## IMPLICATIONS OF ENVIRONMENTAL SETTINGS FOR WATER QUALITY AND AQUATIC BIOTA

Surface waters and ground waters in the study area exhibit significant variations in quality; surface waters also contain a diversity of aquatic biota. In areas where human presence is minimal, the quality of waters and aquatic communities may approach natural or "pristine" conditions. Conversely, waters in areas that have been significantly altered by man could be highly degraded chemically and biologically. This section summarizes publications that provide an overview of water quality and aquatic biota in the study area and for particular environmental settings.

### Surface Water

Bedrock geology controls the natural quality of surface waters in the study area. The presence of weather-resistent igneous and metamorphic rock units and thin soils results in surface waters that naturally contain low concentrations of dissolved and suspended solids. Rainwater (1962) notes that surface waters in New England contain less than 100 mg/L of dissolved solids and 275 mg/L of dissolved solids and suspended solids, respectively; these amounts are small compared to waters nationally. Calcium and magnesium ions are the prevalent cations in New England waters (Rainwater, 1962). Carbonate-bicarbonate anions are the principal anions in waters found in the high altitudes and sulfate and chloride anions are the principal anions in waters near the Atlantic Coast.

Alkalinity generally is low in the highest elevations and high in valleys having agricultural and urban lands (fig. 22). Most streams have alkalinity values less than 200 μeq/L (Griffith and Omernik, 1988). In comparison to other areas of the Eastern United States, Hendrey and others (1980) found that the New England Coastal Basins are underlain by large amounts of bedrock with low to no buffering capacity. As a result, the surface waters of the study area are highly susceptible to acidification by acidic precipitation.

Establishing the natural quality of the major rivers is difficult because the hydrology of the watersheds of all the major rivers in the study area have been significantly modified by man for nearly 3 centuries. Information from studies of small headwater streams in relatively undisturbed watersheds can be used to provide a general assessment of natural water quality in the study area. The chemistry of surface waters in the Hubbard Brook Experimental Forest (HBEF), White Mountain National Forest, New Hampshire, has been studied extensively since the early 1960s and the conclusions are summarized by Likens and Bormann (1995). Streams in the HBEF drain 30-106 acres and represent high-gradient streams draining northern hardwood forests in the Northeastern Highlands ecoregion. HBEF streams are acidic (pH of 4-5) because of the dominating presence of sulfuric and nitric acids from precipitation. Geochemical-weathering reactions neutralize the acids and bicarbonate alkalinity increases as water travels through the watersheds. Likens and Bormann (1995) found that even though there are steep slopes and high precipitation rates, erosion and transport of suspended (particulate) matter from forested watersheds is relatively low.

The Wild River at Gilead, Maine (drainage area of 70 $mi^2$) is monitored as part of the USGS Hydrologic Bench-Mark Network; stations in this network provide data for watersheds affected principally by natural conditions. During water years 1987-89, the median value for specific conductance was approximately 10 *u*S/cm, dissolved oxygen was 12 milligrams per liter (mg/L), fecal coliform and fecal streptococcus bacteria was 1 colony per 100 mL, alkalinity was 3 mg/L, dissolved solids was 17 mg/L, suspended solids were 2 mg/L, and dissolved nitrate plus nitrite was less than 1 mg/L (Olson and Cowing, 1993). The Wild River is mildly acidic with pH ranging between 6.0 and 6.5. On the basis of USGS water-quality monitoring in Rhode Island. Concentrations of dissolved inorganic constituents in streams in undeveloped areas are low (generally less than 100 mg/L) according to Bell (1993). Stream waters are also typically soft (hardness of less than 60 mg/L as calcium carbonate) and slightly acidic. Bedrock, glacial deposits, and soils in Maine that are composed largely of relatively insoluble silicate minerals determine these stream-quality conditions.

The influence of human activities on stream-water quality varies from the headwaters or upstream sections of the major river basins to the outlets of the rivers near their discharge to coastal waters. Human population is generally greatest near the coast and, as a result, water-quality and habitat degradation is more pronounced. In addition, human activities during the

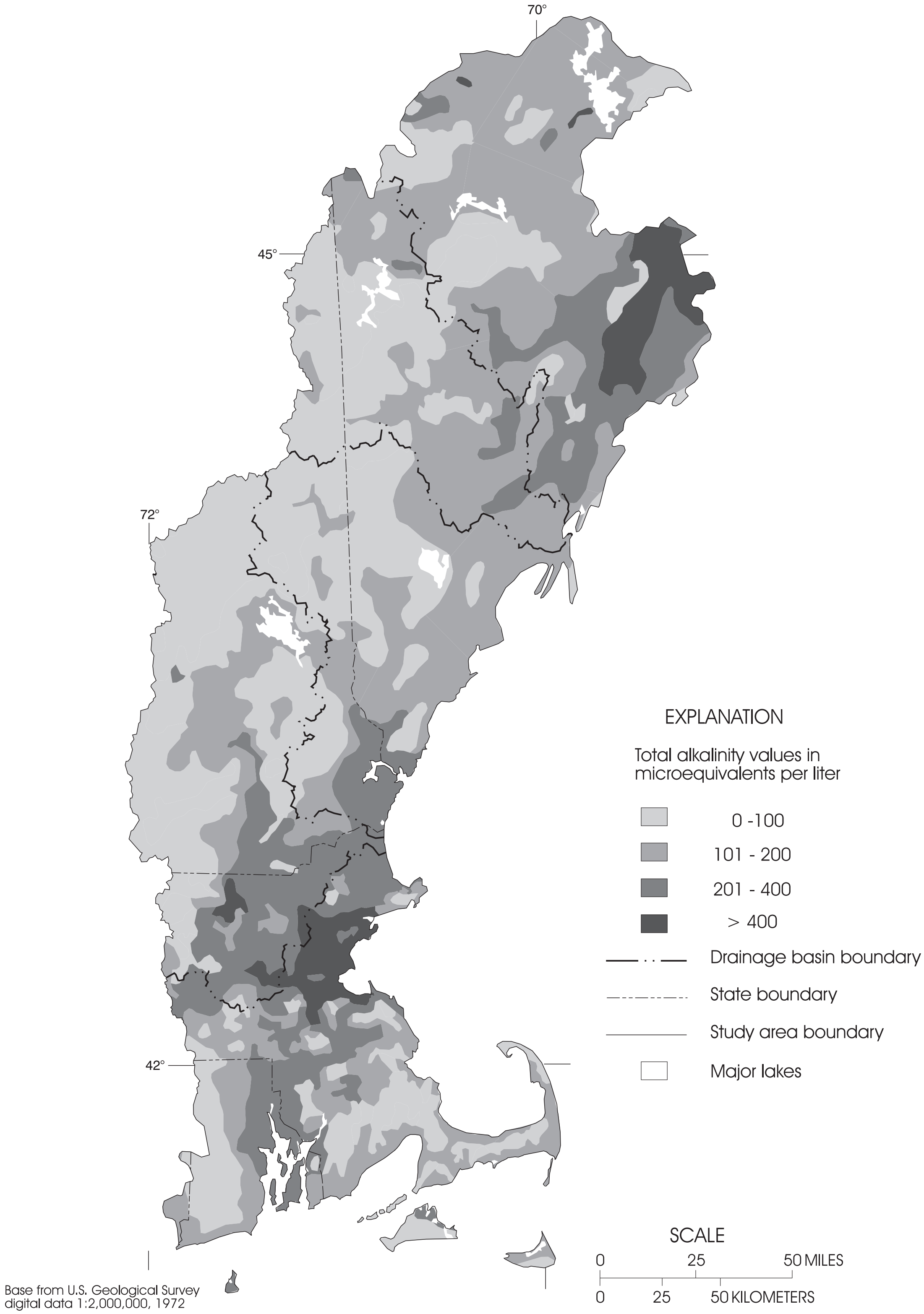


**Figure 22.** Total alkalinity of streams and rivers in the New England Coastal Basins study area (modified from Griffith and Omernik, 1988).

past 200 years have had significant historical effects on the waters in the study area. The discharge of raw sewage from population centers and wastes from tanneries, textile, and pulp and paper mills was pervasive earlier this century. The Androscoggin River in Maine (fig. 7) was classified as one of the Nation's 10 most polluted rivers in the 1960s and 1970s (Olson and Cowing, 1993) and typhoid and cholera outbreaks were common in cities that withdrew drinking water from rivers in the study area (Mills, 1987; and Anthony, 1969). River water quality has improved throughout New England since the passage of the Federal Water Pollution Control Act in 1972 (U.S. Environmental Protection Agency, 1995).

The quality of streams in the study area in relation to specific state water-quality criteria, and the factors that cause water-quality degradation, have been described by each state in State Water-Quality Inventory Reports (Maine Department of Environmental Protection, 1994; Rhode Island Department of Environmental Management, 1994; Massachusetts Department of Environmental Protection, 1995; New Hampshire Department of Environmental Services, 1996). According to information in these reports and summarized by the USEPA (data from http://www.epa.gov/surf/IWI/data, December 1997), approximately 82 percent of the rivers and streams assessed in the study area meet state water-quality criteria designated for each water body and 18 percent are partially or fully impaired. Typically, waters are impaired if they are of unsuitable quality for swimming, maintaining healthy aquatic biota, and (or) have a fish consumption advisory posted. Rivers and streams classified as partially or fully impaired are found throughout the study area but, overall, more waters are impaired in Massachusetts and Rhode Island than in Maine and New Hampshire. Pathogens, volatile organic compounds, organic enrichment, nutrients, and metals rank as the most common causes of impairment. Sources for these causes include industrial and municipal point sources, urban runoff, streamflow regulation, impoundments, unknown sources, natural sources, and contaminated sediments (Maine Department of Environmental Protection, 1994; Rhode Island Department of Environmental Management, 1994; Massachusetts Department of Environmental Protection, 1995; New Hampshire Department of Environmental Services, 1996).

A summary of surface-water-quality conditions and trends at selected locations and for selected properties and constituents in each of the four states can be found in Bell (1993), Olson and Cowing (1993), Strause (1993), and Toppin (1993). Greater concentrations of dissolved chloride, dissolved sulfate, dissolved solids, dissolved nitrate and nitrite, and total phosphorus were generally found in the Blackstone, Charles, Pawcatuck, and Merrimack Rivers (fig. 7) during water years 1987-89 than in the Kennebec, Androscoggin, Saco, and Presumpscot Rivers. The Blackstone, Charles, Pawcatuck, and Merrimack River Basins all have a greater population density, more urban lands, and greater numbers of wastewater discharges than the Kennebec, Androscoggin, Saco, and Presumpscot River Basins (see figs. 16, 17, 19). Upward trends of dissolved oxygen were found in the Blackstone, Kennebec, and Presumpscot Rivers; increases in dissolved oxygen concentrations are usually associated with improvements in wastewater treatment (Olson and Cowing, 1993; Strause, 1993). Increases in specific conductance were common throughout the Merrimack River Basin and are likely the result of increased usage of road deicing salt and waste discharges in this developing basin (Toppin, 1993). The impact of deicing salts on the water quality of streams can be significant; Mattson and Godfrey (1994) determined that the 223 million kilograms (kg) of road salt applied by the State of Massachusetts annually accounts for 63 percent of the variation in sodium concentrations found in Massachusetts streams.

Preliminary analysis of total phosphorus data collected by the USGS at National Stream-Quality Network sites in the study area from the 1970s to the early 1990s indicates that the greatest total loadings of phosphorus (calculated as mean daily loads) at these sites are in the Merrimack, Kennebec, and Androscoggin River Basins (fig. 23) (Marc Zimmerman, U.S. Geological Survey, written commun., 1997). The greatest yields of phosphorus, calculated in $lb/d/mi^2$, were from the Blackstone, Merrimack, and Charles River Basins. Yields of phosphorus in the Blackstone River (approximately 2.2 $lb/d/mi^2$) were about 2.5 times that found in the Merrimack River (approximately 0.9 $lb/d/mi^2$).

Contaminated sediments are an important water-quality concern in Massachusetts and Rhode Island (Rhode Island Department of Environmental Management, 1994; Massachusetts Department of Environmental Protection, 1995a). The Massachusetts Department of Environmental Protection (1995a)

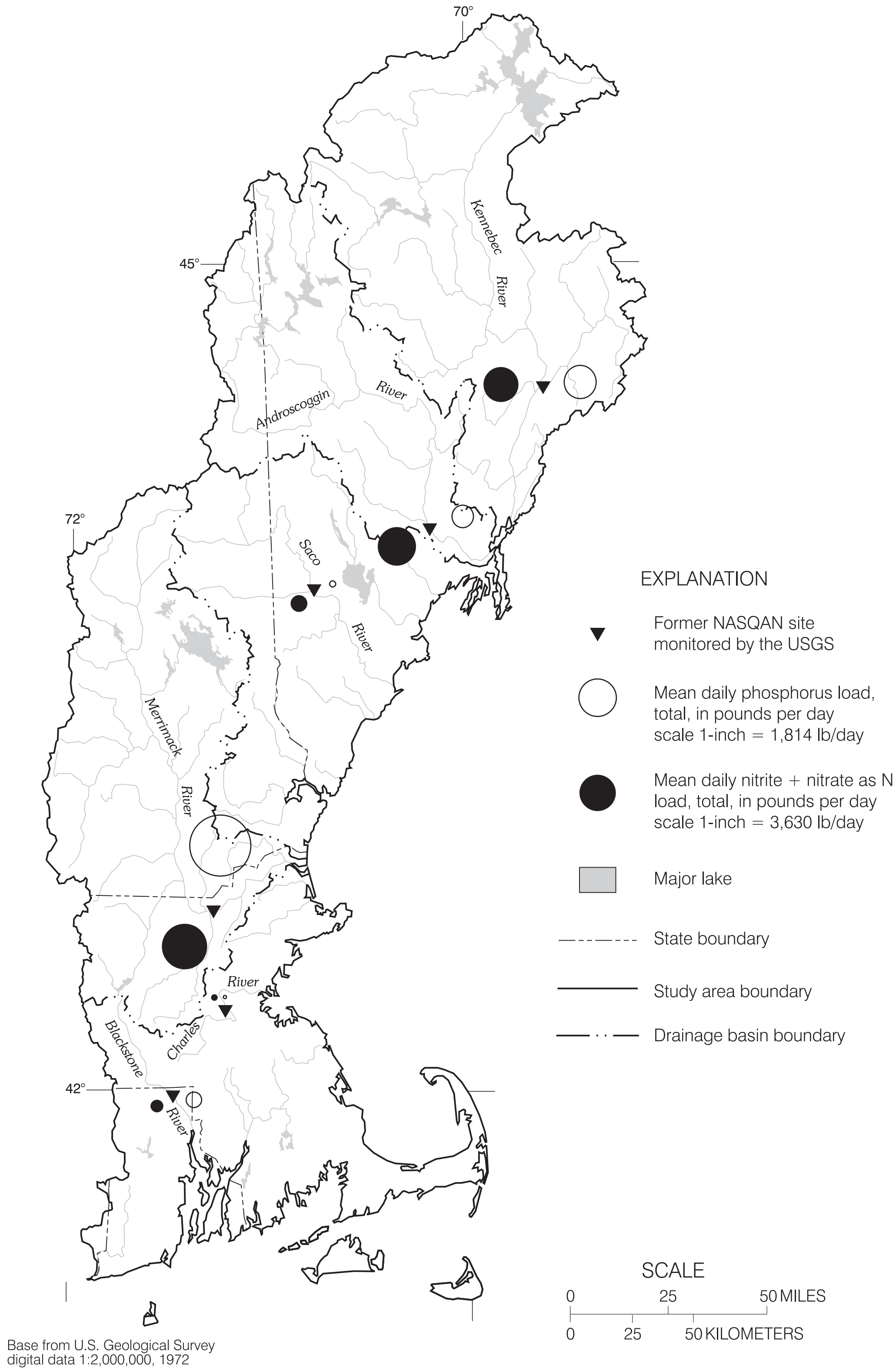


**Figure 23.** Mean daily total phosphorus and total nitrite plus nitrate, as N, loading at selected National Stream-Quality Accounting Network (NASQAN) sites in the New England Coastal Basins study area.

identified a number of streams in the study area that have contaminated sediments; these streams and the contaminants include Blackstone River (metals and synthetic organic compounds), Charles River (metals and oil and grease), Mill River (polychlorinated biphenyls), Sudbury River (mercury), and Ten Mile River (lead). These rivers have a history of industrial and municipal discharges that date to the industrial revolution and numerous impoundments that serve to trap pollutants. Spliethoff and Hemond (1996) assessed sediments for metals in Upper Mystic Lake in the Aberjona River Watershed near Boston. The Aberjona River Watershed historically contained a number of industries including tanneries and chemical manufacturing. They found profiles of arsenic, cadmium, chromium, copper, lead, and zinc in the lake sediments that correspond to periods of intense industrial activities in the Watershed, declines in industrial operations, sewering of the watershed, and remobilization events.

The upstream sections of the Kennebec, Androscoggin, Saco, and Merrimack Rivers, as well as many headwater streams, are largely forested lands, have small population centers, and have mountainous to hilly terrain. Although surface waters in these areas are among the cleanest in the study area, they still suffer from a variety of anthropogenic factors. These include deposition of atmospheric contaminants, silvicultural activities, recreational and tourism-related industries (such as snow-making at ski resorts, summer homes, and associated services), and the hydrologic modification of streams and rivers.

Research performed at the HBEF since the 1960s has described the effects of both atmospheric deposition and silvicultural activities on the hydrology of small headwater basins in environmental settings that are common in the northern part of the study area (Likens and Bormann, 1995; Likens, 1985). The changing chemistry of streams in the HBEF closely mimics the change in precipitation chemistry from the combustion of fossil fuel and industrial processes (Likens and Bormann, 1995). During 1963-93, hydrogen ion and sulfate concentration in HBEF streams decreased as sulfate emissions have decreased. Even with these decreases, sulfate deposition is more than three times the amount that the watershed can neutralize (Likens and Bormann, 1995). Because of the inadequate buffering ability of HBEF streams to neutralize acids, the acidity of streams has increased. Other effects of atmospheric deposition include depletion of calcium from the watersheds, which has been linked to declines in northern forest growth (Likens and Bormann, 1995; Gregory Lawrence, U.S. Geological Survey, written commun., 1997), and nitrogen enrichment of surface waters that can lead to eutrophication of coastal waters (Jaworski and others, 1997). Jaworski and others (1997) estimated that about 64 percent of the total nitrogen exported to coastal waters from 10 basins in the Northeastern United States was due to nitrogen-oxide emissions from fossil fuel combustion. Nitrate fluxes from these basins increased 300-800 percent since the early 1900s and correlate to increases in nitrogen-oxide emissions.

Silvicultural activities include the logging of timber, road building in forests, forest regeneration, and management of forest emergent growth and pests with pesticides. Studies in HBEF found that logging and deforestation in small watersheds (approximately 100 acres or less) can increase streamflow by 30 percent and the export of nutrients 10-40 times (Likens, 1985). Effects of commercial clear cuts in large watersheds of northern New Hampshire found similar, but less extreme responses (Likens, 1985). Smith and McCormack (1988) assessed watershed losses of the herbicide triclopyr from a regenerating forest in northern Maine. They reported that total triclopyr losses from the watershed totalled 0.02 percent of the total herbicide applied. Concentrations of the herbicide in streams leaving the treated area peaked immediately after application and 6 days later as a result of a runoff event. Whereas this study indicates that there is movement of silvicultural pesticides, studies that have tested for concentrations of silvicultural pesticides in surface or ground waters throughout the northern region of the study area are unknown.

Near the major timber harvesting lands are a number of pulp and paper mills. The quality of waters near these industrial operations has been affected in the Kennebec, Androscoggin, Presumpscot, and previously, the Merrimack River Basins (Maine Department of Environmental Protection, 1994; New Hampshire Department of Environmental Services, 1996). Pollutant loadings to surface waters have been significantly reduced by the pulp and paper mills in the last 20 years. Dioxin contamination from pulp and paper mills in the Kennebec and Androscoggin Rivers continues to prevent attainment of state designated stream uses (Maine Department of Environmental Protection, 1994; New Hampshire Department of Environmental Services, 1996).

## Ground Water

Natural ground-water quality is affected predominately by the types of rocks and sediments through which the water travels. Chemically, ground water is affected by four important natural processes (1) mineral dissolution and mineral precipitation, (2) oxidation-reduction reactions that can be either chemically or biologically induced, (3) ion-exchange reactions, and (4) mixing of ground waters of different chemical compositions (Johnson, 1988).

Assessments of the ground-water quality of stratified-drift aquifers for the States of Maine, Massachusetts, New Hampshire, and Rhode Island summarized existing data on dissolved solids, dissolved ions, hardness (as calcium carbonate), nutrients, and trace elements (Frimpter, 1988; Maloney, 1988; Morrissey, 1988; Trombley, 1992; and Johnston and Barlow, 1988; Medalie and Moore, 1995). These reports describe ground water from stratified-drift aquifers as containing small concentrations of dissolved solids, (generally less than 100 mg/L), with a hardness of less than 35 mg/L as calcium carbonate (and, are therefore, considered soft water), and being slightly acidic (pH often being between 5.5 and 6.5). The sand and gravel in stratified-drift aquifers are predominantly quartz and feldspar that originate from crystalline bedrock and are not easily soluble. Another reason for the small amounts of dissolved solids in stratified-drift water is the young age of the water. Because stratified-draft aquifers are generally thin (less than 100 ft) and are composed of sand and gravel, the water in the aquifers is usually recently recharged through precipitation. This results in water that generally is dilute, low in dissolved materials, and contains measurable amounts of dissolved oxygen. Ground water in stratified drift is extremely vulnerable to contamination from activities at the land surface.

Water from stratified-drift aquifers may have concentrations of iron and manganese that require treatment before distribution in public or domestic supplies (Simcox, 1992). These elements, which are the products of weathering of minerals and dissolution of oxide coatings on aquifer sediments, are easily dissolved in acidic water in the absence of oxygen. Water in stratified-drift aquifers commonly contains dissolved oxygen near saturation levels; however, oxygen can become depleted when ground water passes through organic deposits, such as peat or river-bed sediments. As a result, water from a well screened below an organic layer becomes progressively enriched in iron and manganese as pumping draws ground water through the organic layer (Simcox, 1992). A summary of ambient water-quality conditions from stratified-drift aquifers in New Hampshire showed that 51 out of 257 samples had higher dissolved iron concentrations than the USEPA secondary maximum contaminant level (SMCL) of 0.3 mg/L and 136 samples had manganese concentrations exceeding the SMCL of 0.05 mg/L (Medalie and Moore, 1995).

The quality of water from bedrock varies because the chemical composition of the bedrock varies. Water from crystalline-bedrock aquifers has greater concentrations of dissolved solids and higher specific conductance values than water from stratified-drift aquifers (Frimpter, 1988; Maloney, 1988; Morrissey, 1988; and Johnston and Barlow, 1988). Simcox (1992) reports that crystalline-bedrock aquifers in Massachusetts have median dissolved-solids concentrations of 120 mg/L, are moderately hard (median of 90 mg/L as calcium carbonate), and are slightly alkaline (median pH of 7.8). Like water from stratified-drift aquifers, crystalline-bedrock aquifers have waters that frequently contain concentrations of iron and manganese above State and Federal drinking-water standards. Sources of iron include schist and gneiss that contain an abundance of ferromagnesium minerals or appreciable amounts of pyrite and pyrrhotite (Frimpter, 1988).

Water from crystalline bedrock wells tend to contain measurable amounts of arsenic (Frimpter, 1988; Marvinney and others, 1994; and Morrissey, 1988). Approximately 10 to 15 percent of arsenic analyses from ground waters throughout Maine and New Hampshire exceeded the USEPA 50 μg/L maximum contaminant level (Morrissey, 1988; Marvinney and others, 1994). Concentrations of arsenic in Maine were statistically higher in water from bedrock wells than in water from dug wells and springs (Marvinney and others, 1994). The source of arsenic in wells is unknown. In New Hampshire, Boudette and others (1985) did not find any specific cause for the arsenic; in Maine, Marvinney and others (1994) found that the arsenic in wells could not be associated with a particular rock type.

Radon in ground water is most prevalent in the Northeastern United States and especially in New England (Zapecza and Szabo, 1988). Radon-222, a radioactive-decay product of uranium, has been found in elevated concentrations in water from crystalline-rock wells throughout the study area (Hess and others, 1979). The highest levels of radon in ground water in Maine and New Hampshire are found in water pumped from igneous plutons and granites containing the micas muscovite and biotite (Maloney, 1988, Morrissey, 1988) and in high-grade metamorphic rocks (Hall and others, 1985). The New Hampshire Department of Environmental Services estimates that up to 5 percent of the bedrock wells in the State have significant concentrations of radionuclides such as uranium, radium-222, and radium-228 (Morrissey, 1988).

The most frequently detected contaminants in ground water are volatile organic compounds (VOCs) and other petroleum-related substances (Maine Department of Environmental Protection, 1994, New Hampshire Department of Environmental Services, 1996, and Massachusetts Department of Environmental Protection, 1995a, Rhode Island Department of Environmental Management, 1994). The sources of these contaminants are primarily petroleum storage tanks (above and below ground), accidental spills of petroleum products, and the land disposal of wastes. Contamination of public-supply wells in Massachusetts is caused mostly by elevated VOCs found in the solvents of industrial wastes; many of these contaminated wells are in or near industrial parks. The most commonly detected organic compounds in ground water in Massachusetts are trichloroethylene, methyl chloride, and tetrachloroethylene. Simcox (1992) reports that from 1978 to 1990, 74 public-supply wells and wellfields in Massachusetts have been closed because of contamination and more than 600 domestic wells have been contaminated by VOC's. The Rhode Island Department of Environmental Management (1994) found that approximately 15-30 domestic wells are reported to be newly contaminated by VOC's each year.

Other sources of contamination in the study area is the introduction of chloride and sodium to wells from road-salting and elevated concentrations of nitrates from agricultural activities and on-site septic systems. Concentrations of chloride in many New Hampshire public-supply wells in urban areas have increased significantly since the 1940's when the use of salt to de-ice roads greatly increased (Hall, 1975). Contamination from road-salt storage piles and facilities and spreading of salts on roadways was the cause of 79 percent of the contaminated wells in New Hampshire (Morrissey, 1988). Sodium chloride from seawater intrusion, coastal flooding, and highwater deicing salt is the most common cause for elevated concentrations of dissolved solids in ground water on Cape Cod (Frimpter and Gay, 1979).

The Maine Department of Environmental Protection (1994) estimates that 2 percent of the private wells in Maine have concentrations of nitrate exceeding the 10 mg/L primary-drinking water regulation. The highest concentrations of nitrate were in shallow wells in agricultural areas or near septic systems. Simcox (1992) reports that leachate from landfills has resulted in the closing of at least six public-supply wells and numerable domestic wells in Massachusetts. Landfill leachate commonly contains high concentrations of iron, dissolved solids, nitrogen (as ammonia or nitrate) and waste organic compounds.

## Aquatic Biota

Trace elements and synthetic organic compounds, such as organochlorine pesticides and industrial organochlorines, are present in the tissue of fish in some rivers and lakes. As a result, fish consumption advisories have been issued by the States of Maine, New Hampshire, Massachusetts and Rhode Island. Concentrations of mercury greater than or equal to 1 μg/g have been found in predatory fish in many lakes throughout Maine (Stafford, 1994). The primary source of the mercury found in fish tissue is thought to be the incineration and burning of fossil fuels (Terry Haines, U.S. Geological Survey, oral commun., 1994). Furthermore, mercury appears to be the predominant trace metal contaminant in the study area and consequently Maine and New Hampshire have issued comprehensive fish consumption advisories because of its presence in fish tissue (Terry Haines, oral commun., 1994; Dreisig and Dupee, 1994). A fish consumption advisory exists for several rivers and lakes in Massachusetts because of mercury contamination, including the Concord, Merrimack, and Sudbury Rivers, and Walden Pond (Massachusetts Department of Public Health, 1996). In addition to atmospheric deposition, mercury from industrial waste processing has contributed to contamination in Massachusetts and Rhode Island (Russell Isaacs, Massachusetts Department of Environmental Protection, oral commun., 1994). Massachusetts also has a fish consumption advisory for several rivers and lakes because of polychlorinated biphenyl (PCB) contamination, including the Blackstone, Charles, and Muddy Rivers (Massachusetts Department of Public Health, 1996). Rhode Island currently has a fish consumption advisory only for the Woonasquatucket River because of PCB, mercury, and dioxin contamination, but the Rhode Island Department of Health is in the process of assessing the need for a comprehensive statewide advisory because of mercury (Robert Vanderslice, Rhode Island Department of Health, oral commun., 1997).

During 1976-84, the U.S. Fish and Wildlife Service monitored fish tissues in the Kennebec, Androscoggin, and Merrimack Rivers as part of the National Contaminant Biomonitoring Program (NCBP) (Schmitt and Brumbaugh, 1990; and Schmitt and others, 1990). This program analyzed fish tissue for a variety of trace elements and organochlorine compounds from 117 sites nationwide. Results from the program showed that mercury concentrations in fish collected from three sites in the study area tended to be higher than the geometric mean of mercury concentrations determined from the national data set for each year samples were collected. Furthermore, concentrations of PCBs in fish tissue from the Merrimack River were among the highest detected nationally. Among the five NCBP sites in New England (which includes two sites on the Connecticut and Penobscot Rivers), the mean concentrations of lead, cadmium, chlordane, DDT, and PCBs were the highest in fish tissue from the Merrimack River (Major and Carr, 1991).

During the mid-1980s, the U.S Environmental Protection Agency administered the National Study of Chemical Residues in Fish (NSCRF), which involved one-time sampling of fish for trace elements and organochlorine compounds at 388 sites nationwide (U.S. Environmental Protection Agency, 1992). In the study area, five sites were selected on the Androscoggin River, two sites on the Sebasticook River (East and West branches), two sites on the Saco River, and one site on the Merrimack River (fish tissue analyzed for mercury only). Mercury concentrations in fish tissue collected from these rivers were substantially higher than the national median concentrations of mercury. PCB concentrations also were elevated in fish tissue from the Androscoggin River but PCBs were not detected in fish from the Saco River. Concentrations of total chlordane and DDE (primary metabolite of DDT) were generally lower at the sites than the national medians. Overall, among the four rivers containing NSCRF sites, the least contaminated fish tissue were from the Saco River.

Since 1984, the National Oceanic and Atmospheric Administration (NOAA) has coordinated the National Status and Trend Program (NSTP) to monitor spatial distributions and temporal trends of contaminant concentrations in coastal and estuarine regions of the Nation (O'Conner and Beliaeff, 1995). In 1986, the Mussel Watch Project was formed as a component of the NSTP to sample mollusks at about 300 sites nationwide. Although this project has not investigated freshwater systems, the proximity of many sampling sites to the mouths of rivers has provided some indication of the contaminants coming from those rivers. In Massachusetts and Rhode Island, four sampling sites are in Boston Harbor, six in Buzzards Bay (with one site at the mouth of New Bedford Harbor, Mass.), and three in Narragansett Bay. Sites in Boston Harbor and Buzzards Bay were among the most highly contaminated (with PCB's) nationwide. Fish-tissue samples from Boston Harbor had some of the highest concentrations of lead, mercury, and polycyclic aromatic hydrocarbons (PAHs). Overall, however, results of the NSTP have indicated that contaminant concentrations are decreasing in the mollusk tissue in Boston Harbor, Buzzards Bay, and New Bedford Harbor.

The effects of contamination on aquatic biota are reflected in the environment settings of the four States in the study area. Various riverine species of concern, most commonly associated with loss or degradation of habitat, include mollusks, fish, and insects and are inventoried by the State Natural Heritage Program offices. The dwarf wedge mussel (*Alasmidonta heterodon*) is the only biota in the study area on the Federal endangered aquatic species list (U.S. Fish and Wildlife Service, 1990). This mollusk had a historic distribution along coastal basins from New Hampshire to North Carolina, and is found in New Hampshire and Massachusetts. Smith (1995) reported that the mollusk does not live in standing water and is almost extinct in Massachusetts. Martin (1997) described a list of factors responsible for endangering freshwater mussels in Maine that also apply to the entire study area. Primary among these factors are dams, which destroy riffle habitat, create silted and anoxic streambed conditions, alter water temperatures, and interfere with the migration of host fish species. Water withdrawals from rivers, resulting in reduced streamflows, also can affect mussels by exposing or stranding them.