1 Overview of the Nonpoint Source Problem

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1.1 Definition of a Nonpoint Source

Nonpoint sources of water pollution are both diffuse in nature and difficult to define. Nonpoint source (NPS) pollution can generally be defined as the pollution of waters caused by rainfall or snowmelt moving over and through the ground. As water moves over or through soil, it picks up and carries away natural contaminants and pollutants associated with human activity, finally depositing the contaminants into lakes, rivers, wetlands, coastal waters, and ground waters. Habitat alteration, such as the removal of riparian vegetation, and hydrologic modification, such as damming a river or installing bridge supports across the mouth of a bay, can cause adverse effects on the biological and physical integrity of surface waters and are also treated as nonpoint sources of pollution. Atmospheric deposition, the wet and dry deposition of airborne pollutants onto the land and into waterbodies, is also considered to be nonpoint source pollution. At the federal level, the term *nonpoint source* is defined to mean any source of water pollution that does not meet the legal definition of *point source* in Section 502(14) of the Clean Water Act (CWA):

> The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

The distinction between nonpoint sources and diffuse point sources is sometimes unclear. Although diffuse runoff is usually treated as nonpoint source pollution, runoff that enters and is discharged from conveyances, as described above, is treated as a point source discharge and is subject to the federal permit requirements under Section 402 of the Clean Water Act.

Stormwater can be classified as a point or nonpoint source of pollution. Stormwater is classified as a point source when it is regulated through the National Pollution Discharge Elimination System (NPDES) Stormwater Program. An NPDES stormwater permit is required for medium and large municipal separate storm sewer systems (MS4s) of incorporated areas and counties with populations of more than 100,000, certain industrial activities, and construction activities disturbing five ac or more. An NPDES permit is also required for small MS4s in "urbanized areas" and small construction activities disturbing between one and five acres (ac) of land. The NPDES permitting authority may also require operators of small MS4s not in urbanized areas and small construction activities disturbing less than one ac to obtain an NPDES permit based on the potential for contribution to a violation of a water quality standard. Detailed information on the NPDES Storm Water Program is available at http://www.epa.gov/npdes/npdes-stormwater-program. If stormwater originates from a location that does not fall within the NPDES permit requirements, it is considered to be nonpoint source pollution (USEPA 2005). Concentrated animal feeding operations (CAFOs) are also classified as point sources and regulated under the NPDES program (USEPA 2012b). Despite differing regulatory requirements, monitoring issues and concepts encountered for permitted stormwater and CAFOs are similar to those of nonpoint sources.

1.2 Extent of Nonpoint Source Problems in the United States

During the last three decades, significant achievements have been made nationally in the protection and enhancement of water quality. Much of this progress, however, has resulted from controlling point sources of pollution. Pollutant loads from nonpoint sources continue to present problems for achieving water quality goals and maintaining designated uses in many parts of the United States. Nonpoint sources are generally considered the number one cause of water quality problems reported by states, tribes, and territories.

Categories of nonpoint source pollution affecting waterbodies include agriculture, atmospheric deposition, channelization, construction, contaminated sediment, contaminated ground water, flow regulation, forest harvesting (silviculture), ground water loading, highway maintenance/runoff, hydrologic and habitat modification, in-place contamination, land development, land disposal, marinas, onsite disposal systems, recreational activities, removal of riparian vegetation, resource extraction, shoreline modification, streambank destabilization, and unspecified or other nonpoint source pollution.

Nonpoint sources can generate both conventional pollutants (e.g., nutrients, sediment) and toxic pollutants (e.g., pesticides, petroleum products). Even though nonpoint sources can contribute many of the same kinds of pollutants as point sources, these pollutants are usually generated in different timeframes, volumes, combinations, and concentrations.

Pollutants from nonpoint sources are mobilized primarily during rainstorms or snowmelt. Consequently, waterborne NPS pollution is generated episodically, in contrast to the more continuous discharges of point sources of pollution. However, the adverse impacts of NPS pollution downstream from its source, or on downgradient waterbodies, can be continuous under some circumstances. For example, sediment-laden runoff that is not completely flushed out of a surface water prior to a storm can combine with storm runoff to create a continuous adverse impact; toxic pollutants carried in runoff and deposited in sediment can exert a continuous adverse impact long after a rainstorm; physical alterations to a stream course caused by runoff can have a permanent and continuous effect on the watercourse; and the chemical and physical changes caused by NPS pollution can have a continuous adverse impact on resident biota.

Nutrient pollution (i.e., nitrogen [N] and phosphorus [P]) is often associated with NPS and has received increasing attention as algal blooms and resulting hypoxic or "dead" zones caused by the decay of algae have negatively affected waterbodies around the country (NOAA 2012). Various other pollutants contributed by NPS include sediment, pathogens, salts, toxic substances, petroleum products, and pesticides. Each of these pollutants, as well as habitat alteration and hydrologic modification, can have adverse effects on aquatic systems and, in some cases, on human health.

- Waste from livestock, wildlife, and pets contain bacteria that contaminate swimming, drinking, and shellfishing waters, as well as oxygen-demanding substances that deplete dissolved oxygen (DO) levels in aquatic systems. Suspended sediment generated by construction, overgrazing, logging, and other activities in riparian areas, along with particles carried in runoff from cropland, highways, and bridges, reduces sunlight to aquatic plants, smothers fish spawning areas, and clogs filter feeders and fish gills.
- Salts from irrigation water become concentrated at the soil surface through evapotranspiration and are carried off in return flow from surface irrigation. Road salts from deicing accumulate along the edges of roads and are often carried via storm sewer systems to surface waters. Salts cause the soil structure to break down, decrease water infiltration, and decrease the productivity of cropland. Salts can also be toxic to plants at high concentrations.

- Some pesticides are persistent in aquatic systems and biomagnify in animal tissue (primarily fish tissue) as they are passed up through the food chain. Biomagnification has detrimental physiological effects in animals and negative human health impacts. Herbicides can be toxic to aquatic plants and therefore remove a food source for many aquatic animals. Herbicides can also kill off the protective cover that aquatic vegetation offers to many organisms.
- Finally, the trampling of stream bottoms by livestock and equipment; stream bank erosion caused by grazing, logging, and construction; conversion of natural habitats to agricultural, urban, and other land uses; flow regulation; and activities in riparian areas (e.g., tree removal, buffer removal) can reduce the available habitat for aquatic species, increase erosion, increase water temperature via reduced shading, and create flow regimes that are detrimental to aquatic life.

Every two years, states and territories are required to submit a 305(b) report that describes the status of all assessed waters and a 303(d) report that lists the impaired waters, the causes of impairment and the status of their restoration. In 2001, the U.S. Environmental Protection Agency (EPA) issued guidance to the states encouraging submitting one electronic, integrated water monitoring and assessment report. This report is currently expected to include the 305(b), 303(d), and 314 (Clean Lakes Program) assessments (Keehner 2011). Currently there are no plans to release a new National Water Quality Inventory Report to Congress. The last Report to Congress was released in 2009 and provided a synopsis of 2004 data. Information on Integrated Reporting, including the guidance issued by EPA, is available at www.epa.gov/tmdl/integrated-reporting-guidance. The Assessment TMDL Tracking & Implementation System (ATTAINS) provides the most current 305(b) and 303(d) information available for all 50 states and territories. ATTAINS summarizes state-reported data for the nation, individual states, individual waters and the 10 EPA regions.

A national summary of assessment data submitted by the states from 2004 through 2014 (with over 80 percent for the period 2010–2014) documents the extent of the nonpoint source problem (USEPA 2016). The share of waters assessed by the states in these reports was 32 percent of river miles (mi); 45 percent of lake, reservoir, and pond acreage; 40 percent of bay and estuary square mileage; 14 percent of coastal shoreline mi; 3 percent of ocean and near coastal water square mileage; 1 percent of wetlands acreage; 85 percent of Great Lakes shoreline; and 88 percent of Great Lakes open water square mileage. For these assessed waters, Table 1-1 shows national totals for causes of impairments or threats to impairment that are often associated with nonpoint sources. A wide range of causes frequently associated with nonpoint sources are at the top of the list for rivers and streams, including pathogens, sediment, nutrients, organic enrichment/oxygen depletion, temperature, metals, habitat and flow alterations, and turbidity. Nutrients, organic enrichment/oxygen depletion, turbidity, metals, and sediment are also leading causes of impairments and threats to lakes, while pathogens and organic enrichment/ depleted oxygen are among the top causes of problems identified in bays and estuaries and coastal shoreline. Organic enrichment/ depleted oxygen is the largest cause of impairment to wetlands, with metals, pathogens, and nutrients also among the leading causes of impairment. Pesticides were found to be a significant cause of problems in Great Lakes open waters and along the Great Lakes shoreline, while organic enrichment/ depleted oxygen was the largest cause of impairment to ocean and near coastal waters.

Table 1-1. National causes of impairment (excerpted from USEPA 2016)

Cause of Impairment Group	Size of Assessed Waters with Listed Causes of Impairment							
	Rivers and Streams (Miles)	Lakes, Reservoirs, and Ponds (Acres)	Bays and Estuaries (Square Miles)	Coastal Shoreline (Miles)	Ocean and Near Coastal (Square Miles)	Wetlands (Acres)	Great Lakes Shoreline (Miles)	Great Lakes Open Water (Square Miles)
Algal Growth	6,013	908,513	1,474	93		4,631	191	
Ammonia	11,673	214,501	41	22	1	31		
Flow Alteration(s)	42,694	190,228	3			4,387	202	
Habitat Alterations	67,242	319,965	2			2,104	170	
Metals (other than Mercury)	89,069	1,304,587	1,878	60	15	94,630		
Nutrients	117,412	3,586,616	3,605	131	7	67,955	380	
Oil and Grease	3,014	44,285	101	95				
Organic Enrichment/Oxygen Depletion	99,578	1,697,788	5,421	437	579	462,402	138	13,867
Pathogens	178,219	549,515	7,034	1,056	80	72,385	621	
Pesticides	19,565	494,613	1,847	36	52	169	2,483	29,661
Sediment	145,289	788,465	224	5		10,786	319	
Temperature	93,513	240,684	145	96	1	14,900		
Turbidity	47,854	1,341,862	899	331	24	3,915		

Table 1-2 summarizes the extent to which sources often associated with NPS are responsible for documented impairments and threats to impairment for different waterbody types. Agriculture is the top source reported for river and stream problems, with a range of other sources associated with nonpoint sources also contributing significantly, including hydromodification, habitat alteration, urban-related runoff/stormwater, unspecified NPS, forestry, mining, and construction. The states reported that agriculture is the third leading source causing problems in lakes behind atmospheric deposition and unknown sources, with unspecified NPS, hydromodification, and urban-related runoff/stormwater also major sources. Problems in the Nation's bays and estuaries are more commonly associated with unknown sources and atmospheric deposition, but unspecified NPS, urban-related runoff/stormwater, agriculture, habitat alteration, and hydromodification are also significant contributors to these problems according to the states. Urban sources play a substantial role in the problems reported for coastal shoreline, ocean and near coastal waters, and open Great Lakes waters, whereas agriculture is also an important source for impairments and threats to wetlands and Great Lakes shoreline and open waters.

Finally, Table 1-3 shows the number of TMDLs (total maximum daily loads) written since October 1, 1995, for various pollutants. Pathogens, which come from both point and nonpoint sources, are second to mercury at the top of the list, and metals, nutrients, sediment, and other pollutants often associated with NPS have also been the focus of many TMDLs. The figures in Table 1-3 are based on a total of 69,173 TMDLs written to address 72,618 causes of impairment.

Table 1-2. National probable sources contributing to impairments (excerpted from USEPA 2016)

	Size of Assessed Waters with Probable Sources of Impairments							
Probable Source Group	Rivers and Streams (Miles)	Lakes, Reservoirs, and Ponds (Acres)	Bays and Estuaries (Square Miles)	Coastal Shoreline (Miles)	Ocean and Near Coastal (Square Miles)	Wetlands (Acres)	Great Lakes Shoreline (Miles)	Great Lakes Open Water (Square Miles)
Agriculture	148,728	1,241,455	3,056	113		201,786	620	4,373
Construction	21,527	336,942	1	4	4	1,000	18	
Habitat Alterations (Not Directly Related to Hydromodification)	66,932	273,438	2,231			33	90	
Hydromodification	92,067	762,274	1,717	140	7	6,762	231	
Recreational Boating And Marinas	138	38,743	789	106	8	72,320		
Resource Extraction	33,873	524,820	320			32,112		
Silviculture (Forestry)	40,637	162,244	0					
Unspecified NPS	54,142	847,767	3,363	103	4	1,324	6	
Urban-Related Runoff/Stormwater	61,984	744,646	3,086	268	379	54	99	13,867

Table 1-3. National cumulative TMDLs by pollutant (excerpted from USEPA 2016)

Pollutant Group	Number of TMDLs	Number of Causes of Impairment Addressed
Pathogens	13,263	13,572
Metals (other than Mercury)	9,955	10,153
Nutrients	6,154	7,520
Sediment	3,941	4,591
Temperature	2,305	2,315
Organic Enrichment/Oxygen Depletion	2,191	2,315
Turbidity	1,603	1,829
Pesticides	1,351	1,514
Ammonia	1,131	1,230
Algal Growth	95	103
Habitat Alterations	83	84
Oil and Grease	14	14

Many other measures and indicators of the extent of the NPS problem are also available, including the National Rivers and Streams Assessment (NRSA), under which 1,924 river and stream sites were sampled during the summers of 2008 and 2009 (USEPA 2013). This study was based on a robust, commonly used index that combines different measures of the condition of aquatic benthic macroinvertebrates. The draft report indicates that 21 percent of the nation's river and stream length is in good biological condition, 23 percent is in fair condition, and 55 percent is in poor condition (no data for 1 percent). Of the four chemical stressors assessed in this study (total P [TP], total N [TN], salinity, and acidification), it was concluded that P and N are by far the most widespread. It was found that 40 percent of the nation's river and stream length has high[1] levels of P and 28 percent has high levels of N. Poor biological condition (for macroinvertebrates) was found to be 50 percent more likely in rivers and streams with high levels of P and 40 percent more likely in rivers and streams with high levels of N. Four indicators of physical habitat condition (excess streambed sediments, riparian vegetative cover, riparian disturbance, and in-stream fish habitat) were also assessed for the study. Results indicated that poor riparian vegetative cover and high levels of riparian disturbance are the most widespread physical stressors, reported in 24 percent and 20 percent of the nation's river and stream length, respectively. Excess levels of streambed sediments, however, were reported in 15 percent of river and stream length and were found to have a greater impact on biological condition. The study concluded that poor biological condition is 60 percent more likely in rivers and streams with excessive levels of streambed sediments. While this study was not designed to identify the sources of stressors, other research has shown that nonpoint sources are often contributors to both the chemical and physical stressors described here. The draft report was released for comment on March 25, 2013, and is currently undergoing final revision.

EPA also performed a National Wetland Condition Assessment (NWCA) to determine the ecological integrity of wetlands at regional and national scales through a statistical survey approach. Field data were collected in 2011 and a draft report was released for public comment through January 6, 2016 (USEPA 2015c). Draft findings indicate that nationally, 48% of the wetland area is in good condition, 20% is in fair condition and the remaining 32% of the area is in poor condition. The study also assessed a number of physical, chemical, and biological indicators of stress that reflect potential negative impact to wetland condition. These indicators were assigned to "low," "moderate," or "high" stressor levels depending on criteria established for each indicator. Of the six physical indicators, vegetation removal and hardening (e.g., pavement, soil compaction) stressors were assessed as high for 27% of wetland area nationally, while the ditching stressor was high for 23% of wetland area. Both of the chemical indicators (a heavy metal index and soil P concentration) were low for the majority of wetland area nationally, but at variable levels across the four aggregated ecoregions created for the study. A Nonnative Plant Stressor Indicator developed for NWCA was used to assess the level of biological stress in wetlands. Nationally, 61% of wetland area had low stressor levels for nonnative plants, but results varied across aggregated ecoregions.

Still, other reports indicate the pervasive nature of NPS pollution and the need to document and solve the many problems it causes. For example:

- Based on the sampling of over 1,000 lakes across the country in 2007, it was determined that poor lake physical habitat is the biggest problem affecting biological condition, followed by high nutrient levels (USEPA 2009). This statistical survey found that lakes with excess nutrients (i.e., a "poor" stressor condition) are two-and-a-half times more likely to have poor biological health[2].
- EPA's 2012 National Coastal Condition Report noted that U.S. coastal areas are facing significant population pressures and associated higher volumes of urban nonpoint source runoff with 53 percent of the U.S. population living in coastal areas that comprise only 17 percent of the total conterminous U.S. land area (USEPA 2012a). This report rated the U.S. coasts as "fair" on a scale

[1] Thresholds for high, medium and low values were set on a regional basis relative to the least-disturbed reference sites for each of the nine NRSA ecoregions.)
[2] This likelihood is expressed relative to the likelihood of Poor response condition in lakes that have Not-Poor stressor condition (USEPA 2010).

of good, fair, or poor. Dissolved inorganic P levels, one of the five components of the water quality index, was also rated "fair."

- Nonpoint sources, particularly from the agricultural areas north of the confluence of the Ohio and Mississippi Rivers, contribute most of the N and P loads to the Gulf of Mexico (Goolsby et al. 1999). The nitrate load to the Gulf approximately tripled from 1970 to 2000, with the greatest sources believed to be basins in southern Minnesota, Iowa, Illinois, Indiana, and Ohio that drain agricultural land (Goolsby et al. 2001).
- In 2015, the Gulf of Mexico hypoxic zone measured 6,474 square miles (4.14 million ac), larger than the state of Hawaii (USEPA 2015f). The greatest source of pollution causing the hypoxic zone in the Gulf of Mexico is nonpoint source runoff from agriculture. It has been estimated that corn and soybean cultivation contributes 52 percent of the N delivered to the Gulf from the Mississippi River Basin, with other cropland, manure on pasture and rangeland, and forest contributing 14, 5, and 4 percent, respectively (Alexander et al. 2008). It was also estimated that animal manure on pasture and rangeland, corn and soybeans, other cropland, and forest contribute 37, 25, 18, and 8 percent of the P, respectively.

1.3 Major Categories of Nonpoint Source Pollution

1.3.1 Agriculture

The 2012 Census of Agriculture reported that there are 2,109,303 farms covering 914,527,657 acres (ac) in the U.S. (USDA-NASS 2014). Approximately 1.5 million farms grew crops on 390 million ac, and there were about 415 million ac of permanent pasture and range on nearly 1.2 million farms. Woodland covered 77 million acres, while other agricultural features (e.g., farmsteads, buildings, livestock facilities, ponds, and roads) accounted for 32 million ac of farmland. Animal agriculture included nearly 90 million cattle and calves on approximately 900 thousand farms, 66 million hogs and pigs on 63 thousand farms, and 1.5 billion broilers on 42 thousand farms.

The primary agricultural nonpoint source pollutants are inorganic and organic nutrients (N and P), sediment, organic matter and pathogens from animal waste, salts, and agricultural chemicals. Agriculture and agricultural activities can also have direct impacts on aquatic habitat. N and P are applied to agricultural land in several different forms and come from various sources, including commercial fertilizer, manure from animal production facilities, municipal and industrial treatment plant sludge and/or effluent applied to agricultural lands, legumes and crop residues, irrigation water, and atmospheric deposition.

Land disturbance and clearing for agricultural operations can increase sediment loadings in runoff and surface waters. In addition, increased instream flows resulting from this land clearing can also contribute to accelerated stream bank erosion. Sediment loss and runoff are especially high if it rains or if high winds occur while the soil is being disturbed or soon afterward.

Animal waste includes the fecal and urinary wastes of livestock and poultry; process water; and the feed, bedding, litter, and soil from confined animal facilities. Runoff water and process wastewater from confined animal facilities can contain oxygen-demanding substances; N, P, and other nutrients; organic solids; salts; bacteria, viruses, and other microorganisms; and sediment.

Large amounts of salt can be added to agricultural soils by irrigation water that has a natural base load of dissolved mineral salts, regardless of whether the water is supplied by ground water or surface water sources. Irrigation water is consumed by plants and lost to the atmosphere by evaporation, and the salts in the water remain on and become concentrated in the soil. Salt accumulation leads to soil dispersion, soil compaction, and possible toxicity to plants and soil fauna. Salt can also be carried from fields in irrigation return flows.

Agricultural chemicals—including pesticides, herbicides, fungicides, and their degradation products—can enter ground and surface waters in solution, in emulsion, or bound to soil colloids. Some types of agricultural chemicals are resistant to degradation and can persist and accumulate in aquatic ecosystems. Application to agricultural fields is a major source of pesticide contamination of surface water and ground water. Other sources are atmospheric deposition; drift during application; misuse; and spills, leaks, and discharges associated with pesticide storage, handling, and disposal.

Riparian vegetation and its pollutant buffering capacity are lost when crops are planted too close to surface waters. Livestock grazing can cause loss of cover vegetation on pasturelands, resulting in erosion, loss of plant diversity on pasturelands, and adverse impacts on stream courses and surface waters. Cattle with access to streams can directly deliver fecal contamination to waterbodies, trample riparian vegetation and disturb stream bank soils, leading to bank erosion. In addition, grazing can alter riparian vegetation species composition.

1.3.2 Urban Sources

The most common pollutants coming from stormwater sources include sediment, pathogens, nutrients, and metals (USEPA 2015b). Other pollutants in runoff from urban areas include oil, grease and toxic chemicals from motor vehicles; pesticides and nutrients from lawns and gardens; viruses, bacteria and nutrients from pet waste and failing septic systems; road salts; heavy metals from roof shingles, motor vehicles and other sources; and thermal pollution from impervious surfaces such as streets and rooftops (USEPA 2015e). Research has indicated that the unit area contribution of pesticides to watersheds by urbanized areas (e.g. golf courses and home lawn care) may be greater than that from agriculture (Steele et al. 2010).

Urbanization converts large portions of vegetated land to unvegetated, impervious land, thus changing the extent to which the land can absorb and filter rainfall and runoff before it enters waterbodies. The amount of impervious surface in urban areas—such as rooftops, roads, parking lots, and sidewalks—can range from 35 percent or lower in lightly urbanized areas to nearly 100 percent in heavily urbanized areas. These changes to the landscape increase pollutant loadings, stormwater runoff volumes, and peak flow rates in urban streams. Pollutants carried in urban runoff often reach surface waters without treatment.

The impacts of urbanization on local hydrology can be particularly acute. Urban streams are frequently flashy, meaning that discharge rates increase rapidly in response to storms, followed by a quick return to normal after the storm passes. A study in the Piedmont of western Georgia, for example, showed that high flow pulses and elevated peak discharges were more frequent in urban watersheds than any other land cover, and baseflow inputs in urban streams were lower than other watersheds (Schoonover et al. 2006). Streams in urbanized areas are also often characterized by accelerated bank erosion, channel widening, and sedimentation (Roy et al. 2010), with much of this due to the destructive energy of large volumes of rapidly moving stormwater runoff. The frequency of flooding is also increased in many cases, particularly during spring snowmelt and rain-on-snow events (Buttle and Xu 1988, Pitt and McLean 1992). The combination of pollutants and hydrologic impacts in urban settings tends to produce biotic assemblages of low diversity dominated by tolerant and nonnative species (Roy et al. 2010). Wide-ranging research relating impervious cover to stream quality has been incorporated within the Impervious Cover Model

(ICM), a watershed planning model that predicts that most stream quality indicators decline when watershed impervious cover exceeds 10 percent, with severe degradation expected beyond 25 percent impervious cover (CWP 2003). Urbanization can change in-stream processing of nutrients and other elements through the combined impacts of changes to stream hydrology, sediment texture, organic matter levels, and stream flora and fauna (Steele et al. 2010).

1.3.3 Removal of Streamside Vegetation

Riparian zones are transitional areas, containing elements of both aquatic and terrestrial habitats (Knutson and Naef 1997). Riparian habitat performs many functions, including (Knutson and Naef 1997, USDOI 1991):

- providing shade to cool stream waters;
- stabilizing stream banks and controlling erosion and sedimentation;
- rebuilding floodplains; and
- contributing leaves, twigs, and insects to streams, thereby providing basic food and nutrients that support fish and aquatic wildlife.

Fish also benefit from large trees that fall into streams creating pools, riffles, backwater, small dams, and off-channel habitat. In addition, riparian areas filter sediments and pollutants from runoff and moderate stream volumes by reducing peak flows and slowly releasing water to maintain base flows.

Losses of riparian or streamside vegetation are attributed to conversion to farmland, drainage for agriculture, forest harvesting, channelization, damming, creating impoundments, irrigation diversions, ground water pumping, and overgrazing (Brinson et al. 1981). Riparian vegetation is also lost due to urbanization (MSD 2012, Ozawa and Yeakley 2007).

Removal of riparian vegetation cuts off the natural supply of nutrients and energy to biological communities in low-order streams (USEPA 1991). Terrestrial and aquatic habitat available for shelter, forage, and reproduction is destroyed, and canopy removal results in increased stream temperatures and greater temperature fluctuations. Streambank stability is reduced and erosion and sedimentation are increased when the rooting systems of riparian vegetation are destroyed or removed (Brinson et al. 1981). In addition, stream flow buffering is reduced, flooding may increase, and in-stream sedimentation and pollutant loads may increase, all of which can cause severe stress to aquatic plant and animal communities.

1.3.4 Hydromodification

Hydromodification is the alteration of the hydrologic characteristics of coastal and non-coastal waters, which in turn could cause degradation of water resources (USEPA 2007). It includes channelization or channel modification and flow alteration. Channel modification is river and stream channel engineering undertaken for the purpose of flood control, navigation, drainage improvement, or reduction of channel migration potential (Brookes 1990). Examples of channel modification include straightening, widening, deepening, or relocating existing stream channels; excavation of borrow pits, canals, underwater mining, and other practices that change the depth, width, or location of waterways or embayments in coastal areas; and clearing or snagging operations. Channel modification typically results in more uniform channel cross sections, steeper stream gradients, and reduced average pool depths.

Flow alteration describes a category of hydromodification activities that results in either an increase or a decrease in the usual supply of fresh water to a stream, river, wetland, lake, or estuary. Flow alterations include diversions, withdrawals, and impoundments. In rivers and streams, flow alteration can also result from transportation embankments, tide gates, sluice gates, weirs, and the installation of undersized culverts. Levees and dikes are also flow alteration structures.

Channel modification can deprive wetlands and estuarine shorelines of enriching sediment; change the ability of natural systems to absorb hydraulic energy and filter pollutants from surface waters; increase transport of suspended sediment to coastal and near-coastal waters during high-flow events; increase instream water temperature; and accelerate the discharge of pollutants (Sherwood et al. 1990). Channelization can also increase the risk of flooding by causing higher flows during storm events (USEPA 2007). Hydromodification often diminishes the suitability of instream and riparian habitat for fish and wildlife through reduced flushing, lowered DO levels, saltwater intrusion, interruption of the life cycles of aquatic organisms, and loss of streamside vegetation. Dams, for example, can change water temperatures and impact fish spawning (USEPA 2007).

1.3.5 Mining

Much of the environmental damage caused by mining occurred prior to passage of the Surface Mining Control and Reclamation Act (SMCRA) of 1977, when standards for environmental protection during mining operations and the means for reclaiming abandoned mines were generally lacking (Demchak et al. 2004). For example, past practices used to mine silver (Ag) and gold (Au) from low-grade ore generated large volumes of waste material (spoil) that were dumped at the heads of drainages, potentially serving as sources of sediment to streams as they weathered over time (Sidle and Sharma 1996). Mercury (Hg) was used to separate Au and Ag from ore in the past and is contained in waste piles from the amalgamation process (Oak Ridge National Laboratory 1993). Numerous pollutants are released from coal and ore mining. Acid drainage from coal mining contains sulfates, acidity, heavy metals, ferric hydroxide, and silt (USEPA/USDOI 1995, Stewart and Skousen 2003). The heavy metals released from mining activities include Ag, arsenic (As), copper (Cu), cadmium (Cd), Hg, lead (Pb), antimony (Sb), and zinc (Zn) (Horowitz et al. 1993).

While modern-day mining practices are much improved, there remains a need to address the environmental impacts of past mining practices in many locations. For example, two Section 319 National Nonpoint Source Monitoring Program (NNPSMP) projects were designed to monitor the effects of restoration activities on water quality in areas impacted by past mining activities. In Pennsylvania, monitoring was carried out to determine the effectiveness of remediation efforts designed to counter the impact of abandoned anthracite mines on the aquatic ecosystem and designated beneficial uses of Swatara Creek (Cravotta et al. 2010). Impairments were caused both by acid mine drainage and losses of surface water to the abandoned underground mines. In Michigan's Keweenaw Peninsula efforts are underway to address problems caused by fine-grained stamp sands from historic copper mining operations (Rathbun 2007). These sands erode into streams and wetlands and degrade fish and macroinvertebrate communities by smothering aquatic habitat features and leaching copper into the water column.

While remediation efforts often result in water quality improvements, solutions are sometimes more complicated than initially envisioned. For example, acid mine drainage resulting from Cu mining in the Ducktown Mining District of Tennessee introduced significant amounts of toxic trace metals into tributaries of the Ocoee River (Lee et al. 2008). Downstream neutralization of acidic water resulted in the precipitation of iron hydroxides and the sorption of trace metals to the suspended particulates which were then transported downstream to a lake where they settled on the lake bottom. This sediment layer contains elevated levels of Fe, Al, Mn, and trace metals such as Cu, Zn, Pb, Ni, and Co. Study results have shown that even a modest decrease in pH of the sediment pore water from 6.4 to 5.9 caused significant release of trace metals to the environment, creating a risk of ingestion by bottom-dwelling aquatic species.

1.3.6 Forestry

Forestry operations can degrade water quality in several ways, with sediment, organic debris, nutrients, and silvicultural chemicals the major pollutants of concern (Binkley et al. 1999, Michael 2003, Ryan and Grant 1991). Construction of forest roads and yarding areas, as well as log dragging during harvesting, can accelerate erosion and sediment deposition in streams, thus harming instream habitats (Ryan and Grant 1991, USEPA 2015a). Road construction and road use are the primary sources of NPS pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations (USEPA 2015a). Removal of overstory riparian shade can increase stream water temperatures (USEPA 2015a). Harvesting operations can leave slash and other organic debris to accumulate in waterbodies, resulting in depleted dissolved oxygen (DO) and altered instream habitats. Fertilizer applications can increase nutrient levels and accelerate eutrophication, whereas pesticide applications can lead to adverse wildlife and habitat impacts (Brown 1985). Herbicides can be applied with reduced or shorter-term environmental impact, however, in situations where macroinvertebrate recolonization is rapid and herbicide concentrations are low and short-lived because of acidic soil and water conditions (Michael 2003).

A review of forest fertilization studies around the world concluded that, in general, peak stream concentrations of nitrate-N increase after forest fertilization, with a few studies reporting concentrations as high as 10-25 milligrams (mg) nitrate (NO_3)-N/L (lithium) (Binkley et al. 1999). In addition, the highest reported annual average NO_3-N concentration found was 4 mg N/L. The higher nitrate concentrations were related to repeated fertilization, use of ammonium nitrate instead of urea, and fertilization of N-saturated hardwood forests. It was found that phosphate fertilization could create peak concentrations exceeding 1 mg P/L, but annual averages remain below 0.25 mg P/L. A study of the effects of fertilizer addition to an artificially drained North Carolina pine plantation resulted in the flushing out of all excess nutrients by three major rain events within 47 days of application (Beltran et al. 2010). Researchers considered this to be a worst-case scenario, however, noting that N concentrations did not exceed EPA’s drinking water standard of 10 mg N/L and loading rates returned to pretreatment or lower levels as soon as 90 days after fertilization. Still, the results point out the importance of timing of fertilizer applications to reduce potential losses.

The use of forest lands for application of biosolids and animal wastes has received increased attention in the literature, reflecting concerns that such applications could increase nutrient loadings from these lands. For example, a study designed to evaluate the potential for using loblolly pine stands for poultry litter application in the South indicated that moderate application rates (~20 kilograms [kg] N/ hectare (ha), ~92 kg P/ha) can increase tree growth with minimal impacts to water quality (Friend et al. 2006). Higher application rates (800 kg N/ha, 370 kg P/ha), however, resulted in soil water nitrate levels exceeding 10 mg N/L and P buildup in soils. A study examining surface runoff of N and P in a small, forested watershed in Washington yielded no evidence of direct runoff of N or P from biosolids into surface waters (Grey and Henry 2002). This study illustrated the importance of best management practices (BMPs) as N-based application rates were used and a 20-meter (m) buffer was established around the creek and all ephemeral drainages. Only 40 percent of the watershed received nutrient applications (700 kg N/ha, 500 kg P/ha) and the acidic soils were expected to reduce P mobility. Before biosolids application, however, there was no relationship between discharge and nitrate-N concentration, but within nine months of application discharge and nitrate-N concentrations were positively correlated, indicating the potential for impacts to water quality with continued biosolids applications.

1.3.7 Construction

Stormwater runoff from construction activities can have a significant impact on water quality (USEPA 2015g). As stormwater flows over a construction site, it can pick up pollutants like sediment, debris, and chemicals and transport these to a nearby storm sewer system or directly to a river, lake, or coastal water. Although construction activities are generally temporary at any given location, polluted runoff from construction sites can harm or kill fish and other wildlife. Sedimentation can destroy aquatic habitat, high volumes of runoff can cause stream bank erosion, and debris can clog waterways.

Potential pollutants associated with construction activities include sediment, suspended solids, nutrients, chemicals, petroleum products, fuel, fertilizers, pesticides, and pH modifying contaminants (e.g., bulk cement) (WA DOE 2014). The variety of pollutants present and the severity of their effects depend on the nature of the construction activity, the physical characteristics of the construction site, and the proximity of surface waters to the construction area.

Soil loss rates from construction sites can be 1,000 times the average of natural soil erosion rates and 20 times that from agricultural lands (Keener et al. 2007). Even with control measures, waters discharged from disturbed lands often contain higher than desired concentrations of suspended solids, particularly the finer particles (Przepiora, et al. 1998). Ehrhart et al. (2002) investigated the effects of sedimentation basin discharges on receiving streams at three construction sites, reporting that stream sediment concentrations increased significantly with high levels persisting for at least 100 m below the basin discharge. A two-year study of runoff from three residential construction sites in Wisconsin showed that pollutant loads (suspended solids and nutrients) from these sites are variable and site dependent (Daniel et al. 1979). Compared to an adjacent watershed in dairy agriculture, however, the annual yield of suspended solids from the construction sites was considerably higher (19.2 vs. < 1 metric ton/ha). Similar differences in total nutrient yields were also observed between the construction and agricultural sites.

The 10-year Jordan Creek (CT) NNPSMP project compared stormwater runoff from three urban watersheds using a paired-watershed design (Clausen 2007). The watersheds were: a developed watershed serving as the control, a watershed being developed using traditional practices and subdivision requirements, and a watershed developed using a BMP approach (e.g., alternative driveway pavement treatments). The volume of stormwater runoff from the BMP watershed decreased (-97%) during the construction period compared to the control watershed while stormwater runoff from the traditional watershed increased compared to the control watershed. The concentrations of total suspended solids (TSS), NO_3-N, NH_3-N, total Kjeldahl nitrogen (TKN), and TP increased during construction in the BMP watershed, with peaks associated with turfgrass development. Because of the decreased stormwater runoff volume, however, exports from the BMP watershed generally did not change during the construction period, except for TSS and TP which increased and Zn which decreased. In the traditional watershed, concentrations either did not change or, for TKN and TP, declined during construction. Because of the increased stormwater runoff volume, however, exports from the traditional site increased for all variables during construction despite the observation that the erosion and sediment controls used during construction appeared to work.

Chemical pollutants, such as paints, acids for cleaning masonry surfaces, cleaning solvents, asphalt products, soil additives used for stabilization, pollutants in wash water from concrete mixers, and concrete-curing compounds, can also be carried in runoff from construction sites. When eroded sediment is transported to nearby surface waters, it can carry with it fertilizers, pesticides, fuels, and other contaminants and substances that readily attach to soil particles (Keener et al. 2007). Pollutants attached to sediment from construction sites can become desorbed quickly and transported in their soluble form which is often more reactive and bioavailable to organisms (Faucette et al. 2009).

Petroleum products used during construction include fuels and lubricants for vehicles, power tools, and general equipment maintenance. Asphalt paving also can be harmful because it releases various oils for a considerable time period after application. Solid waste on construction sites includes trees and shrubs removed during land clearing and structure installation, wood and paper from packaging and building materials, scrap metal, sanitary wastes, rubber, plastic, glass, and masonry and asphalt products.

1.3.8 Marinas

Because marinas are located right at the water's edge, there is a high potential for marina waters to become contaminated with pollutants generated from the various activities that occur there, such as boat cleaning, fueling operations, and marine head discharge, or from the entry of stormwater runoff from parking lots and hull maintenance and repair areas into marina basins (USEPA 2015d). Chemicals used to maintain and repair boats, such as solvents, oils, paints, and cleansers, may spill into the water, or make their way into waterbodies via runoff (NOAA 2013). Spilling fuel (gasoline or oil) at marinas or discharging uncombusted fuels from engines also contribute to NPS pollution (McCoy and Johnson 2010). In addition, poorly maintained sanitary waste systems aboard boats or poorly maintained pump-out stations at marinas can significantly increase bacteria and nutrient levels in the water.

Studies have shown that boats can be a source of fecal coliform bacteria in estuaries with high boat densities and poor flushing (Fisher et al. 1987, Gaines and Solow 1990, Milliken and Lee 1990, NCDEM 1990, Sawyer and Golding 1990, Seabloom et al. 1989). Fecal coliform levels in marinas and mooring fields become most elevated during periods of high boat occupancy and usage, such as holiday weekends. In addition, DO levels in marina basins can be lowered by inadequate water circulation and the decomposition of organic materials from sources such as sewage and fish waste.

Both the construction and design of marina or port construction can negatively affect the ecology of an area; effects include loss of habitat and alterations to local hydrodynamics. Protective measures like bulkheads, breakwaters and jetties are built near marinas to prevent damage to boats and shoreline structures, but these structures can have unintended water quality impacts. Both the attenuation of waves by in-water structures and the creation of waves by the increased boat traffic in marinas and ports affect shoreline processes, often result in increased turbidity, resuspension of sediment-bound pollutants, and increased shoreline erosion (USFWS 1982).

Metals and metal-containing compounds are contained in fuel additives, antifouling paints, ballast, and other marina structures. Arsenic is used in paint pigments, pesticides, and wood preservatives. Zn anodes are used to deter corrosion of metal hulls and engine parts (McCoy and Johnson 2010). Cu and tin (Sn) are used as biocides in antifoulant paints (McCoy and Johnson 2010). Other metals (Fe, chrome, etc.) are used in the construction of marinas and boats. These metals are released to marina waters through spillage, incomplete fuel combustion, wear on boat hulls and marina structures, and boat bilge discharges (McCoy and Johnson 2010, NCDEM 1990). Elevated levels of Cu, Zn, Cd, Cr, Pb, Sn, and PCBs have been found in oysters, other bivalves, and algae in some marinas (CARWQCB 1989, Marcus and Stokes 1985, McMahon 1989, NCDEM 1990, Nixon et al. 1973, SCDHEC 1987, Wendt et al. 1990, Young et al. 1979).

1.4 Solving the Problem

A wide range of federal, state, and local efforts with varying objectives, methods, and resources have been employed over the past few decades to address NPS problems at the local to national levels. A program central to many of these efforts is EPA's NPS program authorized under Section 319 of the CWA. Under this program, states, territories and tribes receive grant money that supports a wide variety of activities including technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring to assess the success of specific NPS implementation projects. Federal funds allocated under Section 319(h) of the CWA are distributed based on a state-by-state allocation formula to implement approved nonpoint source management programs. Section 319 funding grew from its initial funding level of $37 million in FY1990 to $238.5 million in FY2003, dropping back to $164.5 million in FY2012. Additional information on Section 319, including success stories, is available at EPA's website.

While the Section 319 program is a very important part of efforts to solve the NPS problem, there are numerous other programs and activities that are carried out in conjunction with or separate from Section 319 to address various aspects of the problem. Information about state programs can be found at EPA's NPS program website. Other examples include:

- The new Urban Waters Federal Partnership was designed to reconnect urban communities with their waterways by improving coordination among federal agencies and collaborating with community-led revitalization efforts to improve our nation's water systems and promote their economic, environmental and social benefits (USEPA 2015h). Stormwater runoff is one of several sources of pollution in urban settings creating public and environmental health hazards such as lowered drinking water quality and water bodies that are unsafe for swimming.
- The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP) is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of 10 years in length. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland. In addition, a purpose of EQIP is to help producers meet federal, state, tribal and local environmental regulations.
- Under the USDA's National Water Quality Initiative, the NRCS works with farmers and ranchers in small watersheds throughout the nation to improve water quality where this is a critical concern. In 2013, NRCS will provide nearly $35 million in financial assistance to help farmers and ranchers implement conservation systems to reduce N, P, sediment and pathogen contributions from agricultural land. This is the second year of the initiative; NRCS provided $34 million in 2012.
- Efforts that help define the problem also support NPS programs. For example, in 2011, numeric nutrient water quality standards were established for lakes and flowing waters in Florida to address harmful algal blooms caused by excess nutrients from fertilizer, stormwater, and wastewater runoff (FLDEP 2015).
- Hundreds of local projects across the nation are addressing various NPS problems. For example, alum (aluminum sulfate) treatments and upland nutrient management practices have been employed in the Grand Lake St. Marys watershed in western Ohio to address hypereutrophic conditions caused by high inflows of P (Tetra Tech 2013).

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