SEPTIC SYSTEM IMPACT ON SURFACE WATERS

A Review for the Inland Northwest

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June 2005

TRI-STATE
WATER QUALITY COUNCIL
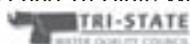
INTRODUCTION

Montana, Idaho, Washington, and Oregon have experienced tremendous population growth in the past 15 years, and this growth is expected to continue. To many people's surprise, a great deal of this growth is occurring in rural areas without centralized infrastructure, such as sewage treatment plants. This rural growth tends to be concentrated near rivers and lakes, where increased wastewater loads can threaten water quality. One of the biggest challenges facing state and local governments is how to deal with the increase in wastewater while protecting the water quality that is crucial to the natural beauty of these areas.

Septic systems, also known as "on-site wastewater treatment systems," are widely used in rural and suburban settings to dispose of wastewater. When operating properly, septic systems remove many pollutants and provide some measure of protection for human health and for the environment. But as rural populations grow and aquifers exhaust their ability to dilute wastes from ever-increasing numbers of septic tanks, water quality steadily deteriorates. Most state and local governments have regulations designed to protect public health from the worst contaminants from septic systems: water-borne pathogens and nitrates. But very few governments have created effective measures to address the increasing threat that septic tanks pose to the ecosystems of rivers and lakes.

Why have communities not done more to prevent septic systems from harming our streams and lakes? Perhaps because in the past, when rural populations were lower, the impacts were minimal and there was little threat to our surface waters. Or it may be that the connection between groundwater and streams (or lakes) was simply not well understood. But scientists have demonstrated that septic wastes in groundwater do ultimately flow into rivers or lakes,

and that in many areas these wastes are already degrading the quality of nearby waters. The goal of this paper is to discuss this issue by examining the technical background of the problem, clarifying the risks, and reviewing options for mitigation.

Through a review of scientific and policy studies, this paper will discuss the following questions:

- What risk does septic effluent pose to streams and lakes?
- How do contaminants get from septic systems to groundwater?
- How do contaminants get from groundwater to streams and lakes?
- What are the wastewater treatment options when trying to achieve public health and resource protection goals?
- What are the existing policy and regulatory options for mitigating surface water impacts?

This paper is intended to give policymakers a broader appreciation of the risks that traditional septic systems pose to our surface waters, in the hope that this will lead them to develop strategies that maintain and improve the water quality of our lakes and rivers.

Waste's Journey from House to Water Table to Lakes and Streams

septic system

septic tank

drainfield

Household waste passes through the septic tank, into the drainfield, then downward through the soil until it reaches the water table.

contaminants move toward water

LAKE or RIVER

groundwater movement

saturated soil

Up close: Septic Tank

inspection port   manhole   inspection port

water level

scum

inlet from house

inlet baffle

liquid

sludge

outlet to drainfield
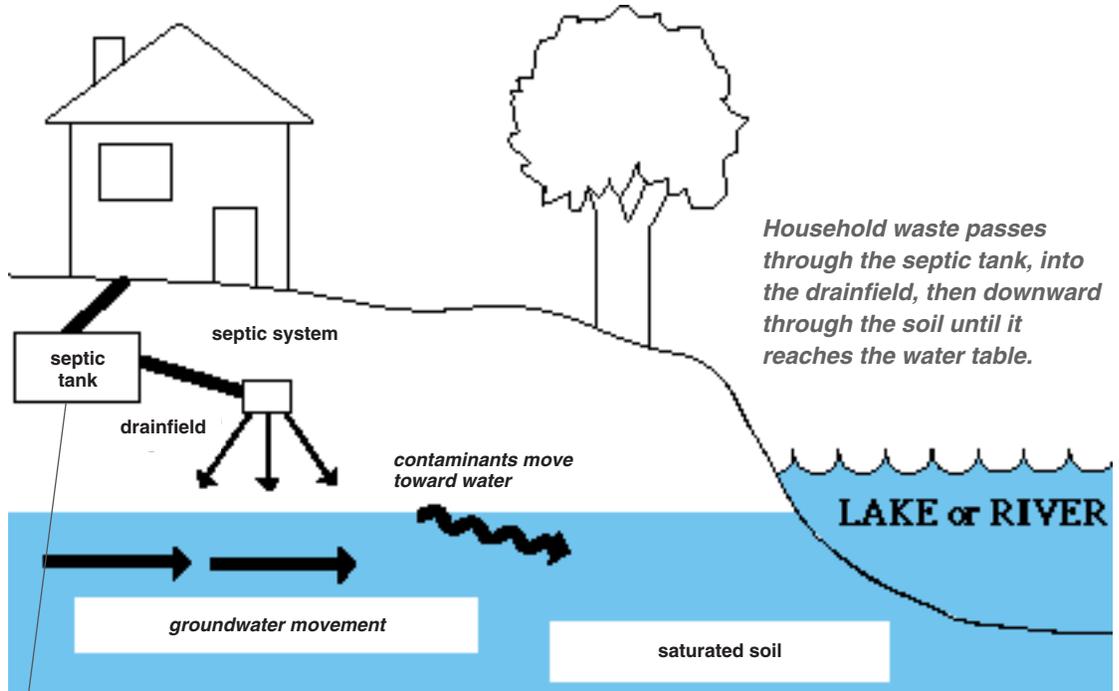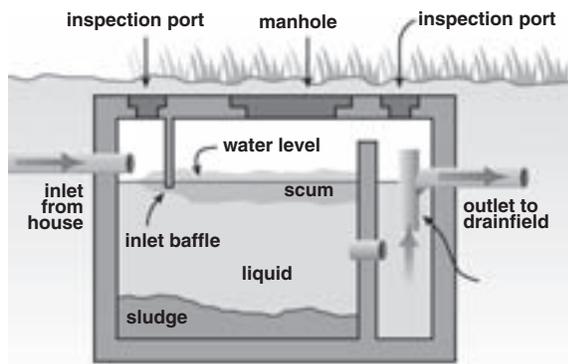
Up close: Drainfield

septic tank

perforated pipe

crushed rock

groundwater or bedrock

SEPTIC EFFLUENT: What risk
does it pose to streams and lakes?

Septic systems discharge a variety of contaminants which can affect surface waters, including nutrients, pathogens, organic matter and solids. Conventional septic tank and drainfield systems treat wastewater by settling solids and partly digesting the organic matter, allowing liquid effluent, which still contains nutrients and pathogens (bacteria, protozoa and viruses) to be discharged into the soil beneath the drainfield.

In the soil, biological processes, filtration, and adsorption remove most pathogens and some nutrients. However, conventional septic systems are not adequate for removing nitrate, and only partly remove phosphorus, certain pathogens, and certain other compounds, especially where soils or ground water conditions are marginally suitable, or where septic system densities are too high (EPA, 2002). Anything that is not removed by the soil under the drainfield will end up in groundwater.

Nutrient enrichment and its effect on lakes and rivers:

Septic systems are among the many sources of nutrients in groundwater and surface water—other major sources include agricultural fertilizers, livestock manure, air pollution, forest fires, eroded sediments, municipal wastewater, and storm-water runoff. Nutrient enrichment, or eutrophication, is the over-fertilization of surface waters by nitrogen and phosphorus, and is one of the leading causes of pollution of lakes, rivers, and coastal bays in the United States (EPA, 2004***).

Nutrient enrichment can cause a host of negative ecological effects on streams and lakes, including loss of water clarity, proliferation of aquatic weeds, algae blooms, and drop-offs in dissolved oxygen (a critical factor for fish and other aquatic life). Algae blooms can also make drinking water taste and smell bad, can release toxins (in the case of blue-green algae), and can contribute to the problem of carcinogenic tri-halomethanes formed by chlorination of drinking waters high in organic detritus (Carpenter, et.al., 1998, "Nonpoint Pollution of Surface Waters with N&P", Ecological Society of America, http://esa.sdsc.edu/).

Nitrogen, in its nitrate form, is also a direct risk to human and livestock health if it reaches high concentrations in drinking water (10 milligrams/Liter is the EPA maximum contaminant level for drinking water). However, the levels of nitrogen and phosphorus that cause ecological damage in lakes and rivers are far lower—usually more than 10 times lower—than the levels which are toxic to humans and livestock. Therefore, the precautions taken by communities to protect groundwater used for drinking are not sufficient to protect rivers and lakes from ecological impacts.

The issue of "limiting nutrients" in lakes and rivers:

Some state and local governments assume that phosphorus is the only nutrient of concern for surface water pollution, but this is not the case. In lakes and rivers a certain ratio of nitrogen to phosphorus is required to trigger an algal bloom or excessive growth of aquatic plants, and the nutrient which is in shortest supply is known as the "limiting nutrient." In freshwater systems, the limiting

Septic systems can contribute nutrients to surface waters, especially nitrogen; while associated development activities—e.g., construction, roads, lawns—increase phosphorus. The combination threatens sensitive waters.

nutrient is often, but not always, phosphorus. In parts of the Clark Fork River, for example, nitrogen is the limiting nutrient.

Nitrogen from septic systems can cause nutrient enrichment in fresh water if:

1) complementary sources of phosphorus are available, or could become available, such as phosphorus associated with soil erosion, phosphorus associated with wildfires, phosphorus from municipal/industrial wastewaters; or phosphorus in urban and suburban storm runoff; and/or

2) septic-derived phosphorus can reach surface water, which is more likely when the septic system is very close to a stream or lake, as in a lake-front home. Note that many of these sources of phosphorus increase with development.

Rural and suburban regions experiencing growth near lakes and rivers:

Much of the northwestern United States has experienced accelerated growth rates in the last 15 years, including many formerly rural counties in Idaho, western Montana, Oregon and Washington. The growth in these areas was far higher than the national average from 1990 to 2000, as was growth in western Montana. Much of this growth is concentrated near well-known rivers and lakes or coastal waters. The counties listed in Table 1 below experienced growth rates that are more than *double the national average* of 13% between 1990 and 2000.

Table 1: Fast-Growing Counties in the Northwest USA

State/County	Growth Rate, 1990 - 2000	Key Surface Waters & Tributaries:
MT- Gallatin Co.	34%	Gallatin River and tributaries
MT- Ravalli Co.	44%	Bitterroot River and tributaries
MT- Lake Co.	26%	Flathead Lake and river
MT- Flathead Co.	26%	Flathead Lake, Swan Lake, Whitefish Lake, many others
ID- Kootenai Co.	56%	Spokane River, Coeur d'Alene & other lakes
ID- Bonner Co.	38%	Pend Oreille Lake
ID- Ada, Canyon, Elmore & Boise Cos.	37 - 90%	Boise River, Payette River, Snake River and reservoirs
ID- Teton Co	74%	Upper Snake River
OR- Crook, Deschutes, Jefferson Cos.	36% - 54%	Deschutes River and tributaries
OR- Yamhill & Washington Cos.	30% - 43%	Willamette and tributaries
WA- Whatcom, Skagit, Snohomish & Thurston	29% - 30%	Nooksak, Skagit, Skykomish, Stillaguamish rivers, lakes, Puget Sound
WA- Benton, Franklin, & Grant Cos.	27% - 36%	Yakima River, Columbia River, various lakes
WA- Stevens & Pend Oreille Cos.	27% - 32%	Spokane and Pend Oreille Rivers, Roosevelt Lake
WA- Chelan Co.	27%	Columbia tributaries & lakes

Source: U.S. Census Quickfacts

Of these high-growth counties, only a few are associated with major metropolitan areas; most are associated with smaller cities or small towns. In these rural and suburban counties, much of the development is in un-sewered areas on septic systems. The 1990 census indicated that between 29% and 37% of state residents in Montana, Idaho, Washington, and Oregon used septic systems (EPA, 2002, OWTS). It is likely that a much greater percentage of the new residents in rural counties are using septic systems.

Data from county health departments in rural areas (shown in Charts 1 and 2 below) illustrates the rapid growth in number of septic systems in the fast-growing counties of the inland northwest. These data illustrate the rapid growth of septics, many of which are located near the area's beautiful lakes and rivers, or are situated over alluvial aquifers closely connected to surface waters:

The question posed by this phenomenal growth in septic systems is this: Does the discharge of contaminants from these systems into shallow groundwater also impose a large additional load of nitrates and other contaminants on our rivers and lakes? This paper examines the question of how this growth in septic systems puts surface water quality at risk.

157,000
people in the Clark Fork basin of Montana use septic systems

144,000
people in the Clark Fork basin are on sewer/wastewater treatment plants

52% of the people in the Clark Fork basin are on septics

—based on data from 10 counties

Chart 1: Number of Septic Systems Approved in Panhandle Health District, ID, 1976-2000

(includes Kootenai, Bonner, Benewah, Boundary, and Shoshone counties)

▶▶
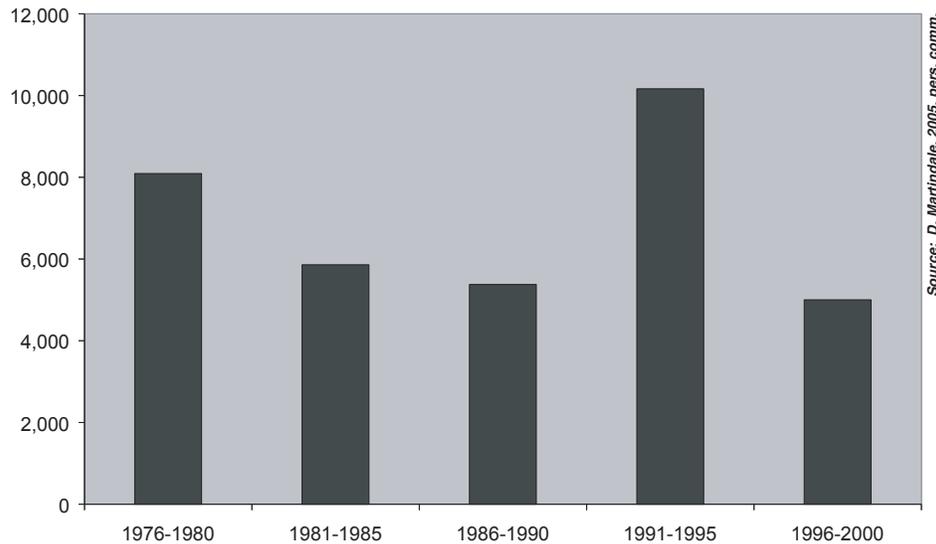
Source: D. Martindale, 2005, pers. comm.

Chart 2: Number of Septic System Approved in Rural Clark Fork Basin Counties, MT, 1980-2000*
▼ ▼

■ Ravalli County
■ Four other rural counties
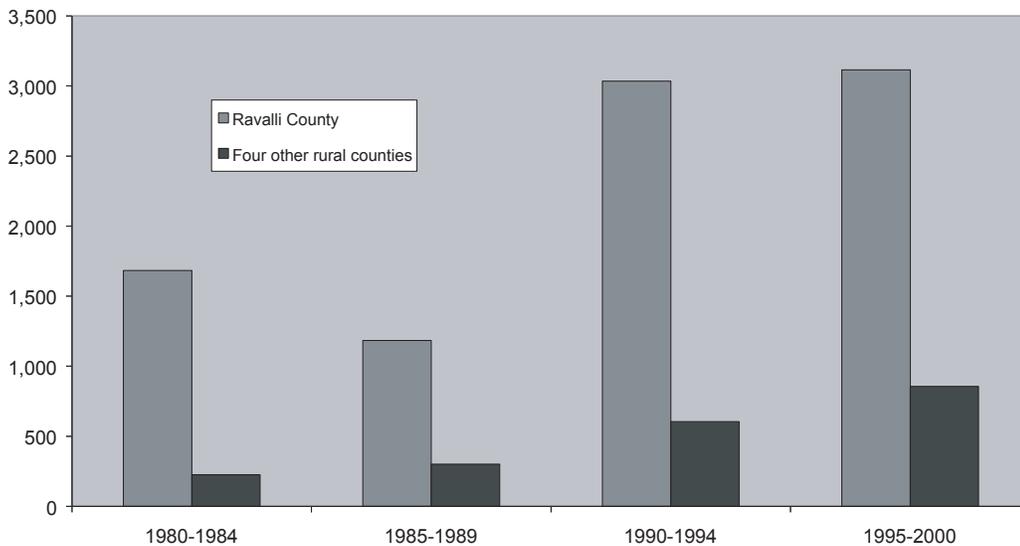
Source: McDowell, W., 2001

* Missoula County approved a total of 5,185 septic systems from 1980-2000, but is now reducing the county's total number of septic systems by hooking them up to sewer.

Examples of waters with water quality issues related to septic systems:

A number of important water bodies in the Northwest already have nutrient enrichment problems, and in some cases septic systems have been identified as a significant source of those nutrients. Examples include:

■ *Clark Fork River, Missoula County, MT:*
The Missoula County Health Department and Missoula Valley Water Quality District have documented a large impact from septic systems discharging into the Missoula valley aquifer and then into the Bitterroot and Clark Fork rivers. The total load of nutrients (both nitrogen and phosphorus) discharged by groundwater in the Missoula valley is estimated to be approximately 40% of the TMDL nutrient load allocation for the Clark Fork River below the Bitterroot confluence (VNRP, 1998). Reducing this groundwater nutrient load by expanding sewers is a major goal of the Voluntary Nutrient Reduction Program for the Clark Fork (Missoula Valley Water Quality District, "Evaluation of Unsewered Areas in Missoula, MT", Missoula City-County Health Dept., 1996).

■ *Lake Pend Oreille, Bonner County, ID:*
Studies done by Idaho's Dept. of Environmental Quality have demonstrated that nutrient concentrations and resulting algae in the near-shore waters of Lake Pend Oreille are partly due to un-sewered lake-front properties leaking septic effluent into the Lake. Efforts are underway to sewer lake-front communities, and avoid discharging treated wastewater into the Lake (Idaho Division of Environmental Quality. Phase I Diagnostic and Feasibility Analysis: A Strategy for Managing the Water Quality of Pend Oreille Lake, Bonner and Kootenai Counties, ID. Coeur d'Alene, ID. 1993).

■ *Clackamas River, Clackamas County, OR:*
High algal biomass has been documented as a recent phenomena on the lower Clackamus River, a mostly forested watershed upstream from Portland, Oregon. The highest algal counts, as well as the highest N and P concentrations, were measured on Sieben Creek, the site of recent urbanization. It's likely that a combination of urban storm-water runoff and septic system inputs are responsible for a significant part of this problem (Carpenter, Kurt, 2003, USGS Water Resource Investigations Report 02-4189, "Water Quality and Algal Conditions in the Clackamas River Basin, Oregon, and their Relations to Land and Water Management").


Septic system contamination of surface waters is a different, less well-known issue than the typical human health issue addressed by most current septic system regulation.

THE PATH OF CONTAMINATION:
## How do contaminants get from septic systems to groundwater?

Wastewater leaving the drainfield of a septic system trickles first to unsaturated soil above the water table, and eventually to the water table below. All continuously operated septic systems are expected to discharge to groundwater eventually (Woessner in McDowell, 2001 newsletter). Where the depth to the water table is shallow and overlying soils are permeable, as is typical in valleys near streams, rivers, or lakes within the inland Northwest, recharge from septic systems to groundwater is relatively rapid. Although it is possible for wastewater to be absorbed by plant roots, in reality this should not happen because properly-designed drainfields are installed below the root zone of grasses and outside the rooting areas of trees. Therefore, most septic effluent reaches the water table. This water carries with it some of the soluble contaminants of effluent that are not absorbed by soil, including nitrogen, various bacteria and viruses.
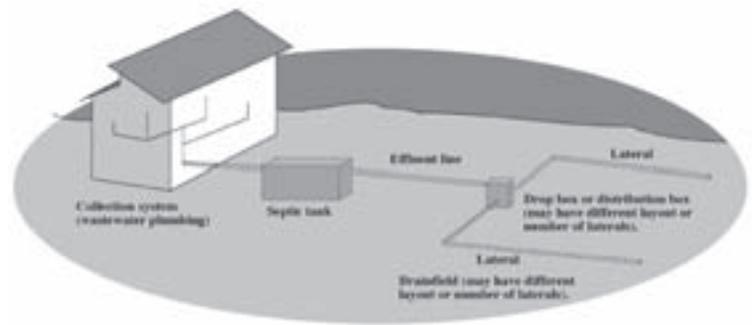
Typical Onsite Wastewater Treatment System

Clark Fork River, downtown Missoula, Montana

Removal of Pollutants through Septic System Treatment of Wastewater:

Conventional septic systems consist of two primary components: the septic tank, which initially receives the wastewater, and the drainfield, which is the underground area that receives the outflow from the septic tank. The septic tank provides primary treatment to the wastewater by settling solids, and trapping greases, oils, and other floatable matter. Solid materials are partially converted to liquids by biological processes at the bottom of the tank. The liquid effluent is discharged into the drainfield. Further treatment occurs below the drainfield as the effluent percolates downward, in a micro-biologically active area known as a bio-mat. This area further treats the wastewater, trapping solids and metabolizing some nutrients and carbon. The bio-mat typically controls the infiltration rate in coarse or medium-textured soils, and treated
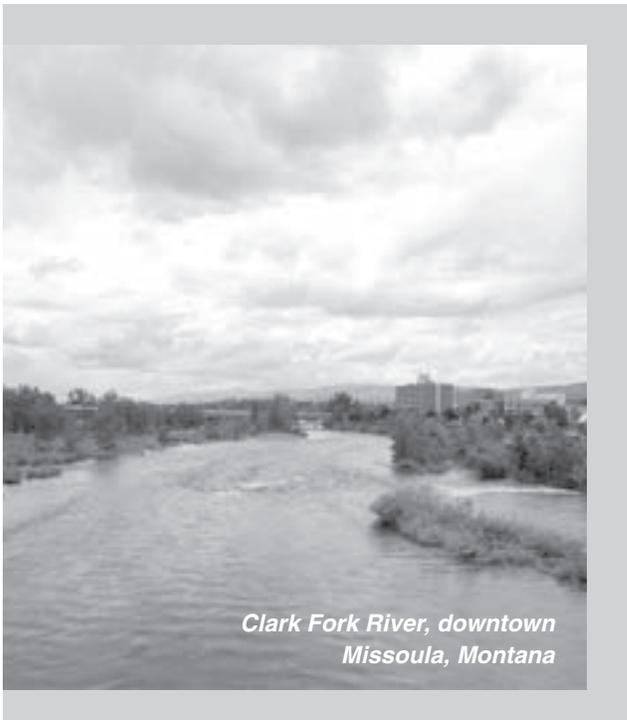
effluent passes down through a partly-oxygenated unsaturated zone before reaching groundwater.

When a conventional septic system is properly designed, operated, and maintained, it is capable of nearly complete removal of suspended solids, bio-degradable organic compounds, and fecal coliforms. (EPA, 2002). However, conventional systems are not able to completely remove several of the constituents typically found in wastewater. Table 2 summarizes the effectiveness of typical septic tank and drainfield systems in removing common constituents.

is common for this process to remove 85-95% of phosphorous, and complete removal typically occurs long before effluent reaches surface water. However, this is not always the case—particularly where soils are coarse and distances to surface water are short. Significant phosphorus has been detected in groundwater below some drainfields, and phosphorus plumes have been measured moving down-gradient from septic drainfields in sandy shallow aquifers (Harman et.al. 1996, Ver Hey, 1987).

Conventional septic systems are also generally quite effective in removing pathogenic bacteria

Table 2: Wastewater Efffluent Constituents and Treatment Efficiency in Soil

Constituent:	Effluent content (leaving tank): mg/L	Removal after percolation and treatment in a 3-5 foot vertical ìinfiltration zoneî
Biochemical Oxygen Demand	140-200	>90%
Nitrogen	40-100	10-20%
Phosphorus	5-15	0-100% (often 85-95%)
Fecal coliform bacteria	106-108	>99.99%
Organic chemicals (solvents, pesticides, etc.)	trace	>99%

Source: EPA, 2002 Tables 3-7 and 3-17 and 3-19

As the table makes clear, a major weakness of conventional septic systems is the inability to effectively treat nitrogen. Once septic effluent enters the soil profile below the drainfield, almost all the nitrogen is converted by nitrification to nitrate (NO3). Nitrate is a very soluble chemical, which is transported readily in dissolved form into and through the groundwater and ultimately to surface water. Thus it should come as no surprise that one of the biggest concerns in areas with large numbers of septic systems is high nitrogen levels in surface and groundwater.

On the other hand, one of the major strengths of septic systems in general is the ability to treat phosphorous. Phosphorus in wastewater effluent tends to attach itself, or sorb to soil particles in the unsaturated zone below septic drainfields. It

and viruses via infiltration and treatment below the drainfield. Once again, however, this treatment is not perfect. Outbreaks of groundwater borne pathogens linked to septic systems have been documented in several locations in the Northwest. Over 400 people were infected with gastroenteritis related to contaminated groundwater in Flathead County, Montana, in 1995; an outbreak of typhoid fever in Yakima County, Washington, 1981, was related to a septic system contaminating a shallow well; and a number of major outbreaks of gastroenteritis have been attributed to groundwater borne Norwalk-like virus in numerous states (Missoula Valley Water Quality District, 1996). Other pathogens of concern in wastewater effluent are protozoans like Cryptosporidium and Giardia. Improperly constructed drainfields, high water tables, or inappropriate geologic settings (fractured

OTHER CONSTITUENTS OF WASTEWATER

Surfactants are chemicals which are used in laundry detergents and other cleaning products to decrease the surface tension of water, and they are present in septic system effluent. The most common surfactants in household laundry detergents are linear akylbenzenesulfonate (LAS) and akylbenzenesulfonate (ABS). Surfactants can be readily bio-degraded by micro-organisms in aerobic conditions and possibly in saturated sediments. Concerns with surfactants include their ability to decrease adsorption and even actively desorb organic pollutants like trichlorobenzene from soils, and their deleterious effects on soil structure and infiltration rates (EPA, 2002).

Various chemicals known as "endocrine disruptors" have been detected in domestic wastewater. These chemicals, including bisphenol A (BPA) which is widely used in dental materials and plastic food and beverage containers, can interfere with the natural sex hormones in the body of fish and amphibians. Estradiol, a synthetic estrogen used in birth-control pills, is often found in domestic wastewater, and has been shown to cause major alterations in the sexuality of fish at extremely low concentrations (Kidd, K., 2003, Canadian Freshwater Institute). It has not yet been established whether the most common endrocrine disruptors are retained in soil during septic effluent filtration and treatment.

bedrock or karst systems) can allow pathogenic bacteria and viruses to reach groundwater, where they can survive for days and travel up to 30 meters.

Wastewater flow rates:

To get an idea of the combined impacts that septic systems in an area might have on adjacent waters, one must first estimate the amount of effluent typically discharged by each system, and the typical concentration of nitrogen. These numbers allow one to calculate the total amount, or load of nitrogen that can potentially reach adjacent waters.

The load to soils below a typical septic drainfield is estimated to be 25 lbs of nitrate and 4 lbs of ortho-phosphate annually. Some of these nutrients—particularly phosphorous—are further removed by biological, geochemical, and physical filtering processes in the soil below the drainfield. This process is quite variable depending on the type of soil, depth to groundwater, loading rate, age of system and other factors. The performance

of soil filtration in removing nutrients below septic drainfields ranges from 10 to 40 percent for total nitrogen and from 85 to 95 percent for total phosphorus. Using these numbers, one can reasonably estimate that a typical septic system discharges a total load of 19 lbs/year of nitrate and 0.4 lbs/year of orthophosphate to groundwater.

Not surprisingly, then, septic systems are the most frequently reported source of groundwater contamination in the U.S., and the single largest source, by volume, of wastewater discharged to groundwater. Nitrate is the primary contaminant that septic systems contribute to groundwater, and nitrate contamination in groundwater below septic drainfields is documented by an enormous literature. Studies have shown that groundwater nitrate loads and concentrations increase in areas with a high density of septic systems. In Helena, Montana, for example, a study has found that, between 1990 and 1994, average nitrate concentrations increased from an average of 1.25 mg/l to 1.70 mg/l as numbers of septic systems increased by 26% from 2,475 to 3,081.

SURFACE WATERS: How do contaminants get from groundwater to streams and lakes?

To understand how pollutants from septic systems can contaminate surface water, it is important to first understand the ways in which groundwater flows beneath the earth's surface and interacts with surface streams and lakes. Groundwater does not stay in one place, but flows from areas of higher water table elevation towards areas of lower water table elevation. Streams, rivers and lakes are usually low points in a watershed, and shallow groundwater within a watershed flows toward and discharges to these water bodies.

How Groundwater Flows

Groundwater flow paths vary greatly in length, depth, and travel time from points of recharge to points of discharge in the groundwater system.

RECHARGE AREA

DISCHARGE AREA

Stream

Water table

Unconfined aquifer

Years

Days

Confining bed

Confined aquifer

Centuries

Confined aquifer

Millennia
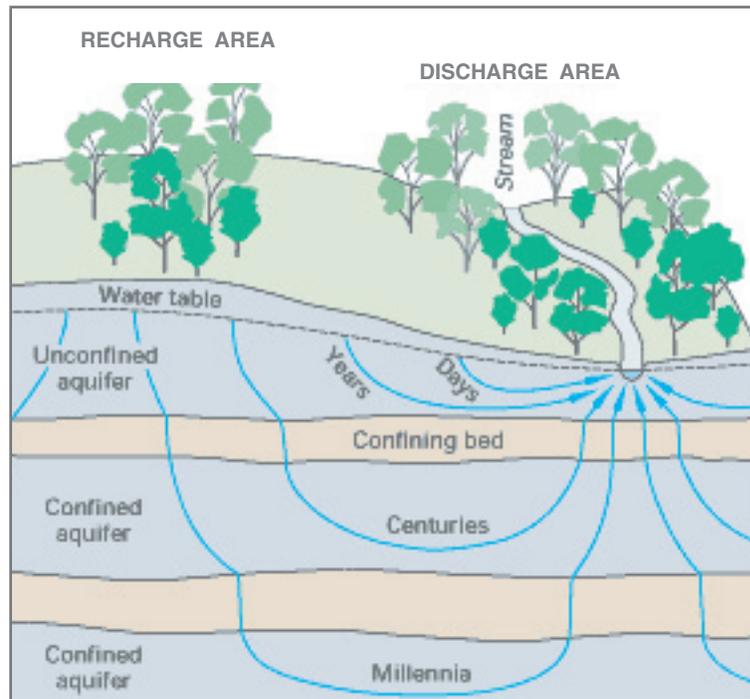
Figure from U.S. Geological Survey Circular 1139

Most of the broad inter-mountain valleys of western Montana, northern Idaho, and northeastern Washington are underlain by aquifers made up of silt, sand, gravel, and cobbles that were deposited by receding glaciers and the streams that flowed from them. These aquifers tend to be shallow, and produce abundant water for domestic, municipal and irrigation water supply wells. The high permeability of many of these aquifers permits relatively rapid infiltration of recharge waters from precipitation, flooding, irrigation, and septic systems. Examples include the Missoula valley aquifer, the Bitterroot valley aquifers, the Spokane River/Rathdrum Prairie aquifer near Couer d'Alene and Spokane, and aquifers in the Flathead valley, Mission Valley, Swan Valley, parts of the upper Blackfoot, and Deer Lodge valleys in Montana, and the Pend Oreille valley in Washington. (Glacial lake sediments, glacial till, and plutonic and volcanic rocks also are important aquifer materials in many areas of the inland Northwest, but are generally much less permeable than the Quaternary alluvial systems described above.)

Groundwater and surface water interact in complex and dynamic ways. The important concept is that surface water and groundwater are not separate, but rather consist of the same water circulating through the hydrologic system. Consequently, any impact to groundwater, such as the discharge from septic systems, will ultimately impact surface water. Managers of septic systems and other sources of groundwater contamination need to recognize that—in many of the geologic settings, such as basin-fill river valleys and lakeshores undergoing intense development pressure—groundwater contamination can have an impact on our surface waters, and vice versa.

Shallow groundwater transport of nitrogen and phosphorus to surface waters:

The discussion above shows that septic systems deliver significant loads of nutrients—and particularly nitrogen—to groundwater. Moreover, we know that groundwater in most intermountain valleys of the Northwest generally flows toward surface water and ultimately discharges to streams, river and lakes. Thus, one would expect to find that, in some cases, septic systems are contributing significant amounts of nutrients to surface waters, and causing negative impacts to area waters. This indeed turns out to be the case. Below are examples where such impacts have been documented and linked to the cumulative load from individual septic systems.

■ *Missoula Valley, Montana:* Groundwater enters the Missoula valley at its east end, flows west beneath the city and residential areas, and eventually discharges to the Clark Fork and Bitterroot Rivers on the west side of the valley. The east half of the valley is sewered, but the west side of the valley, which is experiencing significant population growth, is on individual septic systems. As groundwater flows from the sewered to the unsewered parts of the valley, nitrate concentrations increase above background levels. In general, nitrate concentrations increase by 0.5 to 2.5 mg/L as groundwater flows under the west valley toward the Bitterroot River (Land and Water, 1999).
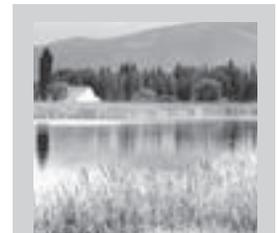
Septic systems have the potential to contaminate surface water in geologic settings—alluvial river valleys and lake fronts—where most development is concentrated.

1996 Nitrate-N Concentrations: Unsewered Missosula Area Study

Nitrate concentrations increase as groundwater moves west through Missoula Valley.
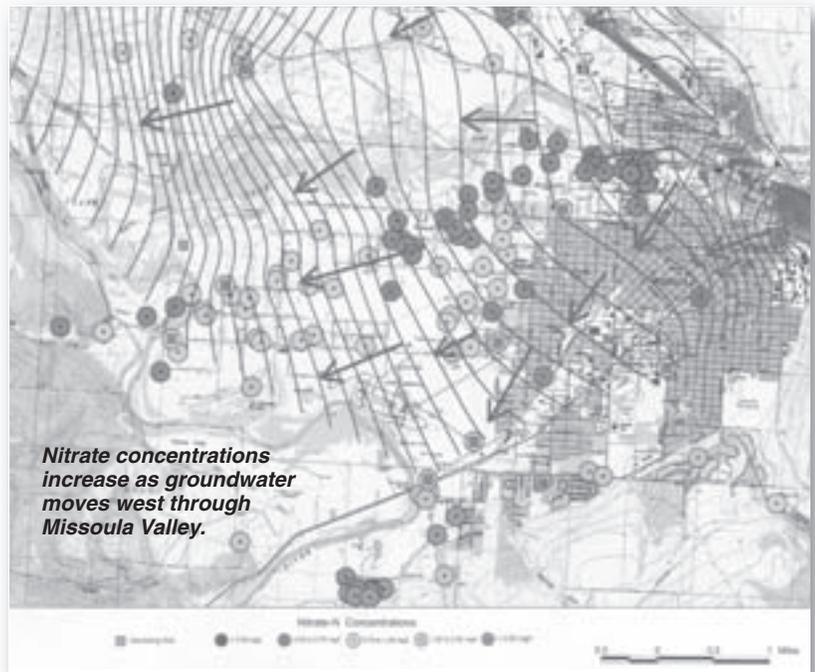
Source: "Evaluation of Unsewered Areas in Missoula, Montana," Missoula Valley Water Water Quality District, et al, March, 1996

Seeps and springs that discharge directly to the river have nitrate concentrations of 0.8 to 1.3 mg/L, which is significantly higher than normal concentrations in the river of 0.01 to 0.24 mg/L. The estimated flux of nitrate to the Clark Fork and Bitterroot Rivers is 120 tons of nitrate per year, and while the flux is seasonally variable, there are increases in nitrate concentration during summer months in the Bitterroot River as it flows past Missoula (Land and Water, 1999).

■ *Rattlesnake Valley, Missoula, Montana:* A similar pattern occurs in Rattlesnake Creek in the Missoula area. Upstream of the developed and unsewered portions of the valley, nitrate concentrations in the stream during baseflow conditions are extremely low (2.5 to 7.6 micrograms/L, equal to 0.002 to 0.007 mg/L), while below un-sewered development, stream nitrate increases 4 to 10 fold above background (Missoula Water Quality District unpublished data). Nitrate concentrations in monitoring wells in the valley are also elevated over background conditions, and contain detectable levels of pharmaceutical chemicals, indicative of a septic system source (Godfrey, 2004).

■ *Butte, Montana:* In the Summit Valley area of Butte, Montana, the Montana Bureau of Mines and Geology is investigating the impact of high nitrate in groundwater on surface drainages (LaFave, 2004). Out of about 150 recent and historic groundwater samples from the alluvial and bedrock aquifers, 64% have elevated nitrate concentrations (between 2 and 10 mg/L), and 15% exceed the drinking water standard of 10 mg/L. The nitrate-rich groundwater occurs below both sewered and unsewered parts of town, in both shallow and deep wells, and in areas not likely affected by past mining operations. The impact on local streams is obvious; upstream of populated areas, nitrate in Blacktail Creek is undetectable during base flow conditions (November 2001), but the concentration increases to over 1.0 mg/L over a 5-mile stretch through the most densely populated part of the valley. Analyses of nitrogen and oxygen isotopes in the contaminated groundwater point to an animal or septic waste source for the nitrate rather than fertilizer.

■ *Pine Lake, Washington:* Studies of Pine Lake, a small natural lake situated in glacial till in the Puget Sound area of Washington, analyzed the potential for shoreline septic systems to discharge nutrients to the lake (Gilliom, RJ, and CR Patmont, 1983, "Lake Phosphorus Loading from Septic Systems by Seasonally Perched Groundwater," J. Water Poll. Control Fed., Vol. 55:10, p.1297-1305.) The authors concluded that septic effluent was moving through perched groundwater toward the lake, and that 11% of the shallow groundwater from monitoring wells below residences near the lake was actually wastewater effluent. A small amount of phosphorus (less than

Mouth of the Clark Fork River and Lake Pend Oreille, Idaho

1 percent of the septic P load) was shown to be moving in the effluent towards the lake, and in a few cases where older septic systems were situated in saturated soils, a larger portion of the phosphorus was reaching the lake, either through shallow groundwater, or by surfacing of effluent which then passed into the lake as overland flow.

■ *Crystal Lake, Michigan:* In a classic study of septic wastewater influence on a clear-water, low-nutrient lake, Kerfoot and Skinner (1981) showed that both nitrogen and small quantities of phosphorus were being discharged into the lake where shallow groundwater was flowing rapidly towards the lake through lakefront developments. Septic effluent entered the lake by: 1) erupting plumes of effluent coming through the near-shore lake-bottom; 2) by "dormant" or passive plumes coming through the lake bottom; and 3) and by surface flow into the lake, at small streams that received septic effluent upstream of the lake.

These authors measured background levels of phosphorus in the lake and unaffected lakeshore groundwater at 0.004 mg/L, while shallow groundwater in septic effluent plumes along the lake was 0.017 mg/L dissolved phosphorus on average. They noted that this increase in concentration in phosphorus, although still low-level, was sufficient to cause impressive blooms of nuisance Cladophora green algae in the near-shore areas around the erupting septic plumes. They concluded that most of the septic effluent phosphorus had been retained by soil treatment, but that the small proportion (slightly less than 1%) which made it to the lake (called phosphorus "breakthrough") was sufficient to cause localized noxious algae blooms, but not sufficient to cause a change in the generalized lake level of phosphorus. They also verified that some coliform bacteria as well as UV light-sensitive detergent compounds were present in the septic discharge plumes entering the lake through shallow groundwater, and that the septic plumes could be easily detected with UV-sensitive equipment.

BACKGROUND NUTRIENT CONCENTRATIONS IN GROUNDWATER

To understand the potential impact of septic systems on shallow groundwater and on surface water, it is important to know the natural condition of the groundwater discharging into streams. Views on this subject have evolved in recent years.

Although earlier studies from the U.S.Geological Survey (USGS) defined concentrations of nitrate in groundwater exceeding 2 mg/L or even exceeding 3 mg/L as the levels indicating human impact on aquifer water quality (Madison and Burnett, 1985, Mueller et.al., 1995), newer studies have shown that natural nitrate concentrations are generally far lower .

In 2003, new USGS studies based on the National Water Quality Assessment (NAWQA) program for the continental U.S. concluded that, "Mean concentrations of nitrate in NAWQA land use studies showed 2.8 mg/L in agricultural areas, 1.45 mg/L in urban areas, and 0.06 mg/L in undeveloped areas." (Nolan and Hitte, 2003.) In relatively undeveloped areas, the median groundwater nitrate levels were 0.1 mg/L. These values are similar to data from similar land uses in Montana, Idaho, and Washington.

From the perspective of surface water contamination, the elevation of nitrate in alluvial groundwater to even the 1-3 mg/L level typical of urban and agricultural land uses, can be significant if groundwater is a major contributor to surface water flows. This is because typical levels of nitrate in natural streams, rivers, and lakes of the inland Northwest/Northern Rockies are 5 - 10 times lower than that level. (EPA, 2000, "Ambient Water Quality Criteria Recommendations-Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregion II, EPA Office of Water, Office of Science and Technology, Washington, DC; Clark Fork VNRP, Tri-State Water Quality Council, 1998). Therefore, nutrient-sensitive surface waters can experience significant excess nutrient loading from groundwater typical of agricultural or urban landscapes.

Mitigation of Nutrient Discharge from Septics to Surface Waters:

The previous sections discussed how significant quantities of nutrients from septic tanks can reach groundwater, and how that contaminated groundwater can reach streams and lakes and contribute to harmful nutrient enrichment. However, not all of the nutrients that reach groundwater necessarily make it to surface water. As we have seen, most or all phosphorous from septic systems usually sorbs onto soil particles long before reaching a stream or lake. Moreover, there are two processes that can eliminate at least some of the nitrogen from groundwater: plant uptake and denitrification. These two processes can reduce, but not always eliminate, impacts to surface water.

Plants will uptake nitrate from groundwater if their roots reach the water table. Plants incorporate nitrate into their tissues, where it remains until it is released back to the soil when plants die and decay. Thus, vegetation does not remove nitrogen from the ecosystem, but temporarily decreases its mobility. Nutrient uptake by vegetation occurs only during parts of the year when plants are growing; this precludes about half the year in western Montana.

Apart from uptake by plants, denitrification is the only other natural process that potentially removes nitrate from groundwater. Denitrification is a microbially mediated reaction in which nitrate in groundwater is reduced to nitrogen gas which diffuses to the atmosphere, effectively removing nitrogen from the terrestrial environment. The denitrification reaction requires a low-oxygen environment and a source of energy for the microbes. Typically the energy source is the dissolved organic carbon found in fertile, organic soils, but denitrification can also occur in the presence of ferrous iron, sulfide, or methane (Postma et al., 1991; Korom, 1992; Böhlke and Denver, 1995; Star and Gillham, 1993; Böhlke et al., 2002). Consequently, denitrification is most likely to occur in water-logged soils, in shallow groundwater overlain by rich organic soil, in organic-rich riparian areas where groundwater is close to the surface, and in aquifers containing trace amounts of iron sulfide (pyrite). Denitrification can occur anywhere in an aquifer if conditions are right: up-gradient from streams, in riparian areas, in the zone of groundwater-stream mixing, and in the benthic environment of the stream itself (Böttcher et al., 1990; Smith et al., 1991; Postma et al, 1991; Vogel et al., 1981).

Denitrification also requires a flow regime that brings groundwater into contact with reactive substrates for a sufficient amount of time to allow the reaction to occur. For example, shallow groundwater that discharges rapidly to a stream, or deep groundwater that discharges vertically to the stream bottom is less likely to undergo denitrification (Böhlke and Denver, 1995). Likewise, groundwater flow that discharges to ditches or drains will bypass the riparian zone and is less likely to be denitrified (Puckett, 2004). Denitrification is also less likely to occur where groundwater moves rapidly through coarse, gravelly, alluvial material (Pinay et al., 2003). A review of numerous studies of groundwater in riparian areas shows highly varying efficiencies of nitrate removal from groundwater, ranging from 0% to over 90% (Peterjohn and Correll, 1984; Lowrance et al., 1984; Jacobs and Gilliam, 1985; Lowrance, 1992; Korom, 1992; Puckett, 2004). As a mechanism of nitrate removal, denitrification may be very important in some areas, and completely negligible in others.

Regional examples demonstrate the conditions under which denitrification occurs. In the Upper Snake River basin of Idaho and western

Wyoming, areas with rapidly drained soils correlate with high-nitrate groundwater while areas with poorly drained soils contain groundwater with the lowest nitrate concentrations (Rupert, 1997). Out of 61 groundwater samples collected from wells in western Montana, northern Idaho, and eastern Washington, the USGS found no correlation between nitrate concentration and well depth or depth of the water table, but there was a strong correlation with dissolved oxygen; groundwater with undetectable nitrate also had very low dissolved oxygen concentrations, possibly indicating that denitrification was removing nitrate from groundwater (Caldwell et al, 2004).

In the Missoula valley, soil and groundwater sampling immediately beneath and down-gradient from septic systems demonstrates different mechanisms of nitrate dilution and potential attenuation in the aquifer. In the Orchard Homes area, nitrate was not removed in the soils below two separate drain fields, but dilution in groundwater was responsible for reducing nitrate to background concentrations (Ver Hey, 1987). Subsequent studies indicate that nitrate may be attenuated by factors other than dilution. By comparing ratios of nitrate to the non-reactive chloride ion, King (1987) found that nitrate decreased faster than chloride with increasing distance from drain fields, up to a threshold value, at which point the ratios remained constant. The reduction of nitrate concentrations in the aquifer could result from denitrification, or possibly from uptake by native bacteria in the aquifer.

Clark Fork River flowing west through Missoula, Montana

WASTEWATER TREATMENT:
What are the options when trying to achieve public health and resource protection goals?

Every community must find ways to treat its wastewater to levels that protect public health and water quality in streams, lakes, and aquifers. Communities in rural areas can often meet these goals using conventional septic systems, thanks to low population density and large lot sizes. Larger communities are often able to meet the same goals using centralized sewage treatment plants, thanks to their larger capital base. Caught in the middle are fast-growing suburban and semi-rural areas, which present the most difficult challenges for effective wastewater management. These communities often cannot use centralized sewer systems due to limitations on available capital. At the same time, the resources these communities must protect are often particularly sensitive to impacts, since residents typically rely on individual wells for drinking water, and residential development in the Northwest often occurs near rivers and streams that are sensitive to nutrient enrichment.

When a community must choose among various systems for treating its wastewater – on-site septic systems, centralized sewage plants with sewers, or smaller-scale collective treatment systems serving individual subdivisions – it should carefully weigh the inherent strengths and weaknesses of each. Each type of system poses risks to public health and aquatic environments, and must be managed with the various types of risks in mind.

Centralized systems offer several distinct advantages: they can provide the most nitrogen removal if they are fitted with biological nutrient removal (BNR) or other advanced treatment systems. Moreover, they centralize an entire community's discharge in one place where it can be easily monitored, where any problems can be readily detected, and where treatment upgrades can be installed with relative ease if found to be necessary in the future. On the other hand, centralized systems generally do not provide the same level of phosphorous treatment as on-site systems, at least when they discharge directly into a river and therefore do not get the benefit of treatment in the soil. Centralized systems can sometimes overcome this disadvantage by discharging to constructed wetlands or land-applying effluent to agricultural fields, but these solutions present additional design and operational challenges.

On-site septic systems treat phosphorous well. Although conventional on-site systems remove very little nitrogen, advanced septic designs are now available that can provide levels of nitrogen removal comparable to BNR at centralized systems, if they are maintained and operated properly. But ensuring proper maintenance and operation of these systems is a challenge. Their nutrient removal components can fail without showing any trouble signs to alert the homeowner to the failure. Moreover, these

systems effectively disperse wastewater treatment at hundreds or thousands of individual home sites, rendering effective monitoring, inspection, and enforcement virtually impossible. In addition, advanced systems are expensive.

Collective treatment systems – in which wastewater at the subdivision level (from several dozen to a few hundred homes (??)) is routed to a single on-site system – offer some of the advantages of both centralized and individual systems. Like individual systems, they allow for ample treatment of phosphorous in the soil before effluent reaches surface water. And like centralized systems, they route individual waste streams to a central point where monitoring, maintenance, and upgrades in treatment are much more feasible. In addition, collective treatment systems generally are required

to obtain groundwater discharge permits, which provide a way of ensuring that the systems are being properly monitored and maintained so that treatment is meeting design standards.

Comparison of Alternative Wastewater Treatment Systems in Nutrient Removal:

Table 3 below shows the nitrogen and phosphorous concentrations in wastewater effluent from different sources. It also illustrates the dangers of directly comparing effluent concentrations from different types of systems without considering the additional treatment provided in soil between the discharge and surface water.

Table 3: Comparison of Nutrient Concentrations Discharged from Various Types of Wastewater Treatment

Wastewater Treatment Technology (examples)	Total Nitrogen	Total Phosphorus
1. Lolo Conventional Secondary Wastewater Treatment 2. Missoula WWTP in 1992 – Secondary Treatment	22.0 mg/l 21.9 mg/l	3.8 mg/l 3.5 mg/l
3. Kalispell Biological Nutrient Removal WWTP - 2001 4. Missoula Biological Nutrient Removal (Design Goals)	9.4 mg/l 10.0 mg/l	0.11 mg/l 1.0 mg/l
5. Conventional on-site septic tank (EPA 2002).	40 - 100 mg/l	5 - 15 mg/l
6. Estimated Removal by Drainfield Soil Treatment (conventional septic system): (EPA, 2002, Table 3.17)**	10 - 40%	85 - 95%
7. Estimated Remaining Nutrients Discharged to Ground Water (based on #6 above) :	30 - 45mg/ l	0.5 - 1.6 mg/l
8. Montana Level 2 Nitrogen Removal Systems*	24 mg/l	10.6 mg/l (0.5 - 1.6 mg/l after soil treatment)

*Only three approved Level 2 systems exist for Montana
**Montana assumes residences discharge 50 mg/L nitrate to groundwater

REDUCING THE IMPACTS:
What are the existing policy and regulatory options for mitigating the impacts to surface waters?

As described in preceding sections of this paper, there is now a good deal of data establishing that septic tanks can, and often do, have significant effects on the water quality of streams and lakes, especially in regards to nutrients. To date, however, the potential for septic systems to degrade surface water quality has gone largely unrecognized in the federal, state, and local laws that are designed to protect surface water quality. As a result, many thousands of septic tanks are being permitted and installed in the Northwest each year with little or no analysis of their cumulative impacts on surface lakes and streams.

The following section describes the existing regulatory scheme that one state, Montana, uses for permitting septic tanks and other private sewage treatment systems. This discussion will focus on the ways in which that permitting scheme addresses— and fails to address—potential impacts to surface water. Montana was chosen as an example not only because it is most familiar to the authors of this paper, but also because it appears to have done more than any other state in the region to address surface water impacts from private wastewater systems. The Montana example then serves as the basis for a discussion of different alternatives for expanding existing laws and policies in ways that would recognize and mitigate these impacts.

Prescriptive versus performance-based approaches to wastewater management:

The various Montana laws governing wastewater systems use one of two general approaches to regulate impacts. The prescriptive approach focuses on the source of pollutants—the septic system itself —and sets forth minimum requirements for septic system design, siting and installation. An example of such requirements would be minimum setback distances from drinking water wells, surface water, and groundwater. In contrast, the performance-based approach focuses on the waters potentially at risk from pollution. This approach identifies the lakes, streams, or aquifers at risk, then attempts to calculate whether the these waters can assimilate the pollutant load from the wastewater system or systems in question without degrading water below acceptable levels (usually defined by ambient water quality standards). If not, the design approach requires alternatives such as advanced treatment, different siting, or not allowing the system to be installed at all. (EPA 2002).

At present, Montana regulates septic systems primarily by the design approach. Although Montana does not generally apply the design approach to prevent septic system impacts to surface waters, it does have the legal framework in place to impose such controls if it were deemed necessary to do so.

Prescriptive-based laws and regulations:

- *State and local septic system regulations:* As mandated by statute, the Montana Department of Environmental Quality (MDEQ) has enacted minimum standards for the design, installation, and maintenance of conventional septic systems. These regulations generally ensure the systems will provide the level of treatment described

in Chapter 3 of this paper – i.e., removal of most pathogens and the nutrient phosphorous. Recently, MDEQ enacted a set of minimum standards for advanced septic systems that can remove significant levels of nitrogen as well. These systems, designated Level II systems, are available for use when conventional systems are unable to meet minimum water quality standards required by performance-based laws discussed in section 6.3, below.

State law requires local boards of health to enact and enforce septic system regulations that are at least as stringent as the MDEQ standards discussed above.[1] Local boards may also, under certain conditions, enact septic regulations that go beyond state standards. These may be used to restrict or prohibit septic systems in certain areas due to local conditions. For example, the Missoula City-County Health Board has established three separate districts where new or enhanced treatment is required. In one case the district was established because an area has high existing groundwater nitrate concentrations, and in another case because the area has high groundwater elevations. The third district comprises the entire service area of the Missoula municipal wastewater treatment plant, where the policy is to encourage new development to connect to the sewer system as soon as it is practical to do so.

■ *State subdivision regulations:* Montana's subdivision laws contain density limitations or minimum lot area requirements for septic systems, which are primarily intended to mitigate impacts to human health. These regulations require a minimum lot size of one acre for each on-site wastewater system and well in a proposed subdivision. If a community water supply or wastewater system will serve the subdivision, the minimum lot size is decreased to 20,000 square feet. If both a community water supply and a community wastewater system are provided, lot sizes can be smaller.

(Montana ARM 17.36.340). The intent of these regulations is to protect human health by providing adequate buffers between septic systems and drinking water wells to allow adequate treatment of pathogens and other harmful substances. However, these regulations may provide incidental benefits to surface waters to the extent they limit the total number of homes that can be built in an area, thereby limiting the total nutrient load.

Performance-based laws and regulations:

■ *Nondegradation policy:* The primary performance-based Montana law protecting surface water quality is the state nondegradation policy, codified at MCA 75-5-303, which implements the substantive requirements of the federal Clean Water Act.[2] The nondegradation policy makes it illegal to engage in any activity that will cause significant degradation of high-quality waters, which include the vast majority of natural surface waters in the state.[3] Both the statute and related administrative rules contain extensive provisions describing activities that, by definition, are not legally significant degradation.[4]

In order to obtain a permit for a septic or other private wastewater system, one must establish that any deterioration in water quality caused by the system will fit within one of the recognized definitions of nonsignificant degradation. Since most systems are permitted in the context of proposed subdivisions of land, this nondegradation analysis is usually done by the developer as a condition of receiving final
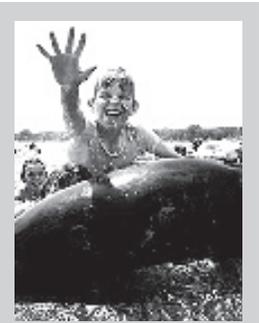
Regulatory systems designed to protect groundwater will *NOT* protect surface water adequately.

*Blackfoot River, Montana*

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[1] MCA § 50-2-116(1)(h)(i).

[2] *See* 40 CFR § 131.12.

[3] *See* MCA §§ 75-5-303(2), -301(5)(c).

[4] *See* MCA §§ 75-5-301(5)(c), -301(5)(d), and -317; ARM §§ 17.30.715 and -716.

approval for the subdivision from the local government authority.[5] The developer does this by submitting site-specific sampling data and analysis, which is reviewed by specialists at the state Department of Environmental Quality (MDEQ) or, in some cases, by local specialists certified by MDEQ.[6] In the case of sewage systems, the analysis focuses on nitrogen and phosphorous, the two relevant pollutants for which the state has adopted water quality standards.[7]

The nondegradation rules provide several ways to establish that a discharge of nitrogen and phosphorous will not significantly degrade surface water. In the case of nitrogen, most domestic sewage systems are not required to undergo any surface water nondegradation analysis at all. The only exceptions are those systems that are close enough to a lake or stream to be considered "adjacent" to surface water, a determination that MDEQ makes on a case-by-case basis. In these cases, the permitee must submit site-specific data and modeling to establish either (1) that the discharge will not cause the surface water concentration of

nitrogen to increase by more than the trigger value for nitrogen (.01ppm), or (2) that the discharge will not violate the narrative standard prohibiting any "measurable changes in aquatic life or ecological integrity."[8]

In the case of phosphorous, the vast majority of discharges are found to be nonsignificant by the submission of a "phosphorous breakthrough analysis" that analyzes the adsorption capacity of the local soil. A discharge is considered not to cause a significant degradation of surface water if the breakthrough analysis shows that no phosphorous from the system will reach surface water for at least 50 years.[9] In the rare cases where a site fails to pass the breakthrough analysis, the permitee can establish that the discharge is nonsignificant using the trigger value approach described above (except that the trigger value for phosphorous is .001 ppm), or by showing the discharge will not have a measurable impact on aquatic life or ecological integrity.[10]

A weakness of the trigger value and narrative standard approaches is that they do not consider cumulative impacts. That is, the question in each case is whether the individual development being reviewed will cause the trigger value or narrative standard to be exceeded, without regard to the impacts of existing or future development.[11] As a practical matter, the discharge from a single small subdivision, much less a single septic system, is seldom if ever sufficient to cause a .01 mg/l increase in nitrogen in a river or lake, especially considering that compliance is not measured where the discharge to surface water occurs, but rather at the end of a potentially lengthy mixing zone. As a result, the trigger value approach has had little or no effect on the permitting of domestic wastewater systems, even in areas of the Clark Fork and lower Bitterroot

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5 *See* MCA §§ 76-3-504(1)(f)(3) and -76-3-604.

6 The permitee need not submit a site-specific nondegradation analysis if site-specific data show that the site qualifies for one of the categorical exemptions spelled out in the rule. These exemptions are based on considerations such as soil type, depth to groundwater, and distance to surface water. See ARM 17.30.716(2).

7 *See generally,* "How to Perform a Nondegradayion Analysis for Subsurface Wastewater Treatment Systems," MDEQ handbook, March 2005.

8 This section of the rule applies where only narrative standards for nutrients exist. On the Clark Fork River between Warm Springs

Ponds and the Flathead River, where numeric standards for nitrogen and phosphorous has been adopted, the permitee would have to show that the predicted in-stream concentration after the discharge is mixed in-stream was less than 15% of the numeric standard in order for the discharge to be considered nonsignificant.

9 ARM § 17.30.715(1)(e).

10 ARM §§ 17.30.715(1)(c) and -715(1)(g). Trigger values are found in DEQ Circular WQB-7 (numeric water quality standards).

11 *See* "How to Perform a Nondegradation Analysis," p. 45. However, multiple phases of a single development proposal are considered to be a single development and are reviewed together for trigger value compliance. Id.

valleys where data suggest that the cumulative load from these systems far exceeds the trigger value, and is likely a significant contributor to algae growth as well.

In addition to the above provisions related to surface water, Montana's nondegradation rules contain other, far more extensive provisions regulating the concentration of nitrogen in groundwater.[12] These groundwater regulations are driven primarily by the need to keep levels of nitrogen from approaching the 10 mg/l human health standard for groundwater. In actual practice, compliance with groundwater standards—which is highly dependent on local factors such as, lot sizes, alignment of drainfields, and dispersion rates—dominates the nondegradation analysis for most proposed subdivisions. Surface water concerns play only a minor role.

■ *Surface water discharge permit regulations:* Montana regulates point-source discharges to surface water under the Montana Point Source Discharge Elimination System, or MPDES program. All wastewater systems, including septic tanks, technically qualify as point sources under the MPDES regulations, which define that term as "any discernible, confined, or discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, [or] conduit . . . from which pollutants are or may be discharged."[13] Despite this, however, MDEQ does not require privately-owned sewage systems to obtain MPDES permits, even when they discharge pollutants to surface water via hydrologically-connected groundwater. The legal reason for this is not clear.[14] MDEQ does require point-source discharges to hydrologically-connected groundwater in other contexts, such as mining, to obtain MPDES permits. Therefore, MDEQ does have the legal authority to regulate septic systems that have the potential to discharge nutrients to surface water under the MPDES program, should MDEQ choose to exercise that authority.

There are several potential ways the MPDES system could fit into an overall scheme to control cumulative nutrient impacts from septic tanks and other sewage systems. For example, while it would obviously be unmanageable to require every septic tank that discharges to alluvial aquifers in a river basin to get an MPDES permit, the state could prepare a general permit setting forth specific requirements for geographical areas within basins where nutrients are known to be a problem. Such requirements could include the use of level II treatment systems where appropriate. In the case of collective systems, it might be desirable to require individual MPDES permits, not only to require advanced nutrient treatment, but also as a way to implement monitoring requirements to insure that nutrient removal is functioning effectively and to provide information about the load these sources are contributing to surface water. Such information could help to equitably allocate cumulative loads among various dischargers, as discussed in more detail below.

■ *Groundwater discharge permit regulations:* Montana regulates discharges of pollutants to groundwater under the Montana Groundwater Pollution Control System (the MGWPCS program). Due to a series of statutory and regulatory exclusions, privately-owned sewage systems are not required to obtain MGWPCS permits unless they have a design capacity of greater than 5,000 gallons per day (equivalent to about 25

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[12] *See* ARM §§ 17.30.715(1)(d) and -716(2); see generally "How to Perform a Nondegradation Analysis."

[13] ARM § 17.30.1304(41).

residences).[14] In many cases, these exemptions allow developments to avoid being regulated by the MGWPCS system by installing two or more smaller-capacity collective systems instead of a single large system, or by installing individual septic tanks. As noted in Chapter 5, centralized, permitted systems offer several advantages over individualized systems because they route sewage to a single collection point and treatment system, greatly simplifying the tasks of monitoring, maintenance, and inspection. In addition, the effluent limits and ambient monitoring requirements imposed by MGWPCS permits could provide important information that could be used for equitable load allocation.[15]

■ *Total Maximum Daily Load provisions:* The Montana Water Quality Act contains a process for reducing pollutants such as nitrogen and phosphorous to allowable levels in a stream or lake where they currently fail to meet water quality standards. This process, which is set forth in the federal Clean Water Act, is known as the Total Maximum Daily Load, or TMDL program.[16]   The basic concept behind the TMDL process is relatively simple. In basic terms, the process consists of determining the total load of a pollutant that can be discharged into a waterbody while still meeting standards,

allocating equitable portions of that load to each of the identified sources of that pollutant, and then implementing controls on each source to ensure it does not exceed its allowable load.[17]

In reality, the process of developing a TMDL is very complex to say the least. In practical terms, the process is complicated by variables such as flow rates, discharge rates, and in-stream attenuation, each of which can be highly variable across time and space. In legal terms, the process is complicated by the fact that regulators may impose mandatory restrictions only on point sources, while all controls on non-point sources are voluntary. Therefore, if there is a general increase in loading from non-point sources over time, point sources tend to suffer, since they are the only sources on which regulators can impose mandatory restrictions to meet standards.

Despite the complications, Montana has developed a TMDL for nitrogen and phosphorous in one 200-mile long reach of river, the Clark Fork River between Warm Springs Ponds and the Flathead River confluence. This TMDL is based on a computer model that considers the discharges from the four largest point sources on this reach (three municipalities and one paper mill), an estimated cumulative

Bitterroot River, Montana

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[14] *See* MCA § 75-5-401(5)(h); ARM § 17.30.1022(c) through (f).

[15] *See* ARM § 17.30.1031(5).

[16] *See* 33 U.S.C. § 1313(d)(1)(C); 40 CFR § 130.7; MCA § 75-5-03.

[17] *See* 40 CFR §§ 130.7(c) and 130.2.

discharge from over 6,000 septic systems in the Missoula valley, the inputs from each major tributary, and a calculated allowance for the total non-point discharge for each designated sub-reach of river. Measures were then developed to reduce the discharge from each of the four major point sources, and one concentrated group of septic systems in Missoula, and, using the model, a prediction was made that if the point sources implemented these measures the river would comply with numeric standards for nitrogen and phosphorous. These numeric standards were developed for this particular reach of river based on many years of monitoring data for both nutrients and algae.

A weakness of the Clark Fork River TMDL is that it does not allocate nitrogen and phosphorous loads to point sources other than the four major dischargers. Although plans exist to bring smaller point-sources that discharge directly to surface water into the TMDL in the next few years as their MPDES permits are renewed, there currently are no plans to allocate loads to sources such as sewage systems that discharge nutrients to surface water indirectly via hydrologically-connected groundwater. Instead, the TMDL treats these discharges as non-point source pollution. Therefore, the TMDL presently contains no mechanism to prevent the increasing load from septic tanks and privately-owned collective sewage treatment systems from "eating into" the load that is presently allocated to point sources that discharge to surface water directly.

It is possible to assign load allocations to groundwater dischargers in a surface water TMDL. Collective sewage systems with capacities greater than 5,000 gpd already have MGWPCS permits, with calculated limits on the maximum load they may discharge to groundwater. Where adequate aquifer data exist, rough estimates could be made of the amount of their load that reaches surface water, and this load could be incorporated into the TMDL. Where systems discharge in close proximity to the river, it might make sense to conservatively estimate that 100% of

the load goes directly to surface water, while in the case of more-distant dischargers, some fraction of the load might be more appropriate. Although smaller systems such as septic tanks would provide a greater challenge due to their sheer numbers, estimates of their surface water load could still be made in many cases. Local governments have data on the location of most if not all septic permits within their jurisdictions, and standard assumptions could be used regarding the average daily load generated by a residential septic system. Although the surface water loading calculations for all groundwater dischargers would necessarily be inexact, they might represent a significant improvement over the alternative of simply ignoring these point sources in a nutrient TMDL.

Discussion of policy alternatives:

It is clear that the existing legal framework in Montana already provides the tools that could be used in concert to mitigate and prevent surface water quality impacts from septic systems. These tools include both prescriptive and performance-based approaches. Montana's water quality-based standards and non-degradation policy could be used to identify waters that are impaired or at risk from excessive nutrients. The non-degradation policy could be used—provided some way were developed to account for cumulative impacts—to identify development projects that threaten to cause unacceptable degrees of degradation. Point-source regulations and design standards could then be used in conjunction with land use regulations to control the size of cumulative nutrient loads, both by requiring higher levels of treatment and limiting the number of systems allowed in a given area. The TMDL system could provide a way of allocating cumulative nutrient loads between different areas, and between point and non-point sources. Finally, local governments could identify areas within their boundaries that are particularly sensitive to nutrient impacts—as Missoula County has already done—and apply higher levels of protection to those areas by requiring advanced treatment, collective on-site systems, or connection to a municipal sewer system.

CONCLUSIONS

- Rapid development of valleys and property near streams and lakes in rural counties of the inland Northwest highlights the potential for septic systems to contaminate surface waters—a different issue than the typical human health focus of septic system regulation.

- Septic system effluent is discharged to shallow groundwater, which moves along flow lines and eventually carries soluble constituents like nitrate nitrogen toward surface water.

- Other constituents of septic effluent, such as phosphorus, pathogenic organisms, and some household products, are mostly removed during the soil treatment process, but have also been detected in groundwater near septic systems.

- Shallow groundwater affected by septic effluent discharges into streams, rivers, and lakes in many geologic settings. Alluvial basin-fill valleys and lakeshore areas where shallow groundwater flows towards waterfront are prime areas for septic nutrients—especially nitrates, but sometimes small quantities of phosphorus—to be discharged through the groundwater into surface water.

- As nutrients from septic effluent are transported in ground water, partial mitigation by chemical denitrification or biological uptake may occur, but is not assured.

- Levels of nitrate nitrogen in shallow groundwater under developing areas are often far higher than background concentrations, and far higher than their concentrations in healthy surface waters. Phosphorus concentrations in groundwater, even when low, are often higher than levels in clean streams and lakes. This means that shallow groundwater flowing into streams, rivers and lakes from developed areas is expected to increase nutrients, especially nitrates, in these surface waters.

- In settings where septic-contaminated groundwater inflow makes up a significant portion of surface water flows, surface water nutrient loading from septic effluent will occur, and can be a significant portion of total nutrient loads to sensitive waters.

- In lake-front settings, septic systems have been documented to discharge not only nitrogen but also phosphorus to the lakes via a shallow groundwater aquifer, causing near-shore noxious algae blooms.

- In general, septic systems are a significant source of nutrients, especially nitrates, to groundwater and surface water in rural areas experiencing rapid growth. New septic systems inexorably add nitrates to the cumulative nutrient loads in surface waters. Other factors common to land development (e.g. construction sediments, road runoff, fertilizers, industrial projects) also typically increase phosphorus loading to surface waters. This combination of nitrate and phosphorus loading is highly detrimental to fresh water lakes and streams.

- Technical options for reducing the septic nutrient load to surface waters include various alternative septic systems, but management of septic system impact will require attention to cumulative effects at a watershed level, not just technical options.

- In some cases, using new nutrient-reduction septic systems actually encourages further development in sensitive watershed areas that would not have been built out with traditional septic systems. For nutrient-sensitive surface waters, this could result in a net loss of water quality.

- Subdivision-scale collective treatment systems may offer the best way to control wastewater nutrients in suburban and semi-rural settings, combining some advantages of both centralized sewers and individual septic systems.

- Some states address the possibility of phosphorus "breakthrough" into surface waters from older septic systems. Other states ignore this possibility.

- Some states currently require analysis of septic nutrient loading to surface waters, including phosphorus "breakthrough" as septic systems age. Other states do not address this issue.

- It is unclear to what extent TMDL implementation will address the cumulative nutrient load issues of septic systems in rapidly growing rural areas.

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