S&E SCIENCE AND THE ENVIRONMENT BULLETIN S&E
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WILDLIFE TRACKING TECHNOLOGIES

In 1997-1998, biologists discovered 5,000 dead Swainson's hawks at roosting sites in southern Argentina—nine of them wearing leg bands that originated in western Canada. The find proved a vital clue in solving the mystery of why the number of breeding hawks in Alberta and Saskatchewan was declining.

An Environment Canada scientist fits a tranquilized polar bear with a collar equipped with a satellite transmitter

Autopsies revealed that the birds had ingested the pesticide monocrotophos by eating contaminated grasshoppers. To determine the scope of the threat, biologists at Environment Canada's Canadian Wildlife Service outfitted six hawks the following year with special satellite tracking devices before they departed for their annual 13,000-kilometre journey south. Their discovery that individual hawks roamed throughout the region in winter contributed to the nationwide ban of the pesticide in Argentina, and was instrumental in eliminating this significant threat to the species' survival.

Satellite telemetry and banding are just two technologies biologists use to determine when and where populations move. This information is vital because it enables them to detect causes of population decline, assess potential threats, and monitor habitat quality throughout a species' range. The data gathered through tracking are used in wildlife management and conservation programs, to set game bird hunting regulations, in recovery plans for endangered species, and to address issues ranging from disease to environmental contamination.

Before the 1960s, the primary method of tracking wildlife was to capture and mark individuals with an identifying tag or band, and then to either observe them in the wild or recover them through recapture or by finding deceased remains. From these studies, scientists are able to determine individual longevity and cause of mortality, the age structure of populations, and limited information on movement and fidelity to certain sites.

Since 1904, over 59 million birds have been banded in North America—and close to 250,000 birds are still banded annually in Canada. Metal leg bands carry a unique identification number that corresponds to a file of information about the date and location of capture and other vital statistics about the bird. Information is collected when game birds are shot by hunters, or when birds are found dead or recaptured. The problem with bands is that fewer than one per cent of those attached to songbirds and fewer than 10 per cent attached to game birds are ever recovered. Coloured plastic leg bands, streamers, nasal disks, wing tags and collars are also used to identify individual birds, as they can be spotted from several hundred metres away using a telescope. They can yield information about survival rates and breeding success for birds that return to identified breeding, molting or wintering sites each year. But the lives of farther-ranging species that spend their time in unobservable or remote regions remain a mystery.

During World War II, radar operators began to realize that some of the blips on their screens were flocks of birds passing through their range. Scientists

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at Environment Canada have used this technology to learn more about the direction and form of migrations and the movement of local concentrations of birds between their roosting and feeding areas—particularly where they pose a hazard to aircraft. Although radar can't distinguish between species, scientists are experimenting with toothpick-sized transponders that could be attached to individual birds to identify the flights of specific flocks.

A brown noddy fitted with coloured plastic and metal leg bands.

The first big breakthrough in tracking technology took place in the early 1960s with the advent of radio telemetry. Like satellite telemeters, radio telemeters consist of a transmitter, antenna and power cell that are attached to the subject by a variety of means. For large animals, a harness or collar is the most common method, while glue, subcutaneous prongs and surgical implants are used in cases where harnesses are too much of an impediment—as with diving ducks. Although larger packages have a longer range and lifespan, small animals will only be fitted with transmitters not exceeding six per cent of their body weight and for birds, less than three per cent, to ensure their welfare. The smallest radio transmitters—which have been used to study toads, bats and songbirds—are the size of a dime and weigh just one gram each.

Signals emitted by the transmitters are detected using receivers—either by homing toward the signal and observing the subject, or by using triangulation. In the latter case, a directional bearing is taken from two or more receiver positions at precisely the same time. These bearings are then drawn on a map, with the point at which the directional lines intersect marking the location of the animal. Receivers can be operated on foot or in cars, boats or small aircraft. Computer-based remote tracking systems can also be programmed to run independently.

Because its signals have a limited range, radio telemetry tends to be used for localized studies on populations in a well defined and accessible area. Environment Canada has used radio collars to study a variety of mammals, including elk, caribou and timber wolves. Radio telemetry has revealed important information on territorial boundaries, interaction among different populations, breeding locations and rates, food consumption and other behaviours by making it possible to locate and observe individual animals.

Radio telemetry is also used to study the movements of birds—although rarely over a large area. This technology has revealed much about the behaviour of species, including the fact that prairie falcons in southern Alberta travel up to 25 kilometres from their nesting sites on riverside cliffs to catch ground squirrels on range land. It has shown that approximately half of endangered burrowing owls die between the time they leave their nest and migrate south, and provided the first clues to their winter range when three transmitter-carrying owls were detected in southern Texas. Telemetry also helped to confirm that the world's only tree-nesting seabird, the marbled murrelet, nests in British Columbia's old-growth forests, which are under severe pressure from the lumber industry.

The first satellite telemeter used in wildlife tracking was a bulky five-kilogram unit attached to a grizzly bear in the mid-1970s. Since then, the miniaturization of the electronics in the platform transmitter terminal (PTT) and the addition of on-board sensors to collect data on movement, temperature, altitude, humidity, heart rate and other factors have revolutionized conservation ornithology. In 1993, PTTs weighing 28 grams—about the size of a disposable lighter—were attached to peregrine falcons to test the PTTs' capabilities on far-ranging species. In just two years, satellite studies revealed more about the species' range and critical breeding, migratory and wintering habitats in North and South America than 25 years of conventional field studies and banding returns. For example, although peregrines inhabit very small areas during winter, during migration they travel long distances very quickly—one subject making the flight from northern Alberta to Veracruz, Mexico, in just 23 days.

Satellite transmitters operate on an ultra-high frequency, sending out an identification code and other information to satellites that collect data as they pass overhead. Ground-based computers use the Doppler effect—shifts in the frequency of the received signal caused by the satellite's movement—to figure out the animal's location to within several hundred metres. Because they send their signals into space, satellite transmitters require more battery power, and are therefore heavier than radio transmitters. To extend battery life, most units can be programmed to transmit at different rates at different times of year. Transmitters weighing only 15 grams are being tested, but the smallest model currently available is 20 grams—light enough for a duck.

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In the future, small PTTs may carry Global Positioning System (GPS) receivers, which can pinpoint a position anywhere on earth almost instantly and to within 20 metres. Already used to track grizzly bears, these devices are capable of storing data over a period of time and then transmitting them as a single message when a satellite is overhead. Although a 100-gram GPS will likely be on the market soon, the technology is still too heavy for birds.

Because they spend so much time offshore, sea ducks have been a major focus of Environment Canada's satellite telemetry work. In eastern North America, scientists using the technology to study endangered harlequin ducks made the surprising discovery that birds breeding in Quebec were actually two separate populations—one that molted along the Labrador coast and the other that molted in Greenland. Since then, scientists in the two countries have begun meeting to discuss the challenges of managing this species across its range.

Biologists also began using satellite tracking last year to study the declining Atlantic population of the Barrow's goldeneye—one of the few ducks that lays its eggs in the cavities of old trees. The initiative led to the documentation of the first breeding record for eastern North America and identified several important molting sites. A similar initiative to determine why western Canada's king eider population has dropped 50 per cent since 1976 has revealed two key staging areas for males in the eastern Beaufort Sea, molting sites as far west as the Siberian Bering Sea and wintering sites on the Bering Sea and the Gulf of Alaska. Further studies may confirm suspicions that changes in marine habitat conditions at these sites are behind the decline.

While satellite tracking is particularly useful for avian species, Environment Canada scientists have also used satellite collars on female polar bears and their cubs since 1996 to delineate the population and determine how mothers select their dens. The Department is also supporting a study on the habitat use and movements of harbour porpoises off the coast of New Brunswick, where they are threatened by gill net fishing activity.

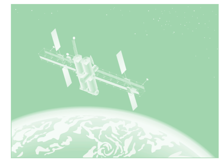
A new and unobtrusive way to track species that are too small for transmitters was discovered by scientists in Saskatchewan, who determined that continental patterns in hydrogen isotopes in water are translated through the food web to the tissue of animals. Field studies of songbirds and migratory monarch butterflies have proven the method a reliable indicator of the latitude of origin of species that breed in North America.

In recent years, many wildlife tracking projects have taken on the role of virtual science classrooms for thousands of schoolchildren and others who follow the movement of species on special Internet sites. This fall, the Canadian Space Agency and Environment Canada will launch a pilot project to engage students in scientific research on the conservation of three migratory wildlife species: the peregrine falcon, polar bear and leatherback turtle. Students will follow the movement of satellite-tagged subjects on the Internet and conduct research on habitats, weather, and other local conditions in an effort to assess threats to the survival of these species throughout their range.

In the future, lighter, longer-lasting, less obtrusive and more accurate satellite tracking technologies—used in combination with other methods such as banding, colour marking, and radio telemetry—promise to unlock a wealth of information on the many species whose movements and behaviours remain a mystery to biologists. S&E

How They Stack Up...

Satellite Telemetry



- expensive (transmitters $5,000, satellite time $2,000 per year per transmitter)
- data collection instantaneous (usually at intervals of less than one hour)
- unlimited range
- accurate to within several hundred metres
- smallest package weighs 20 grams
- shorter-term (batteries last up to one year for external transmitters and eight months for internal ones)
- transmitter may break, malfunction or fall off

Radio Telemetry

- moderately expensive (transmitters $200, receivers $1,500)
- data collection very labour-intensive
- tracking by aircraft expensive and reliant on weather and accessibility
- limited tracking range (up to 30 kilometres from aircraft, 10 on ground)
- accurate to within 100 metres
- smallest package weighs one gram
- large transmitters are relatively long-term (batteries can last up to three years), but small ones may last as little as a week
- transmitter may break, malfunction or fall off

Banding/Marking

- inexpensive (about $10 per bird)
- provides essential baseline data on population dynamics
- recovery rate low
- provides no information on movements in unobservable areas, and very little in areas where few people live
- can be used on any size of bird
- observational errors can affect accuracy of data
- useful for determining cause of mortality
- useful for determining long-term data, such as maximum life span
- can be reported anywhere in North America by calling 1-800-327-BAND (2263)

GREEN SKYLINES OFFER URBAN RE-LEAF

Vine-covered façades and lush rooftop gardens offer more than a green oasis in the concrete jungle. Studies show that they can help urban areas adapt to climate change and also decrease greenhouse gas emissions by reducing the energy spent on heating and cooling.

Vines, like those on the walls of this Toronto home, provide effective insulation against outside temperatures and wind.

According to scientists, climate change will result in more frequent heat waves and several climate models indicate an increase in precipitation intensity, suggesting the possibility of more extreme rainfall events. These effects will be exacerbated in urban areas, where concrete and pavement re-radiate heat and prevent storm-water from being absorbed into the ground. In addition, urban areas must also cope with air quality problems, which may worsen in coming years.

Proven to greatly mitigate these impacts, vertical and rooftop gardening has seen a widespread renaissance in Europe in recent years, but is still little used in North America. To investigate its application in Canada, Environment Canada and several private sector partners recently completed a report on the benefits of rooftop and vertical gardens, titled *Greenbacks from Green Roofs: Forging a New Industry in Canada*, for the Canada Mortgage and Housing Corporation.

According to the report, one of the chief benefits of planting vegetation on buildings is to reduce energy usage and therefore greenhouse gas emissions. By protecting buildings from wind, plants can reduce heating in winter by 25 per cent and, through direct shading and evaporative cooling, air conditioning in summer can be reduced by 50 to 75 per cent. A 16-centimetre thick blanket of plants can increase the R-value of a wall by as much as 30 per cent.

Wall and rooftop gardens also regulate the “urban heat island,” a phenomenon that causes cities to be up to 8°C warmer than the surrounding countryside due to re-radiated heat. Through evapo-transpiration, a layer of vegetation can reduce the amount of re-radiated heat on a hot summer day by up to 50 per cent, thereby reducing the urban heat island by several degrees.

One of the most tangible effects of green roofs is their ability to retain stormwater. In urban areas, most runoff flows into stormsewers, picking up contaminants such as oil, grease and heavy metals on the way, and depositing them into lakes, rivers or groundwater aquifers. According to European studies, rooftop gardens retain 70 to 100 per cent of precipitation that falls on them in summer and about half that in winter—storing it until it is taken up by the plants and returned to the atmosphere through evapotranspira-tion. Studies also show that plants act as a natural filter for runoff—remov-ing up to 95 per cent of heavy metals such as cadmium, copper and lead.

Rooftop gardens also improve air quality, filtering out gaseous pollutants and particles. They protect building membranes from ultraviolet radiation and physical damage, and can be used to grow food, serve as habitat for wildlife, and even to foster well being.

Case studies show that the handful of major rooftop gardens in Canada—which run the gamut from a subsidized apartment in Toronto where tenants grow their own rooftop produce to a parking garage in Quebec City where a rooftop meadow has solved a rainwater leakage problem—are successful. However, the report suggests that demonstration projects, awareness campaigns and economic incentives are needed if green skylines are to become widespread in Canada.

With their data collection and review complete, Environment Canada scientists and partners from the National Research Council and the roofing industry are planning to embark on a five-year monitoring project to compare differences in water quality, energy usage and other environmental factors between two similar buildings in Ottawa—one with and one without a rooftop garden. By using climate data to simulate the effects of these technologies in other cities, they hope to raise awareness of the potential rooftop and vertical gardens hold in helping Canadians meet the climate change challenges of the new millennium. S&E

THE TWO-STROKE SOLUTION

The roar of a chainsaw engine can shatter the silence of a peaceful day at the cottage, but in Karachi and Lahore, Pakistan, thousands of these two-stroke engines operate at once—powering the main mode of transportation known as the auto-rickshaw.

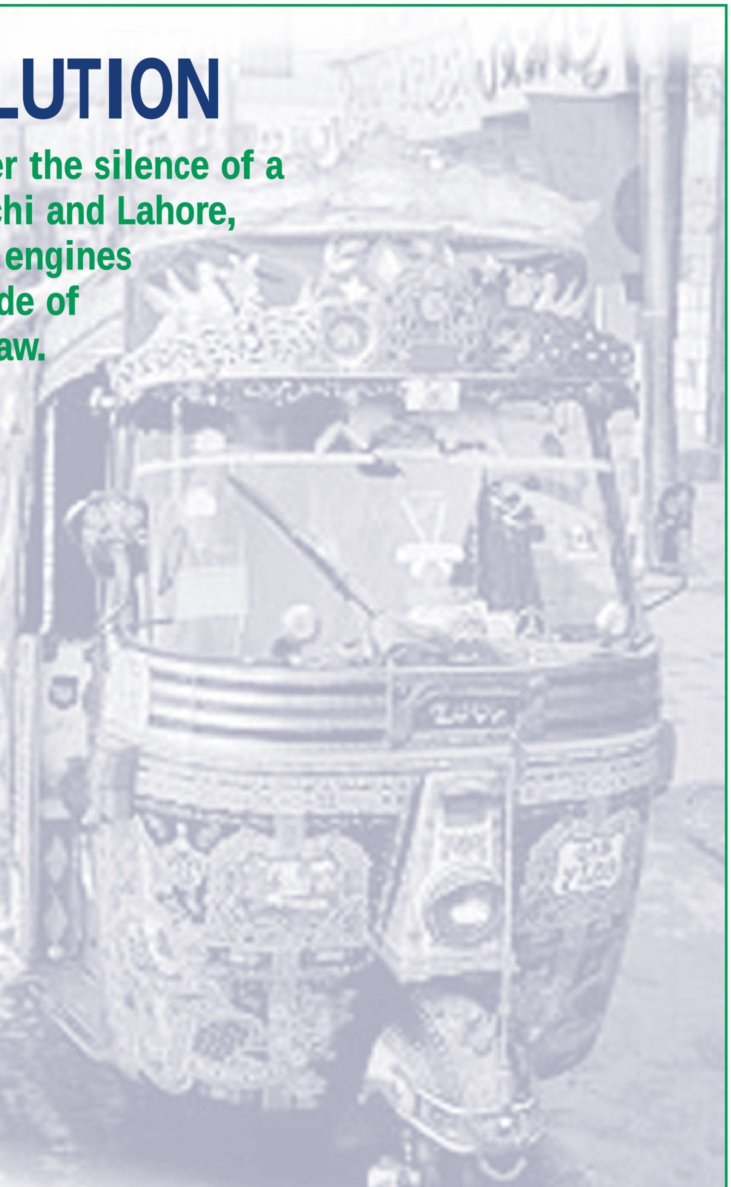
The most accessible and least expensive form of transportation in many major cities in Asia, the three-wheeled auto-rickshaw—combined with motorcycles and other vehicles that operate on two-stroke engines—has become a major environmental problem. Two-stroke engines operate in a similar manner to the four-stroke versions found in most automobiles; however, fuel is not burned as completely or as efficiently. The result is a noisy engine that emits high volumes of carbon dioxide and other pollutants.

Add the still-prevalent use of leaded fuel in Pakistan and the result is a pollution problem so great that one province in Pakistan has stopped issuing new permits for auto-rickshaws. Treating this now as an environmental priority, the Government of Pakistan has made a commitment to establish natural gas fueling centres in all major cities in the hopes of promoting the cleaner-burning fuel as an alternative to leaded gasoline.

For three years, researchers at Environment Canada's Environmental Technology Centre have been working with Yugo-Tech, a Mississauga-based company, to develop a technology that will allow two-stroke engines to run on cleaner-burning compressed natural gas instead of regular leaded gas. Already successfully tested at the Centre's labs, this technology will now be field tested in Lahore, Karachi and Quetta—a smoke-filled city in Pakistan once known for its clean air.

The demonstration project, which is funded under Canada's Climate Change Action Fund, will involve converting 35 auto-rickshaws, creating conversion and emission test centres in Quetta, and providing training and education for rickshaw drivers on the importance of using cleaner fuel. Raja Group in Pakistan, a manufacturer of the auto-rickshaw, will collaborate in converting the engines.

Over the two years it is scheduled to run, the demonstration project will result in a reduction of 76.5 tonnes of carbon dioxide, a greenhouse gas that contributes to climate change. Based on estimates that the typical rickshaw driver logs 200 kilometres a day, 360 days a year, converting all new and in-use vehicles in Pakistan to compressed natural gas would reduce annual carbon dioxide emissions by 21 per cent, or 370,000 tonnes. In addition, the conversion would greatly reduce emissions of lead, benzene and other pollutants that affect the health and environment of city dwellers.

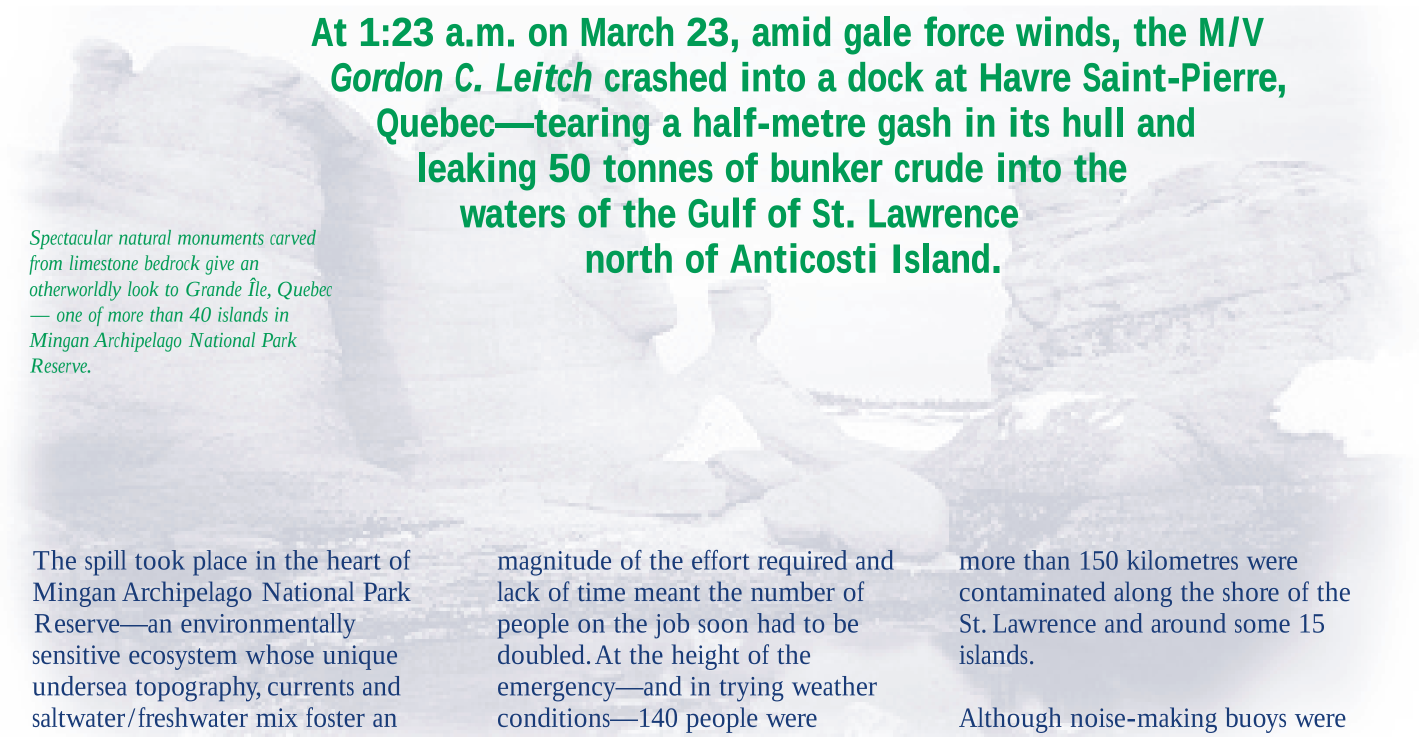


Kaleidoscopic paint jobs make it difficult to miss the huge fleet of auto-rickshaws that operate as taxi cabs in Pakistan's cities. Unfortunately, the tiny vehicles are a major source of both air and noise pollution.

This demonstration project is intended to prove the viability of this Canadian-made technology and simplify its transfer to other Asian countries—making it possible for people in these countries to breathe easier, and contributing to global efforts to minimize the human impact on climate change. S&E

WEATHER COMPLICATES SPILL RESPONSE

At 1:23 a.m. on March 23, amid gale force winds, the M/V *Gordon C. Leitch* crashed into a dock at Havre Saint-Pierre, Quebec—tearing a half-metre gash in its hull and leaking 50 tonnes of bunker crude into the waters of the Gulf of St. Lawrence north of Anticosti Island.



Spectacular natural monuments carved from limestone bedrock give an otherworldly look to Grande Île, Quebec — one of more than 40 islands in Mingan Archipelago National Park Reserve.

The spill took place in the heart of Mingan Archipelago National Park Reserve—an environmentally sensitive ecosystem whose unique undersea topography, currents and saltwater/freshwater mix foster an abundance of life and provide food for seabirds, whales, dolphins and seals. With some 40 islands and more than 2,000 islets and reefs, the threat of extensive shoreline contamination in the area was a serious one.

Despite the urgency of the situation, the arrival of emergency help was delayed by freezing rain, and efforts to contain the spill using oil booms were thwarted by waves up to two metres high. First reports sent to Environment Canada scientists by the Maurice-Lamontagne Institute in Mont-Joli indicated that the oil was moving west along the coast. Soon it had polluted about 10 kilometres of shoreline.

Helicopters arrived to track the spill from the air, while emergency response teams used snowmobiles to assess the amount of contaminated snow along the shore. With spring break-up mere days away, remediation would have to take place immediately, or environmental damage could be catastrophic. On March 24, 50 people began cleaning up the area, but the magnitude of the effort required and lack of time meant the number of people on the job soon had to be doubled. At the height of the emergency—and in trying weather conditions—140 people were working on-site.

Meanwhile, another 110 people were involved in managing the emergency. They included teams of Environment Canada experts who monitored and tracked the spill using specialized scientific and technical resources. The Department's own SCAT (Shoreline Clean-up and Assessment Technique) was used to determine the type and contamination of each site and propose appropriate methods of restoration. Map overlays were produced using its GENIE (Georeference Environmental Network for Information Exchange) software, which identified key environmental features, established priorities for clean-up, and created daily maps of progress.

Two days after the spill, the strong winds changed direction—causing blocks of ice to begin moving offshore and into the centre of the archipelago, toward Île Fantôme. Fisheries and Oceans Canada's ice movement models were vital in directing clean-up teams to priority areas in the days to come. Eventually, more than 150 kilometres were contaminated along the shore of the St. Lawrence and around some 15 islands.

Although noise-making buoys were used to discourage eider ducks, black guillemots, sea eagles and other birds from landing in polluted areas, the oil took a heavy toll. Biologists from Environment Canada's Canadian Wildlife Service set up a centre for cleaning oil-soaked birds, but only 66 of the 1077 picked up during clean-up were saved, and nine others were sent to the Biodôme in Montréal. The effects of the spill on nesting populations of these seabirds will be studied later this year as a follow-up. The spill also caused the temporary closure of some shellfish harvesting areas in the region.

Despite the difficulties of responding under adverse weather conditions and the complications created by the spring break-up, 80 per cent of the oil was cleaned up within a month of the spill occurring. The effectiveness of the Department's technical and scientific tools and close cooperation among all the teams involved prevented this environmental disaster from wreaking even greater havoc in this ecologically sensitive region of the country. S&E

MOVEMENT OF CONTAMINANTS IN ROCK

In 1985, polychlorinated biphenyl (PCB) oil was discovered in a shallow stormwater lagoon in the town of Smithville, Ontario. Investigations revealed that a waste transfer facility had failed, leaking PCBs and other organic contaminants into soil and bedrock, and contaminating groundwater.

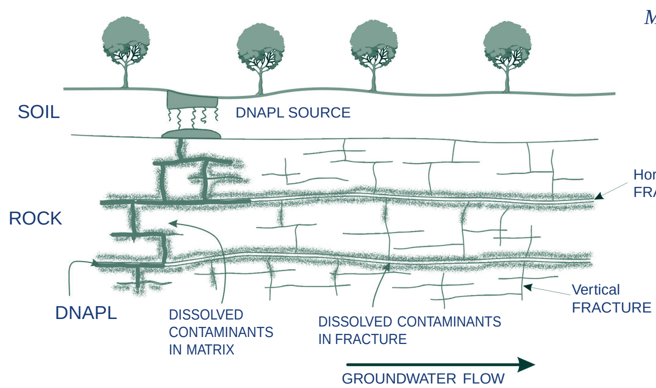
An Environment Canada scientist studies rock fractures in an Ontario quarry.

Fears that the town's drinking water would be contaminated prompted the closure of the municipal well, less than a kilometre away, and the installation of a pipeline to provide the community with potable water. Although the contaminated soil was excavated and destroyed and the contaminated groundwater pumped from the top of the bedrock and treated, removing contaminants from fractures in the bedrock posed a more serious problem.

Relatively little is known about how PCBs and other dense, non-aqueous phase liquids move through fractured rock, and even less is known about how to remove them. What we do know is that they get trapped in fractures in the rock and when groundwater flows over them, it dissolves some of the material—making it possible for contaminants to be released into the groundwater over a long period of time.

To learn more about the movement of groundwater contamination in rock, scientists from Environment Canada's National Water Research Institute, with support from the Province of Ontario and the U.S. Environmental Protection Agency, are conducting extensive research into the chemical and physical properties of the fractures and the solid rock at the Smithville site. By characterizing the variability of the rock, they are discovering more about the processes that control the migration of contaminants in groundwater. This information is crucial to the design and implementation of complex remediation strategies.

Their results show that the properties of rock are highly variable and influence the movement of contaminants. Some types act as a sponge, storing and releasing contaminants at various times. Large fractures provide pathways for contaminant transport, primarily in the horizontal direction, and evidence suggests that biological conditions in the subsurface may naturally degrade some of the contaminants. The research has produced detailed, descriptive data of the site that will be used in computer models to assess the effectiveness of various remediation methods.



Movement of groundwater contamination in porous fractured rock.

DNAPL = dense, non-aqueous phase liquids

Because the Smithville site is similar to many contaminated sites on the American side of the Niagara River, this research will help scientists and environmental managers in Canada and the United States understand the potential for contaminants to migrate into this international river and eventually into Lake Ontario, and assist in preventing it.

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GREAT LAKES LEVELS TAKE A PLUNGE

Low precipitation levels and increased evaporation due to warmer temperatures have contributed to the single largest annual drop in the water levels of lakes Erie and Ontario since 1931. Although scientists say it is still too soon to determine whether or not climate change is responsible for the plunge, the decline has generated both concern and opportunity for shoreline residents.

Lower waters mean larger beaches—a major draw for tourists and shoreline property owners—reduce flood damage, and provide municipalities with a chance to clean up local waterways. The surrounding wetlands also flourish during low periods when their seed banks surface and begin to germinate. At the same time, low levels mean costly dredging efforts for commercial navigation and marina channels, force freighters to carry lighter loads, and reduce spawning areas for many species of fish.

Using monitoring data collected in cooperation with Fisheries and Oceans Canada from more than 30 gauges across the Great Lakes, and historic and hydrological information collected by other Canadian and American agencies over the past 80 years, scientists at Environment Canada are studying changing lake levels to improve their ability to forecast future events and better understand the impact of climate and land-based activities on water levels. Their studies show that although levels in lakes Erie and Ontario plummeted more than half a metre between May 1998 and May 1999, similar trends have occurred in the past, and Great Lakes water levels are still some 60 centimetres above the lowest levels recorded this century.

Conveying this information and improving the public's understanding of lake levels are two of the goals of Environment Canada's research in this field. Over the years, the number of people using the Great Lakes for recreational purposes has increased dramatically—and so, too, has the potential for impacts from fluctuating levels, such as floods, moving sandbars and erosion.

The Department's Great Lakes Water Level Information Office in Burlington, Ontario, helps various sectors of the economy deal with these impacts by providing regular information on lake levels to clients ranging from commercial fisheries to the media. For municipalities, this information is critical for budgeting such works projects as dredging harbours, extending intake pipes for water supplies, and covering exposed outflows. It is also critical to boaters in avoiding sandbars and rocks.

These data are also used for resource management to determine how much water can be released through dams at different times of the year. Most recently, the Department's studies have been used in developing a new model for determining the impact of future land-based development along the Detroit and St. Clair rivers. The *St. Clair and Detroit Rivers Encroachment Analysis* will look at how infill from development and aquatic habitat projects changes the rivers' levels and flows, and aims to prevent the cumulative impacts of these projects from leading to increased ice jams, flooding and erosion. S&E

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SCIENCE AND THE ENVIRONMENT BULLETIN

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Media representatives and others interested in conducting further research may obtain the names and phone numbers of departmental scientists involved in these and related initiatives by contacting the *Bulletin's* editor, Paul Hempel. He can be reached by e-mail at Paul.Hempel@ec.gc.ca and by telephone at (819) 994-7796. Readers are welcome to e-mail their comments and suggestions to this same address.

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