TESTING THE WATERS

State Highlights

Many coastal states have worked hard and invested heavily in improving and preserving their beach water quality and protecting public health. While space does not permit a comprehensive compilation of all efforts to improve beach water quality and better protect the public, descriptions of some of the specific activities that states have shared with NRDC appear in this chapter, along with resulting improvements in water quality, if available. Contaminated runoff is the most commonly reported cause of poor beach water quality, so the chapter begins with a section on reducing the impacts of contaminated runoff. This includes a discussion of states' implementation of green infrastructure, which allows stormwater to infiltrate into the soil instead of being carried, along with pollutants, to natural bodies of water in storm drains. This section also includes examples of stormwater treatment techniques. Sewage is the second-most commonly reported cause of beach water contamination; accordingly, the next section is about preventing sewage from contaminating water by reducing sewage overflows, leaky septic tanks, illicit sewer connections, and discharges from boats. Next is a look at beach maintenance practices and beach infrastructure changes that can result in water quality improvement. A section about special efforts states are making to provide early notification to the public when beach water quality might be compromised includes a discussion of investigations into advanced monitoring technologies, use of predictive models that provide real-time estimates of beach water quality, and improved communication about sewage spills. The chapter concludes with a look at efforts to identify sources of contamination at beaches, with examples of microbial source tracking studies, sanitary surveys, and special monitoring studies.

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REDUCING THE IMPACT OF CONTAMINATED URBAN RUNOFF

Two strategies for reducing contamination carried to beaches by stormwater runoff are discussed in this section: green infrastructure techniques and stormwater treatment.

Green infrastructure techniques

Green infrastructure strategies employ a variety of techniques to reduce urban stormwater discharges to surface waters. These strategies, which are also often termed low-impact development or LID, act to restore natural conditions by increasing the amount of permeable, usually vegetated areas that minimize the volume of stormwater discharges. Most often, these techniques retain and filter rainwater where it falls, letting it soak into the ground rather than dumping it into waterways. Green infrastructure reduces pollutant flows and minimizes the need for more expensive, traditional treatment by utilizing strategically placed rain gardens in yards, tree boxes along city sidewalks, green roofs that use absorbent vegetation on top of buildings, and permeable pavement. Green infrastructure also involves capturing and storing stormwater in rain barrels or cisterns and reusing it, most often for irrigation or other nonpotable uses. Many green infrastructure strategies have the added benefits of augmenting the water supply, providing wildlife habitat, minimizing greenhouse gas generation, and being aesthetically pleasing.[1]

When surveyed for this year's *Testing the Waters*, many states reported that green infrastructure is gaining traction as success stories mount.

- The American Recovery and Reinvestment Act of 2009 specifically directs clean water funding to environmentally innovative projects, and grant recipients are using funds to help improve beach water quality by implementing green infrastructure techniques. For example, in California, the city of Hermosa Beach was awarded nearly $1.3 million in Recovery Act funds in 2010 to turn one of its major thoroughfares into a "green street." The project includes a new storm drain system designed to prevent bacteria-laden runoff from ending up in beach water that is listed as impaired because of high bacteria levels.[2]
- The city of Redondo Beach in California was given $2.2 million in Recovery Act funds to protect coastal waters from urban stormwater by collecting rainwater for irrigation at a park and infiltrating excess water. This project will reduce discharges of bacteria in urban runoff to the city's beaches.[3]
- Green infrastructure techniques are being promoted in an effort to improve the water quality in Wreck Pond, a tidal pond in New Jersey that is high in fecal indicator bacteria and whose discharges are at least sometimes to blame for persistent water quality problems at beaches in the towns of Sea Girt and Spring Lake. The Wreck Pond Regional Stormwater Management Planning Committee is working with Rutgers University's Cooperative Extension to install six showcase rain gardens in the Wreck Pond watershed.[4] These gardens will reduce overall runoff, sediment, and pollutant loading into streams in the Wreck Pond watershed, which will in turn improve water quality at beaches downstream of the pond.
- Bristol Town Beach in Colt State Park in Rhode Island is using green infrastructure to improve beach water quality. Six catch basins have been installed to intercept runoff from the park before it reaches the beach. Rainwater is filtered mechanically in the catch basins, then further filtered by vegetation in bioswales. The bioswales also significantly slow the flow of rainwater, preventing surges of stormwater that may carry bacteria and other contamination. Other water quality projects are planned at this beach: The storm drain will be opened and restored so that it functions like a winding creek, which will help clean the water it carries to the beach; the parking lot will be replaced by an eco-friendly parking lot with bioretention swales and specialized vegetation to further absorb and filter stormwater; and storage tanks for rainwater will reduce combined sewer overflows from the nearest sewage treatment plant during periods of heavy rain.[5]

Parking lots are a beach amenity that can contribute to the degradation of beach water. They are often constructed at the edge of bathing areas for ease of access, but pavement prevents water from soaking into the ground when it rains. Simple strategies like separating roads and parking lots from the beach with a strip of vegetation can prevent contaminated runoff from reaching the beach water.

- A $7 million restoration project at Hobie Beach (Dog Beach) in Miami was conducted primarily for shoreline stabilization, but some of the changes are expected to have beneficial effects on water quality as well. In particular, stormwater management improvements were made to the parking lot and maintenance road. Semipermeable pavers now allows some rainfall to infiltrate into the soil, and a new drainage system is in place.[6]

■ At Zoo Beach and North Beach in Racine, Wisconsin, a series of dune ridges were developed to intercept stormwater from the parking area. The dunes are designed to allow the stormwater to meander and infiltrate as it flows through them. In July 2010 there was flooding due to record rainfall, but the dune ridges retained all of the sheet flow from the parking lot. Together with a constructed wetland, the dunes mitigated the effect of the stormwater discharge, allowing Racine's beaches to remain open when other beaches in the state had preemptive closures.[7]

Green infrastructure policy development

In many locations, current stormwater management cannot meet clean beach water goals, and communities often struggle with the economic burden of repairing or expanding existing stormwater infrastructure. While retrofitting existing development to reduce runoff can be cheaper and more effective than constructing traditional stormwater treatment facilities, the most economical time to implement green infrastructure strategies is during construction. Several coastal areas around the country have developed policies that encourage or require the use of green infrastructure.

■ Measures outlined in Delaware's Inland Bays Pollution Control Strategy emphasize green infrastructure techniques. The strategy was created to meet total maximum daily load limits for nutrients, but many of its provisions will reduce bacterial discharges in runoff to the inland bays as well. For example, the strategy requires the establishment of buffer zones around wetlands as well as tidal and nontidal waters in the inland bay watersheds. It also allows the preservation or establishment of natural features like forest stands and encourages the use of rain gardens, natural landscaping, and constructed wetlands for management of stormwater.[8]

■ Maryland's recent initiatives to reduce stormwater pollution, including the Stormwater Management Act of 2007, a new general permit to control stormwater discharge during construction, and new municipal stormwater permits now being issued for Maryland's 10 largest counties, are expected to reduce urban stormwater by 20 to 30 percent when fully implemented.[9]

■ Duluth, Minnesota, is in the process of adopting a new unified land development code. This code will be informed by the city's comprehensive plan and will encourage green infrastructure and the preservation of open space.

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These dunes, developed and planted by the city of Racine, Wisconsin, help keep contaminated runoff from polluting the beach water.

■ The second phase of a coastal bacteria source identification project being conducted by New Hampshire's Department of Environmental Services and a local environmental firm is scheduled for completion this summer. This phase of the project will identify potential bacteria sources and mitigation processes that will inform the development of plans for the North Hampton State Beach watershed and the Wallis Sands at Wallis Road Beach watershed. These plans will promote the use of green infrastructure.

Stormwater treatment

While prevention of stormwater runoff through the use of green infrastructure is preferred, there are situations in which it is more practical to focus on the treatment of contaminated stormwater. There are many means of treating stormwater to reduce bacterial contaminants, such as installing filters into outfall catch basins and using UV disinfection.

■ While Kure Beach (Ocean Pier at K Avenue) in North Carolina has consistently enjoyed good water quality, the town of Kure Beach was concerned about discharging stormwater with elevated levels of fecal indicator bacteria to outfalls at the beach. The beach has a well-established dune system whose crest is 12 to 14 feet above sea level, and the town decided to explore filtering stormwater through the sand in the dunes in order to remove bacteria. To test the feasibility of this strategy, two filtration units were installed in 2006, treating 95% of the runoff from a residential section of town. There has been no indication of any slumping or eroding of the dunes or of adverse effects on the water table since the treatment units were installed. Fecal indicator bacteria levels of 1,000 cfu/100 ml in runoff at the entrance to the filtration units drop to typical groundwater concentrations of 10 cfu/100 ml at the base of the dunes. A third system was installed in 2009.[10]

■ Beginning in late 2000, a stormwater outfall in Racine, Wisconsin that was affecting water quality at North Beach and Zoo Beach in Racine was reengineered. The improved outfall includes a pretreatment system that removes solid waste and oil from stormwater and then directs it to a series of infiltration/evaporation basins planted with native wetland species. In high-flow situations caused by large storms, stormwater bypasses the treatment structures and wetlands, discharging through a bypass outlet and into a plunge pool that also contains native vegetation before it is released into Lake Michigan.[11]

■ The city of Newport, Rhode Island, has installed a $5.8 million ultraviolet treatment system to reduce bacteria levels from stormwater that discharges at the city's beach. The system was expected to begin operating before the start of the 2011 beach season.[12]

PREVENTING SEWAGE CONTAMINATION

Discharges of partially treated and untreated sewage into waterways are the second-most commonly reported cause of beach water contamination. These discharges can be caused by malufunctions at sewage treatment plants, broken sewer lines, or equipment failures. Some plants treat a combination of stormwater runoff and domestic sewage, and when the volume of water overwhelms the plant's treatment capacity during storms, the plants discharge untreated or partially treated sewage in events called combined sewer overflows, or CSOs. Other sources of sewage contamination at beaches include leaky septic tanks, discharges from boats, and illicit sewer connections to storm drains.

Overflows from sewage treatment plants

Coastal localities that have taken steps to reduce sewer overflows are seeing improvements in beach water quality. One way to reduce overflows is to upgrade sewage treatment plants so they can handle a higher volume of waste. Installing holding tanks that allow sewage generated during high-flow events to be treated is another way to prevent overflows.

■ Lakewalk Beach in Duluth, Minnesota, used to have a number of advisory days every year due to sewage bypasses and overflows. The city installed a series of holding tanks, including one that holds a million gallons of wastewater, to reduce or eliminate sewage bypasses into Lake Superior and the St. Louis River. Water quality at Lakewalk Beach showed immediate improvement, with no advisory days in 2009 and just one in 2010.[13]

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Dune filtration unit under construction at Kure Beach.

■ A 17-foot-diameter combined sewer overflow tunnel in South Boston, Massachusetts, was expected to become operational on June 1, 2011. In addition to holding combined sewer overflows for later treatment, this tunnel will store stormwater flows during all but the largest rainstorms and will pump both stormwater and combined sewer overflows for treatment as capacity allows, thus preventing a large source of bacteria from reaching the beaches of South Boston.[14]

■ Rhode Island's commitment to improving its beach water quality is illustrated by the State Tunnel Project, which was the biggest and longest-running public works project in state history, and which was initiated to address beach water contamination caused by combined sewer overflows. The $359 million project, completed in 2008, consists of a tunnel under downtown Providence. The tunnel can capture up to 1½ inches of the rainfall from a storm and hold it until treatment capacity becomes available.[15]

Leaky septic tanks

Sometimes significant sewage contamination of coastal waters occurs from multiple smaller sources. Many states have found that the water quality at some of their beaches improves after malfunctioning septic systems are eliminated.

■ Eliminating failing septic systems upstream of Fairview Beach in Virginia has improved the water quality at the beach. Microbial source tracking showed that the stormwater outfall at Fairview Beach had a persistent human signature, regardless of rainfall levels. The Virginia Department of Health and local officials located several apartments, homes, and trailers on old septic systems and connected them to the community sewer system.[16] The percentage of samples exceeding the single-sample maximum standard dropped from 37% in 2006, 28% in 2007, and 32% in 2008 to 25% in each of the past two years.

■ In 2009 the city of Warwick, Rhode Island, continued its effort to connect Greenwich Bay homes using septic tanks to municipal sewer systems. Approximately 8,000 homes have been connected to municipal sewage treatment since the beginning of the project. The proportion of samples exceeding water quality standards at City Park Beach in Warwick has dropped from 19% in 2005 to 10% in 2007, 9% in 2008, 4% in 2009 and 2% in 2010. (Some of the reduction may be due to Rhode Island's State Tunnel Project, which has reduced sewer overflows.)

■ In late 2008, several failing septic tanks were identified near Purdy Sandspit County Park in Pierce County, Washington. The beach there was closed, and corrections were made. Last year bacteria tests indicated that water quality met standards, and the beach was reopened in July 2010.[17] According to monitoring results, the beach met state bacteria standards for 95% of the samples taken in 2010.

Other states report plans to eliminate septic tanks in coastal areas.

■ Construction of additional sewage treatment capacity in Delaware's inland bay watersheds and the subsequent elimination of tens of thousands of septic tanks and other sources of sewage contamination are expected to result in water quality improvement in the inland bays.

■ The city of Chatham, Massachusetts, began constructing a new wastewater treatment facility in the spring of 2010. Construction of the plant, five pump stations, and sewer mains will ultimately allow about two-thirds of city residents to be connected to municipal wastewater treatment instead of septic tanks.[18]

■ Construction of additional sewage treatment capacity in Delaware's inland bay watersheds and the subsequent elimination of tens of thousands of septic tanks and other sources of sewage contamination are expected to result in water quality improvement in the inland bays.[19]

Illicit sewer connections

Illicit sewer connections occur when homeowners and businesses unknowingly or purposely connect their sewage lines to storm drains instead of to municipal sewer lines. In coastal areas, the storm drains may flow straight to the beach, and the illicit connection results in beach water contamination.

■ The city of Newport, Oregon, took steps to protect the public when monitoring revealed consistently high bacteria levels in stormwater discharges to Nye Beach in Lincoln County in 2006 and 2007. The city conducted smoke and dye testing of the stormwater and sewer lines and discovered that seven properties were discharging sewage directly to stormwater drains instead of to the city's sewage treatment system. In 2008, these cross-connections were corrected.[20] Beach water quality has improved, from 32% exceedances in 2007 to 7% in 2008, and 0% in 2009 and 2010.

Boater waste

Carelessly handled waste from boats can be a source of fecal contamination at beaches. Maintaining adequate pump-out facilities in marinas and encouraging their use is one way to reduce dumping of boater waste in near-shore waters.

■ Because of elevated levels of enterococcus bacteria at Laite Beach and Camden Yacht Club Recreation Area, Maine Healthy Beaches conducted a boater education campaign. Activities were aimed at convincing boat owners to empty their sewage holding tanks into Camden's pump-out boat instead of emptying them into the ocean. In 2010, the pump-out boat handled 4,000 gallons more sewage than in 2009, though the values in 2009 may have been unusually low due to poor weather conditions and low boat traffic. Still, the 2010 figure represents an increase of 2,000 gallons compared with 2008, when there was similar weather and boat traffic; the additional capture in 2010 reflects well on the campaign.[21]

■ In July 2010, Pleasant Bay on Cape Cod, Massachusetts, became the state's latest no-discharge zone. No-discharge zones are designated by the U.S. EPA and prohibit both treated and untreated sewage discharges from boats. Within these zones, boat operators are required to retain their sewage onboard for disposal at sea (more than three miles from shore) or onshore at a pump-out facility.[22]

BEACH INFRASTRUCTURE AND MAINTENANCE PRACTICES

Often, modifications that are intended to make a beach more attractive or accessible to visitors backfire because they contribute to poor water quality. Breakwaters, for example, make water less turbulent for swimmers, but they also reduce natural water circulation and trap polluted waters in areas where bathers congregate. Ironically, many "mothers' beaches" that are frequented by families with small

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An oyster reef in the making after only two growing seasons in Belleville, Georgia.

children because of their quiet waters are prone to exceeding water quality standards. From a water quality standpoint, beach infrastructure that interferes with water exchange is undesirable.

- The beaches of East San Pedro Bay in Long Beach, California, illustrate the impact of infrastructure designed to reduce waves. Off the coast, a 2.2-mile World War II–era breakwater has been blamed for trapping water pollution from various sources, including the Los Angeles River, resulting in water quality exceedances at the beaches as well as ecological damage to the near-coast environment. The Army Corps of Engineers has lent its support to further study of the possible reconfiguration of the breakwater.[23,24]

- Beachgoers might appreciate a long expanse of relatively flat and tightly packed sand, but sand harbors bacteria, and beach grooming techniques that pack and level the sand can increase the density of bacteria.[25,26] Switching to beach grooming techniques that deeply groom the sand without leveling it can have a positive impact on beach water quality.[27] The city of Racine, Wisconisin, has altered its beach grooming practices to facilitate bacterial die-off in the sand through increased sun exposure and reduction of moisture content.

- Oyster reefs, which once covered the Georgia coastline, have been largely wiped out by pollution, overharvesting, and disease. It is difficult to estimate the original extent of the reefs, but information on commercial harvesting rates provides some sense of how much has been lost. In 1908, Georgia harvested 3.6 million kilograms of oyster meat; a century later less than 6,000 kilograms were harvested.[28] Oyster reefs play an important role in the health of estuaries, providing erosion control, water filtration, food production, and spawning and breeding habitat for many fish species. Georgia is now conducting projects to restore the reefs. These efforts, focused on existing boat ramps, are motivated largely by the need to reduce coastal erosion and provide bank stability, but they are expected to improve beach water quality as well. Oyster reef restoration is accomplished by providing hard surfaces in the intertidal zone where oyster spat can attach and mature.

- Waterfowl also contribute to pollution. Birds are attracted by food sources, including handouts from misguided visitors as well as trash left on beaches and in overflowing garbage cans. Where there are birds there is fecal contamination. Waterfowl congregate more freely when areas adjacent to beaches have been cleared of trees and bushes that would provide cover for predators. Frequently, parking lots at the beach attract shoreline birds, and parking lot runoff washes their fecal matter into the beach water. Using border collies during the beach season to harass gulls every day from dawn to dusk[28] has been an effective means of improving water quality at two gull-impacted beaches in Chicago. The beach water at 63rd Street Beach (Jackson Park) exceeded standards more than half the time in 2006 and 2007. In 2008 border collies were used to reduce the number of gulls at the beach, and only 6% of water samples exceeded standards. In 2009 there was no gull harassment, and 66% of samples exceeded standards. Gull harassment was reinstated in 2010, and exceedances fell to 22%. Similar success was observed at 57th Street Beach. The beach water there exceeded standards 20% of the time in 2006 and 26% of the time in 2007. In 2008, when dogs were used to harass gulls at the beach, there was a 0% exceedance rate. The following year, when dogs were not used, the rate rose to 49%. Gull harassment was again in place in 2010, and 13% of samples exceeded standards.

PROTECTING THE PUBLIC WHEN WATER IS CONTAMINATED

When traditional culture methods are used to measure the fecal indicator bacteria counts that are the basis for beach advisories and closings, there is generally a 24-hour lag time between sampling and the issuance of advisories because it takes 24 hours for culture results to become available. As a result, beachgoers are not advised of high counts the day that bacterial counts exceed standards, but rather a day later. Many times, too, the culture results of samples taken the day a beach is placed under advisory reveal that the water quality on that day had already returned to acceptable levels. Many states are making a push to notify the public on the day that

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Professional gull chasers at work at 63rd Street Beach (Jackson Park) in Chicago.

beach water is thought to be contaminated through improved communication about sewage spills that might impact beaches, investigations into advanced monitoring techniques that will allow faster test results, and the use of models that provide real-time predictions of beach water quality.

Investigating advances in monitoring technologies

For several years, EPA has been conducting research on the use of rapid test methods to determine beach water quality, particularly quantitative polymerase chain reaction (qPCR) methods. This approach detects the presence of specific sequences of genetic material and can be used to quantify the concentration of fecal indicator bacteria. EPA's investigations have studied how qPCR results correlate with other methods of determining fecal indicator bacteria concentrations, whether qPCR detects all strains of fecal indicator bacteria, and whether the method can be used to correlate the amount of indicator bacteria present with illness rates in swimmers. Unlike traditional culture methods, qPCR cannot distinguish between genetic material from dead bacteria and genetic material from live bacteria. It is generally believed that the concentration of living fecal indicator bacteria is a better predictor of human health impacts than the concentration of living and dead indicator bacteria because the presence of pathogens that can cause illness in humans are more likely to correlate with the concentration of living fecal indicator bacteria.

- The EPA included qPCR analysis in its National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Studies, which included water quality sampling and investigations of beachgoer illness rates at beaches on the Great Lakes and in Puerto Rico, Alabama, Florida, South Carolina, California, and Rhode Island.
- In 2007 New Jersey and EPA began an ongoing joint sampling program to study the correlation between two different culture methods and qPCR for enterococcus.
- A qPCR pilot study in Orange County, California, during the summer of 2010 demonstrated the practicality of issuing beach notifications using qPCR. In this project, the qPCR method resulted in higher bacterial counts than traditional culture methods, and more postings were issued than would have been issued if only traditional culture methods had informed the notification decisions.
- Researchers conducting a demonstration project in Racine, Wisconsin, in the summer of 2010 concluded that the same-day test method shows promise as a tool that would provide better public health protection and give beachgoers more timely information about beach water quality than traditional culture methods.[30]

Another promising rapid test method is immunomagnetic separation/adenosine triphosphate (IMS/ATP), which exploits the unique properties of the surfaces of target cells (e.g., enterococcus or *E. coli*) to capture and tag the cells and count their concentrations in a given sample. One of the challenges of IMS/ATP is that strains of indicator bacteria for which antibodies do not yet exist are not detected.[31] The use of IMS/ATP for detecting microbes in surface waters has not been studied as much as the use of qPCR, but the technique has been tested in epidemiological studies. In 2010 two of Ohio's beach water monitoring program partners conducted separate investigations of both qPCR and IMS/ATP.

- The Erie County (Ohio) General Health District worked with the U.S. Geological Survey in ongoing research of these two methods at several of its beaches; in 2011 the agencies will continue to improve IMS/ATP test method protocols.
- The Northeast Ohio Regional Sewer District conducted analysis using IMS/ATP and qPCR at three beaches. It found little correlation between IMS/ATP results and culture-based results at all three sampling locations, and slight but varying degrees of correlation between qPCR results and culture-based results.[32]

In addition to rapid methods for quantifying fecal indicator bacteria, methods for directly identifying pathogens in beach water are being explored.

■ Delaware's Recreational Water Program has been providing support and funding for research into rapid methods of analysis of marine and inland bay waters for the presence of pathogenic and pathogen-like Epsilonproteobacteria. Pathogenic members of this group include *Heliobacter pylori* and *Campylobacter jejuni*, both of which are associated with human gastric disease and gastroenteritis. The correlation between results of this research and fecal indicator values is being studied. The goal is to be able to quickly identify harmful bacteria and improve the safety of recreational waters.[33]

Using models to obtain real-time predictions of beach water quality

Beach water quality generally depends on many complex factors, but for some beaches, predictions of water quality can be fairly accurately calculated on the basis of a few physical measurements of daily conditions. Some states have created computer beach water quality models that rely on data from physical measurements such as rainfall levels, wind speed and direction, tides, wave heights, and currents. These models prepare rapid predictions of beach water quality and allow beaches to be closed or placed under advisory the day that bacterial levels are expected to be high, rather than 24 hours after samples with high bacteria concentrations are taken. The importance of predictive models in protecting public health was illustrated by a local beach manager who demonstrated that one year, advisories and closings based on monitoring results were issued inaccurately 100 percent of the time.[34] In other words, samples taken when the beach was under advisory or closure due to the previous day's monitoring results showed that in every case, the beach water quality met standards on the days that the beach was under advisory or closure.

Predictive models used at coastal waters around the country include the following:

■ Since 2003, San Diego County in California has used a predictive model to trigger beach closings at three beaches near the outlet of the Tijuana River. These beaches are Imperial Beach, Coronado Beach, and Silver Strand State Beach. The model assesses the need for closures based on real-time information about ocean currents and other parameters.[35]

■ Several coastal beach managers in Illinois use predictive modeling (SwimCast) to make swim ban and advisory decisions. At a minimum, predictions are generally made at 9 a.m. and 1 p.m. and whenever hydrometeorological conditions change. For each beach where the SwimCast system exists, similar but slightly different predictive models are utilized. These models predict beach water conditions on a real-time basis, in contrast to standard culture methods for quantifying bacteria. Studies have shown that SwimCast provides a more accurate assessment of current beach water quality than does the previous day's bacterial density.[36]

■ BEACH Act grants have been used to partially fund the development of models that predict beach water quality in Indiana. These models make predictions based on current conditions, turbidity, chlorophyll content, and color. A model called Project SAFE was used in 2010 for Ogden Dunes, Wells Street, Marquette, and Lake Street beaches. Each morning, Monday through Friday, beach managers were given the model's predicted likelihood that the *E. coli* count would exceed safe limits. On that basis, the beach manager chose whether to issue an advisory or closing. Physical bacterial monitoring continued at these beaches to complement the predictive modeling information.

■ Several of New York's beach water quality contracting entities have developed models of various designs and complexity for their beaches. For example, Monroe County uses a model based on amount of rainfall, the flow rate of the Genessee River, turbidity, algae, and other organic debris. The Interstate Environmental Commission has developed an extensive hydrodynamic loading model that is integrated into the beach monitoring and notification programs of the New York City Department of Health & Mental Hygiene and the Westchester, Nassau, and Suffolk County health departments. In 2010 the Chautauqua County Department of Health began using Virtual Beach software to predict water quality at beaches on Lake Erie.

■ Ohio uses a predictive model called Nowcast at two of its beaches, Edgewater and Huntington Beach. This model relies on environmental factors including rainfall, turbidity, and/or wave height to predict *E. coli* levels.

■ The city of Milwaukee, Wisconsin, uses predictive models in addition to monitoring to determine advisories for a few of its beaches.[37] In 2010, Ozaukee County, Wisconsin, began using a predictive model (NowCast) at its beaches.[38]

Improved communication about sewage spills

Communication gaps between those responsible for sewage and stormwater treatment and those charged with protecting public health must be addressed. The public has the right to know that an overflow or discharge has occurred and should be informed when it happens, not several days later, after beach water monitoring results have been analyzed. Representatives of Washington's beach water quality monitoring and notification program (BEACH) are striving to educate municipal sewage treatment plant operators about the importance of notifying them in a timely manner when there is a spill. Most sewage plant permits, but not all, require facility operators to contact Washington's Shellfish Program when there is a spill. Washington's Shellfish Program typically notifies BEACH when it hears of a spill, but the Shellfish Program is not always notified of a spill even when sewage treatment plant permits require it. After working with BEACH, permitting entities have agreed that as permits are renewed, all wastewater treatment facility operators will be required to immediately notify the local health jurisdiction when there is a sewage spill and the Shellfish Program when there is a spill into marine waters.[39]

SOURCE IDENTIFICATION

Information about sources of contamination is invaluable in terms of addressing poor water quality. It is only after sources are identified that the most prudent strategies for addressing those sources can be developed.

Microbial and chemical source tracking

In many cases, visual surveys and a knowledge of upstream sources of contamination (like sewage treatment plants and animal feedlots) fail to reveal the source of beach water contamination. This is often the case when many small or nonpoint sources are contributing to the contamination. Sometimes chemical markers (such as pharmaceuticals or their metabolites) are measured to determine whether a human sewage source is responsible for high bacteria counts. The presence of caffeine or optical whiteners used in laundry detergents is also used to determine whether contamination with human sewage has occurred.

- This year, the Department of Health in Hawaii is working with the Kauai chapter of the Surfrider Foundation to investigate the presence of wastewater constituents in the waters of Nawiliwili Bay. In addition to identifying the species responsible for fecal indicator bacteria found in bay waters, sampling will be conducted for two human pharmaceuticals, carbamazepine (an anticonvulsant) and sulfamethoxazole (an antibiotic).[40] These pharmaceuticals are present in wastewater but are not destroyed during wastewater treatment, which makes them useful indicators for the presence of wastewater effluent.

- Because of elevated levels of enterococcus bacteria at Laite Beach and Camden Yacht Club Recreation Area, the Maine Healthy Beaches Program analyzed samples for enterococcus and optical whiteners. As a result of the effort, the town of Camden identified two illicit sewage cross-connections to the storm drain network.

There are many methods for identifying species responsible for fecal organisms present in water. Most microbial source tracking, as this process is called, relies on matching DNA or RNA "fingerprints" from bacterial strains found in contaminated beach water with those of bacteria found in various animal hosts and human sewage. Quantitative PCR (qPCR) is an example of a laboratory technique used in microbial source tracking.

- Researchers at Stanford, the University of California at Los Angeles, the University of California at Santa Barbara, and the Southern California Coastal Water Research Project are developing a protocol for identifying the sources of fecal indicator bacteria found in beach water. This project will provide guidance for choosing appropriate technologies and sampling strategies for source identification studies. Researchers will select a subset of source identification techniques from among dozens of possibilities to test in detail at 20 to 30 California beaches. At these beaches, samples will be taken in rivers, creeks, and storm drains above the point of tidal influence, at the wave wash zone at the mouth of the outfalls, in sand near the outfalls, and in kelp washed up on the beach at the high tide line. The presence of human and other sources of fecal indicator bacteria will be determined. After the initial testing phase, a more thorough source identification study of the watersheds for some of the beaches will be conducted.[41]

- Beach water at Cole Park and Ropes Park along Corpus Christi Bay in Texas is monitored through the Texas Beach Watch Program. These beaches have a history of exceeding the water quality standard. They both have stormwater outfalls and are located in a residential area of the city of Corpus Christi, so the potential for human contamination is

high. In 2010 water samples from the monitoring stations at Ropes Park and Cole Park were analyzed using the polymerase chain reaction (PCR) method to detect the esp marker as an indicator of human contamination. The results of this preliminary study suggest there is some human contribution, and investigations are continuing.[42]

Sanitary surveys

Sanitary surveys used to be associated mainly with drinking water and shellfish safety programs, but more and more states are conducting sanitary surveys of their recreational beaches, either annually or when exceedances are found. In fact, sanitary surveys were in many cases the first step toward implementing the successful strategies described in this chapter. Beach sanitary surveys involve collecting information at the beach and sometimes information about the surrounding watershed. Information collected at the beach may include data regarding discharge from any outfalls, the number of birds at the site, the amount of litter, and the presence of seaweed or algae. Information about the watershed may reflect land use, the use of residential septic tanks, and locations of wastewater treatment facilities.

- To identify and reduce sources of pollution at Delaware's lifeguarded beaches, the state's recreational water program initiated a beach shoreline survey. As a result of this survey, park staff and shop owners have been educated about the need to locate garbage receptacles away from storm drains, and residents' complaints about malfunctioning septic systems have been addressed.

Special monitoring studies

To help identify sources of contamination, officials may undertake special monitoring studies, in which additional samples are collected during storm events or in additional locations and in sources upstream of contaminated beaches.

- Maine Healthy Beaches conducted special monitoring that revealed that Lincolnville Beach's elevated levels of bacterial pollution are likely caused by malfunctioning septic systems, wildlife, and illicit connections to the storm drainage network along U.S. Route 1.[43]

- In New Jersey, elevated levels of enterococcus bacteria are discharged to the ocean from Wreck Pond's outfall during rain events. Source tracking efforts at Wreck Pond have shown that sources of pollution include stormwater runoff and suspected failing sewage infrastructure in the community surrounding the pond. Wet-weather sampling continues in an effort to pinpoint the sources of contamination at this pond. In 2009 and 2010, this included sampling for enterococcus within some of the stormwater lines that are suspected of causing beach impacts. This work helped to narrow down the areas where sewage infrastructure will be inspected. [44]

1 See NRDC's report "Rooftops to Rivers," www.nrdc.org/water/pollution/rooftops/contents.asp.

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