Swim at your own Risk." The survey respondents were asked, "If you saw this sign posted at this beach, would you swim here?" and could answer either "yes," "no," or "don't know." Results were obtained for several different counties in Wisconsin. For this analysis, EPA weighted the responses by population and used the response rate for "no" as the lower bound of compliance; the upper bound was calculated by adding percent "no" and "don't know". For example, in Door County, 6 percent of the respondents answered "yes," 9 percent

Table. J.5 Calculations for Advisory Compliance Rates

County	Lower Bound	Upper Bound	Population*	Percent of Population
Kenosha	41	95.5	156,209	9.22
Racine			192,284	11.36
Milwaukee			933,221	55.11
Ozaukee	27	73	84,772	5.01
Sheboygan			113,376	6.70
Manitowac			82,065	4.85
Kewaunee			20,455	1.21
Door County	9	94	28,402	1.68
Iron	9	72	6,727	0.40
Ashland			16,561	0.98
Bayfield			15,114	0.89
Douglas			44,093	2.60
Weighted Average	36.42	90.33	1,693,369	

* Population estimates obtained from U.S. Census 2003.

answered "no," and 85 percent responded "don't know." The upper bound of compliance was calculated by adding the response rate for no (9 percent) and don't know (85 percent) to yield 94 percent, and the lower bound of compliance only accounts for the "no" responses (9 percent). Survey results and populations from 12 counties are shown in Table J.5.

In estimating the overall effectiveness of actions, EPA developed a weighted average of the effectiveness of closures (95 percent effective) and advisories (36 to 90 percent effective), weighted by the proportion of CSO- or SSO-caused actions in the baseline that are closures (63 percent) and advisories (37 percent). This results in an estimate that 73 to 93 percent of potential swimmers, on average, will not swim at a beach when the beach is under a CSO- or SSO-related action. Conversely, 7 to 27 percent would swim at a beach when a beach is under a CSO- or SSO-related action.

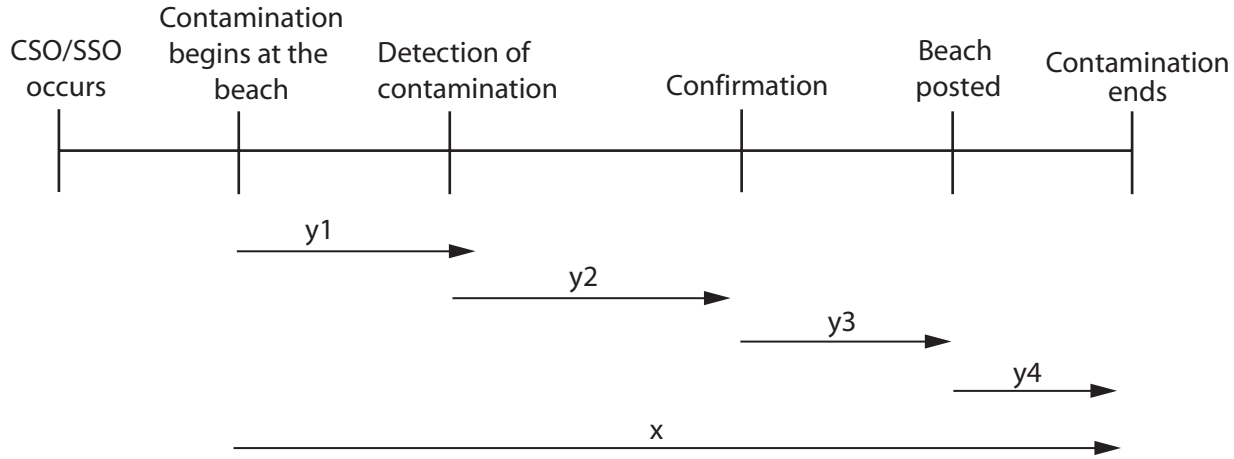
J.7 Monitoring Data Analysis

Figure J.1 presents a timeline that shows the relevant events in detecting and responding to beach contamination from a CSO or SSO discharge and the duration between these events. The timeline is portrayed for instances in which contamination from a CSO or SSO is detected through monitoring at the beach.

The monitoring data from the beach authorities were analyzed to determine approximately when the contamination was discovered, when the existence of the contamination was confirmed by analysis of an additional sample by a beach authority, when the beach authority issued the action, and the period during which the action remained in effect. The results of this analysis are summarized, by category, on the next page and are shown in Table J.6.

Category 1 Beaches with preemptive programs close beaches upon notification of CSO or SSO discharges. It is assumed that the beach is closed prior to contamination and lasts until contamination ends. To calculate exposure duration, duration data from the 2001 and 2002 BEACH Survey (end date subtracted

Figure J.1 Timeline for Response Activities to CSO and SSO Discharges



x = The length of time that contamination from the CSO or SSO exists at the beach.
y1 = The period between the onset of contamination at the beach and when it was detected.
y2 = The period between the detection of contamination and its confirmation by the beach authority.
y3 = The period between confirmation and action (e.g., beach posting, closure, public notification).
y4 = The period during which the action remains in effect.

from start date) were averaged for all Category 1 beaches. The average length of exposure duration was 5.1 days.

Category 2A The preemptive programs for precipitation events (where beaches automatically close or post an advisory due to a precipitation event) prevent the full duration exposure to CSOs and wet weather SSOs, but not dry weather SSOs. Because there is no monitoring or other means to detect dry weather SSOs, it was assumed that exposure to these SSOs occurs. The estimated exposure duration for these events is 2.1 days.

Category 2B Similar to Category 2A, preemptive programs for precipitation events eliminate exposure due to wet weather CSOs and SSOs. Some percent of dry weather SSOs would be detected and actions would be taken; however, some exposure occurs due to the delay from monitoring. For the purposes of this analysis, EPA assumed that the percentage of SSO events that were dry weather and that were wet weather were the same as the percentage of such events reported in the BEACH Survey. That is 34 percent of the events in Category 2B occurred during dry weather and 66 percent were wet weather related. Exposure to contamination due to dry weather events was estimated to last 8.7 days, and exposure during wet weather contamination events was estimated to last 4.5 days.

Category 3 CSOs and SSOs at these beaches are acted upon once monitoring results confirm contamination, and therefore exposure is avoided only during the period of closure. Exposure during the actions is 4.5 days and exposure during the lag period is 4.2 days, for a total exposure period of 8.7 days.

Table J.6. Duration Calculations by Category

Time Periods	Category 1	2A	2B	3	4	Explanation
Y1	NA	NA	2.56	2.56	NA	For beaches for which there were monitoring data (categories 2b and 3), the value was calculated by subtracting the date of the first contaminated sample from the date of the last clean sample and dividing by 2.
Y2	NA	NA	1.00	1.00	NA	For beaches for which there were monitoring data (categories 2b and 3), the value was calculated by subtracting the date of confirmation from the date of the first contaminated sample.
Y3	NA	NA	0.68	0.68	NA	For beaches for which there were monitoring data (categories 2b and 3), the value was calculated by subtracting the start date of the action from the date of confirmation.
Y4	5.13	2.1	4.45	4.45	10.07	For beaches for which there were monitoring data (categories 2b and 3), the value was calculated by subtracting midpoint between the end date as reported in the beach report and the last sample showing contamination from the start date of the action. For beaches for which there was no monitoring data (Categories 1, 2a, and 4), the end date was subtracted from the start date reported in the beach survey.
TOTAL	**5.15**	**2.1**	**8.69**	**8.69**	**10.07**	**Calculated by adding Y1-Y4**

Category 4 Although there were no reported mechanisms in place to detect CSOs and SSOs for these beaches in the BEACH Survey, some of these beaches reported advisories and closings caused by CSOs or SSOs. EPA calculated the duration reported from these beaches to be 10 days.

EPA combined information on the number of baseline CSO- and SSO-related contamination events documented in the BEACH Survey, the duration of events and days of exposure, and the number of swimmer-days, to estimate the number of swimmer-days of exposure to CSOs and SSOs that would occur at the beaches included in this analysis. The results of this analysis are summarized in Table J.7.

Table J.7 Calculations for Exposed Swimmer-Days

Step		Category 1	2A	2B	3	4	**Total**
1999-2002 Beach Survey Data	Number of beaches	3,907	91	985	4,020	668	**9,671**
	Average number of beaches per year	977	23	246	1,005	167	**2,418**
	Number of SSO and CSO events acted upon in survey	118	5	14	77	20	**234**
	Number of events per year, per beach	0.121	0.209	0.055	0.076	0.117	--
	Number of swimmer days/year for beaches	183,920,980	5,004,000	56,864,485	156,097,056	26,914,808	**428,801,329**
Exposure during noncompliance	Days of exposure during noncompliance (per event)	5.13	2.10	4.45	4.45	10.07	--
	Number of such events per year, per beach	0.121	0.209	0.055	0.076	0.117	--
	Number of days of exposure during non-compliance	0.622	0.438	0.244	0.339	1.175	--
	Percent of year	0.17%	0.12%	0.07%	0.09%	0.32%	--
	Number of swimmer days exposed (7-27% of swimmers do not comply)	21,068-83,552	404-1,604	2,555-10,133	9,738-38,620	5,830-23,122	**39,596-157,030**
Exposure before detection	Days of exposure before detection	0	0	4.25	4.25	0	--
	Number of such events per beach	0	0	0.019	0.076	0	--
	Number of days of exposure per year per beach	0	0	0.079	0.323	0	--
	Percent of year	NA	NA	0.022%	0.089%	NA	--
	Number of swimmer days (100 percent swimmers are exposed)	0	0	12,329	138,209	0	**150,538**
Total number of swimmer days occurring during the contamination period		**21,068-83,552**	**404-1,604**	**14,884-22,462**	**147,948-176,830**	**5,830-23,122**	**190,135-307,568**

The first five rows of Table J.7 present information from the 1999-2002 BEACH Surveys. On average, 153 CSO- and SSO-related closure/advisory actions were reported in the BEACH Survey at these beaches between 1999 and 2002. The number of swimmer days includes swimmer days at state-recognized beaches not in the BEACH Survey, as described in Section J.5.

The middle section of the table estimates the level of exposure that occurs when non-compliant swimmers are exposed to CSO and SSO contamination. Multiplying this amount of exposure prevention per event by the frequency of such events gives an estimate for the average number of days of exposure per beach per year occurring for noncompliant swimmers. The number of exposed days is then divided by 365 to calculate the percent of the year when contamination is present at a beach. Next, the percent of the year is multiplied by the number of swimmer days and by 7 percent and 27 percent (to account for the range of noncompliance exposure rates) to estimate the total number of swimmer days of exposure to CSO and SSOs during closures and advisories.

The third section of Table J.7 (exposure before detection) estimates the days of exposure occurring during CSO and SSO contamination events before they are detected. In this case, exposure occurs only during the lag time between actual contamination and when the action begins at Category 2B and 3 beaches. Again, the amount of exposure occurring per event is multiplied by the frequency with which such events occur, to estimate the average number of days of exposure per beach per year occurring during the lag-time between contamination and detection. The number of days is divided by 365 to calculate the percent of the year contamination is present at these beaches. This percentage is multiplied by the number of swimmer days to estimate the number of swimmer days of exposure to CSOs and SSOs before the advisories and closings are in effect.

The last row of the table presents the number of exposed swimmer days for the two different scenarios of exposure.

J.8 SSO Events Excluded From Exposure Duration Calculations

Several SSO actions were removed from the exposure duration analysis because they were determined to be non-representative of typical SSO events. Actions were considered to be non-representative of typical SSO events when:

- Action durations were greater than 100 days for a single event.
- Survey entries were found to be erroneous, based on information supplied by the beach authorities or based on internal quality control checks performed by technical reviewers.

Action durations greater than 100 days for a single event were removed from the analysis or adjusted when appropriate, because EPA assumed that such extended SSO contamination likely represented a continuous SSO problem that was well known, and therefore human exposure is less likely. Additional actions were removed from Categories 1 and 2B calculations. By definition, beach actions issued for these categories were issued preemptively. However, closer review of 2001 BEACH Survey responses indicated that several actions for these categories had been issued based on monitoring data alone. The actions in Categories 1 and 2B that were based on monitoring data alone were not included in these category calculations. In addition, these data were not used in any other duration categories. All of the actions (four in total) were removed from Category 2B because they were issued based on monitoring data alone; therefore, no duration estimates could be calculated for this category based on those four actions.

J.9 Pathogen Concentrations

EPA estimated the average level of pathogens at beaches during closures attributed to CSO and SSO events and through analysis of monitoring data obtained from the states and reported in the 2001 and 2002 BEACH Survey. EPA obtained additional monitoring data from relevant state or county websites and by contacting beach authorities. EPA estimated the in-water concentration during an event by averaging monitoring data observations obtained during the event including: the first monitoring result indicating exceedance of the bacteria standard and the presence of contamination, and all subsequent monitoring results until the first monitoring result indicating that bacteria concentrations had fallen to an acceptable level. The monitoring data indicated similar, highly variable bacteria concentrations for both CSO- and SSO-contaminated recreational waters and were therefore averaged.

- For salt water closures/advisories, data were obtained for 26 actions. The average enterococci concentration during these events was 532/100 mL.
- For freshwater closures/advisories, data were obtained for 29 actions. This E. coli concentration was 695/100 mL.

To account for bacteria levels present at times when SSO and CSO events are not occurring, EPA estimated background levels. This was accomplished by averaging concentration levels from the last monitoring result not below the bacteria standard preceding a contamination event at each beach for which there were data. The monitoring data showed similar, highly variable bacteria concentrations for both CSO- and SSO-contaminated

recreational waters and were therefore averaged.

- The average background enterococci concentration was 12/100 mL
- For freshwater the background E. coli concentration was 71/100 mL

J.10 Dose Response Equations

The following dose-response functions derived by Cabelli (1983) and Dufour (EPA 1984) were used by EPA to relate highly-credible gastrointestinal illness (HCGI) symptoms among swimmers to the concentrations of enterococci (for marine water and for freshwater) or E. coli (for freshwater only):

For marine water:

HCGI symptoms/1000 swimmers = 0.2 + 12.17 log(mean enterococci/100 mL)

For freshwater:

HCGI symptoms/1000 swimmers = -11.74 + 9.4 log(mean E. coli/100 mL)

These equations derive from epidemiological studies sponsored by EPA at several beach locations in the late 1970s and early 1980s, and provide the basis for EPA's current water quality criteria for recreational waters. EPA's marine water quality criterion of 35 enterococci per 100 mL, for example, was derived by solving the first equation for the water quality that would yield the traditionally accepted illness rate of 19 cases per 1000 swimmers. Several of Cabelli's and Dufour's findings are notable:

- The clearest statistical relationships between water quality and swimmer illness rates were found for gastrointestinal illness. The statistical relationships were even more definitive when only "highly credible" gastrointestinal symptoms were considered, in contrast to all gastrointestinal symptoms.
- Enterococci (marine water and freshwater) and E. coli (freshwater) were found to be the best indicator parameters. They correlated with swimmer illness rates more closely than did other possible indicator parameters (e.g., fecal coliform).

Despite EPA's adoption of the Cabelli/Dufour dose-response functions as the basis for recreational water quality criteria, a great deal of uncertainty is associated with the number of illnesses predicted by these functions, as discussed above. EPA believes most other studies generally support the Cabelli/Dufour conclusion that enterococci and E. coli are the best indicators (EPA 1984). A comprehensive recent review of epidemiological studies on health effects from exposure to recreational water conclude similarly that enterococci/fecal streptococci for both marine and freshwater, and E. coli for freshwater, correlate best with health outcomes (Pruss 1998).

EPA's Office of Research and Development recently reviewed the Cabelli/Dufour studies and the other swimmer illness studies conducted since 1984, when the last of Cabelli/Dufour's studies were published. The review concluded:

> *In examining the relationships between water quality and swimming-associated gastrointestinal illness, the epidemiological studies conducted since 1984 offer no new or unique principles that significantly affect the current water quality criteria EPA recommends for protecting and maintaining recreational uses of marine and freshwaters. Many of the studies have, in fact, confirmed and validated the findings of EPA's studies. Thus, EPA has no new scientific information or data justifying a revision of the Agency's recommended 1986 water quality criteria for bacteria at this time* (EPA 2002).

In light of these findings, EPA concluded that Cabelli/Dufour remained the most reliable set of dose-response functions available to estimate swimmer illness rates in the United States.

Cabelli and Dufour found a statistically significant relationship between indicator bacteria density and gastrointestinal symptoms for some beaches. However, they found a stronger statistical relationship between indicator bacteria density and HCGI symptoms, and decided therefore to express their preferred dose-response relationship in terms of HCGI symptoms rather than total gastrointestinal symptoms. The implication for this analysis is that the Cabelli/Dufour dose-response relationships may understate by a factor of two to four the total number of gastrointestinal cases that are likely occurring. This factor may result in EPA substantially underestimating the number of illnesses resulting from exposure to beach water contaminated by CSO and SSO discharges.

J.11 Illness Calculations and Results

The number of HCGI illnesses resulting from exposure to beach water contaminated by CSOs and SSOs was estimated by combining information on the number of exposed swimmer-days, the concentration of indicator bacteria to which swimmers are exposed, and the Cabelli/Dufour dose-response functions for marine and freshwaters. Table J.8 shows how the number of illnesses was calculated from the number of person days exposed to beach water contaminated by CSO and SSO discharges at beaches included in this analysis.

Table J.8 Derivation of Number of HGCI Cases

Steps	Water Type (per dose-response functions)	Category 1	2A	2B	3	4	**Total**
Person Days of Exposure		21,068-83,552	404-1,604	14,884-22,462	147,948-176,830	5,830-23,122	**190,135-307,568**
Allocation of Exposure Days	Percent in marine waters	83	83	83	83	83	**83**
	Percent in freshwaters	17	17	17	17	17	**17**
Person Days of Exposure	In marine waters	17,487-69,348	336-1,331	12,534-18,643	122,797-146,769	4,839-19,191	**157,813-255,282**
	In freshwaters	3,582-14,204	69-273	2,530-3,818	25,151-30,061	991-3,931	**32,323-52,287**
Pathogen Level During Contamination	Marine waters (EN/100 mL)	532	532	532	532	532	**532**
	Freshwaters (E. coli/100 mL)	695	695	695	695	695	**695**
Rate of HCGI Cases	Marine waters (per 1,000 swimmers)	33	33	33	33	33	**33**
	Freshwaters (per 1,000 swimmers)	15	15	15	15	15	**15**
Background Pathogen Level	Marine waters (EN/100 mL)	12	12	12	12	12	**12**
	Freshwaters (E. coli/100 mL)	71	71	71	71	71	**71**
Rate of HCGI Cases	Marine waters (per 1,000 swimmers)	13	13	13	13	13	**13**
	Freshwaters (per 1,000 swimmers)	6	6	6	6	6	**6**
Illness Rate for Contamination Events - Background Levels	Marine waters (per 1,000 swimmers)	20	20	20	20	20	**20**
	Freshwaters (per 1,000 swimmers)	9	9	9	9	9	**9**
Number of Primary HCGI Cases	In marine waters	350-1,387	7-27	247-373	2,456-2,935	97-384	**3,157-5,106**
	In freshwaters	32-128	1-2	23-34	226-271	9-35	**291-470**
Total estimated primary HCGI occuring due to human exposure to SSO and CSO contamination		382-1,515	8-29	270-407	2,682-3,206	106-419	**3,448-5,576**

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