CE 440
Introduction and Overview

Text Reading: Preface, pages 1-43, pages 68-71

Define point source pollution.

Define nonpoint source pollution.

Point and nonpoint pollution are legal terms, thus the term diffuse pollution is sometime used to avoid the legal connotation.

Much of the point source pollution in developed countries has been controlled using waste treatment or waste minimization technology.

In the U. S., over 50% (and probably over 75%) of the remaining pollution is thought to be the result of nonpoint sources, of which agriculture is the largest source.

Control of nonpoint sources has been neglected in the U.S. until recently. The Clean Water Act Amendments of 1987 were the first to address them to any great extent. In some European countries, though, control of nonpoint sources is more advanced.

What characteristics of nonpoint sources would make them more difficult to control than point sources?

Nonpoint sources are characteristic of both rural and urban environments. List a few examples of each type.

Defining Water Quality

How would you define the term water quality?

Water quality variables--chemical, physical, biological

Examples of each

Major causes of environmental impacts are population increase and associated land-use transformation such as:

Key nonpoint pollution problems and associated water quality variables

Sediment (rural and urban)
Salinity (rural, surface and groundwater interactions)
Nutrients (rural and urban)
BOD and DO (rural and urban, surface water)
Metals (rural and urban)
Aquatic habitat, ecological integrity (How would you define integrity?)

The values of water quality variables which are needed to support specific uses are defined legally via water quality standards and criteria.

Waste-assimilative capacity concept, see pages 29-30 in the text.

Water Quality Variables and Standards

Water quality may be described through observation of **chemical, biological, and physical** factors or processes. We call such observations **water quality variables** or sometimes water quality constituents. The term "water quality parameter" is often used as well but is less precise because of possible confusion with the concept of model parameter.

Which water quality variables are most important in NPS pollution management?

Most water quality variables of interest in nonpoint pollution management are simply measurements of concentrations of chemical constituents, typically in mg/l. However, for a complete picture of water quality, biological variables are equally important. Examples of biological variables include population densities of specific organisms, such as rainbow trout or stonefly nymphs or indices which combine several individual measurements.

Diversity indices are sometimes used to describe the health of a particular aquatic ecosystem. The more diversity in species present, the greater the health of the system. A system which is strongly impacted by pollution might be expected to have many fewer species present than an unimpacted system.

A biological variable which has wide application in water quality is **coliform bacteria.** Although total coliforms are sometimes used as a water quality indicator, there are many types of coliforms bacteria, found widely in unpolluted environments. The particular coliform of most interest is *E. Coli*, found in the intestinal tracts of mammals and a valid indicator of fecal contamination. *E. Coli* itself is not pathogenic, but is often used an indicator for disease-causing bacteria. Coliform counts are expressed as a "most probable number" or MPN per 100ml. The MPN is not an actual count but is a tabulated value based on the results of a series of tests.

In the case of agriculture, the major concerns from a ground water perspective are definitely **nitrates** and **pesticides**. The major health concerns are "blue-baby syndrome" and cancer, respectively.

Nitrates are an essential plant nutrient and major component of fertilizers, both synthetic and "organic". Nitrates are of course naturally occurring in the soil as well. In areas with high nitrates in ground water, the source of the problem--natural or the result of fertilizers--is often highly controversial. There are a few very expensive studies, in Nebraska for example, which have definitively shown the local problem to be a result of fertilizers, but these results cannot be extended universally.

In the case of pesticides, we restrict our attention largely to synthetic compounds, although a few (such as pyrethrins) are naturally occurring. Incidentally, the danger posed by natural toxicants in foods is receiving increased attention of late.

Nitrates and pesticides are also a concern in surface water quality. Nitrates are carried into surface water supplies dissolved in surface runoff. Pesticides may be carried in either the dissolved form and/or adsorbed on eroded sediment depending on the adsorption characteristics of the particular chemical.

Phosphorus (occurring in the soil as orthophosphate or phosphate), another essential plant nutrient and major component of fertilizers, is strongly adsorbed on soil particles and is thus a concern only in surface water pollution. The primary polluting effect of phosphate is the eutrophication of lakes. Both nitrates and phosphates are nutrients which are required for algae growth and contribute to eutrophication. Either nutrient may be the limiting factor in algae production, but phosphorus is most often thought of as the primary limiting factor. However, both nutrients must be present for eutrophication to occur.

Metal ions are associated with pollution from mines and application of municipal and industrial sludges to land. Some metals, such as lead, are quite toxic. The primary metals of concern in Colorado are lead, zinc, copper, manganese, nickel, iron and cadmium. Metals problems are closely related to **pH.** At low pH, metals occur in dissolved form. At higher pH, the metal ions are adsorbed on sediments and may be carried along by streams or settle out along with the sediment particles. Most mines are in the mountains were stream velocities are high. Furthermore, mine drainage is often fairly acid, thus metals problems tend to be fairly acute in the mountains close to mines and lessen in severity as the streams flow into rivers and out onto the plains. The Arkansas River is a good example. Fish kills from mine pollution occur as far downstream as Buena Vista, and fish populations are stunted still further downstream. However, metals are not really a problem once the river leaves the mountains.

Once out on the plains, though, the Arkansas, South Platte, and Colorado Rivers are extensively used and reused for irrigation. As water flows through the soil and much is lost by evaporation, **salts are picked up and concentrated**. The result is very salty water for downstream users. Salt concentrations are often too high for irrigating most crops as the Arkansas, or what is left of it, flows out of Colorado into Kansas. The U.S. is spending millions of dollars to remove salt from the Colorado River via a desalting plant at the border with Mexico. A large irrigation improvement project in Colorado and Utah (the Colorado River Salinity Control Project) is designed to minimize deep percolation of irrigation water and keep salt out of the river in the first place. Salinity is a long-term effect of all irrigation projects in arid regions and is **one of the greatest problems facing irrigation worldwide.** Salts may be measured as total dissolved solids, (TDS in mg/l) including nonionic species, or using conductivity measurements (micromhos/cm), which reflect only ionic species. Roughly speaking, 1.5 micromhos/cm (μS/m) conductivity corresponds to about 1.0 mg/l dissolved *salts*. The relationship between the two types of measurements depends on the composition of a particular water system, though.
(Note: 1 mho=1 siemen; 1 mmho/cm=1deciSiemen/m; 1 micromho/cm=1 μS/cm).

Irrigation return flows may become contaminated with toxic chemicals as well. Pesticides are an obvious example, but the naturally occurring element **selenium**--an essential nutrient at small doses--is a big problem as well for irrigation in the Central Valley of California, one of the richest irrigated regions on earth. The now infamous Kesterson Reservoir was used as an evaporation pond (with no outlet) for drainage waters from thousands of acres of irrigated fields. Over time, selenium and pesticide concentrations in the reservoir reached toxic levels, and vast wildlife populations were threatened. (The shallow reservoir/wetlands were ideal habitat for thousands of birds and other wildlife.) Now irrigation return flows have had to be suspended and diverted to other evaporation ponds constructed at large expense. The long-term viability of irrigated agriculture in the area is threatened. Selenium is also a major issue in the Gunnison Basin of western Colorado and in the Colorado River due to its impact on endangered species of fish. Irrigated agriculture is a major source of this contaminant.

Suspended sediment is perhaps the most important nonpoint source water quality impact of agriculture, urbanization, and mining. Anytime that natural cover of vegetation is removed, soil erosion will be accelerated. The resulting damage occurs to the area from which soil is lost in the form of reduced productivity and downstream through destruction of fish habitat and spawning areas, filling in of reservoirs, and transport of nutrients and toxics to reservoirs. Suspended sediment may be measured directly (in mg/l) or indirectly through a surrogate, turbidity, measured in turbidity units via a Jackson candle or nephelometer. The Jackson candle method measures the penetration of light through a sample and the nephelometer measures light scattering. A closely related measurement (of water clarity) is secchi disk depth. One suspends a black and white disk in the water and measures the greatest depth at which it is visible. For extremely clear water, such as Lake Taupo in New Zealand, this depth may be several meters.

Paradoxically, too little suspended sediment in streams and rivers may be as undesirable as too much. Reservoirs, acting as sediment traps, may result in undesirable downstream impacts such as increased bank erosion and destruction of beaches (Lake Powell on the Colorado River) and may result in loss of productivity of soil which was historically replenished by annual floods dropping sediment (High Aswan Dam in Egypt).

Agriculture, especially livestock production, and urbanization may also result in increased loading of organic materials to streams. The resulting biological activity, microbial decomposition of the organic matter, consumes oxygen and may result in the death of fish, trout being among the more sensitive. The **dissolved oxygen concentration (**mg/l) for a particular stream is thus strongly influenced by nonpoint loadings. DO concentrations are highly temperature dependent and exhibit a strong diurnal fluctuation or periodicity.

Biochemical oxygen demand, BOD, and **chemical oxygen demand**, COD, are measures of the organic materials present in a water sample. The most common BOD test takes 5 days, during which time organisms in the water sample consume the organic material present, using oxygen in the process. The drop in dissolved oxygen concentration over the five day period is the BOD_5. For high BOD concentrations, dilution of the sample is necessary to prevent die-off of the organisms due to oxygen depletion during the five-day period. The measurement process is time consuming and subject to large experimental variability. COD measurements are much quicker, involving chemical oxidation of "everything" in the sample using potassium permanganate or other strong oxidizing agent in boiling concentrated sulfuric acid. COD measurements are much more reproducible than BOD measurements, but more material would often be oxidized in the COD experiment than would be in a natural water system. The BOD experiment is more representative of the natural situation.

Physical variables of interest include **temperature** and color. Temperature is especially important because of the relationship dissolved oxygen and temperature. There is an inverse relationship between the DO concentration at saturation and temperature. Thus organisms, such as trout, which are sensitive to low DO levels cannot tolerate higher water temperatures. The practice of removing riparian vegetation as a part of land development for grazing, urbanization, flood control etc. can have a serious effect on stream temperatures.

Other commonly reported water quality variables are total hardness (reflecting mainly calcium plus magnesium concentrations) and alkalinity (or acid neutralizing capacity).

Nonpoint Pollution in Colorado

In Colorado the Department of Health reports that 94% of the stream miles that have been fully assessed have adequate quality for their use classifications. The U.S. Geological Survey reports that ground water, which supplies 18% of the total use within the state, generally is suitable for most uses.   However, there are significant water quality problems resulting from nonpoint pollution. The Colorado Nonpoint Assessment Report indicates that 2087 miles of the major river systems are affected by agricultural nonpoint sources of pollution including **sediment, nutrients and salinity**. Of this total, 585 miles are judged to have experienced "severe" impacts. As a result of mining, 1283 miles of the major streams have been impacted, of which 270 are judged to be "severe". Urban runoff is said to impact on 150 stream miles, while hydrologic modification and silviculture affect only 16 and 43 miles respectively. The same report state that 10,758 stream miles are not impacted by nonpoint sources. The major river basins considered are the Platte, Republican, Arkansas, Rio Grande, San Juan, Colorado and Green.

Ground water resources in the state have not been as thoroughly evaluated, but are being monitored by the Colorado Department of Health and Environment and other agencies. There are significant problems in some areas, the most notable being nitrate contamination. A 1989 survey of wells in Weld County conducted by the North Front Range Water Quality Planning Association found nitrate concentrations above the drinking water standard (10mg/l nitrate nitrogen) in over half of 350 wells samples. The same study found very few nitrate problems in Larimer County. A study of ground water in the San Luis Valley by CSU and the Colorado Department of Health found nitrate exceeding drinking water limits in about one third of the 68 samples tested. Sixteen detections of four different pesticides were also obtained. Those pesticides were sencor, eptam, (both potato herbicides), 2,4-D (grain herbicide) and bravo (potato fungicide). All but one of the pesticide detections were trace amounts, and some may be a result of contamination of the well itself rather than leaching of chemicals over a broad area of the field.

In 1991 EPA released the results of the National Pesticide Survey, a carefully designed sampling program including 564 community wells and 783 rural domestic wells. The survey was designed to answer questions like the following with great statistical precision: What fraction of wells in the U.S. are contaminated by pesticides? What fraction of wells in the U.S. exceed drinking water standards for nitrate? Is the occurrence of pesticides or high nitrates in wells correlated with easily measurable factors such as depth to water table?

The survey found that 10% of community wells and 4% of rural domestic wells had detectable levels of at least on pesticide. Less than 1% of all wells exceeded drinking water limits for pesticides, however. 1.2% of community wells and 2.4% of rural domestic wells exceeded the drinking water standard for nitrate.

Laws and Regulations Governing Nonpoint Pollution

The Clean Water Act

The basic piece of federal legislation regulating water quality impacts on streams is the **Federal Water Pollution Control Act** also known as the **Clean Water Act**. Its original version (PL 84-660) was enacted in 1956. It has since been amended several times. The 1972 amendments (PL 92-500) placed emphasis on the regulation and monitoring of point sources discharges via a permit system, NPDES, which has since been taken over by most states.   The 1987 amendments, also known as the **Water Quality Act of 1987**, first began to seriously address nonpoint sources of pollution.   The pertinent sections of the

1987 Act include 316 (renamed and commonly known as **Section 319**), and 405 (which actually amends section 402.)

Major provisions of the Act include requirements for states to develop **nonpoint assessment reports** and **management plans** and provision for **funding state projects** on nonpoint source management, control, or remediation. The Act also provides for the **regulation of municipal and industrial stormwater discharges** under the NPDES system. Municipalities are now, for the first time, being required to obtain permits, monitor stormwater discharges to streams, and to implement management programs to maintain the quality of stormwater discharges within limits specified in the permit. This will of course result in a large cost and some additional work for environmental engineers. At this time there are no regulatory requirements for agricultural runoff or subsurface discharges (see Section 503). A voluntary program is being tried, but a more regulatory approach may be coming in the future. One possible approach to regulation of nonpoint source, including agriculture is the **TMDL** (total maximum daily load) **process**, which is already mandated for all stream standards that do not meet water quality standards and thus appear on a state's **303d list**.

Other important provisions of the Clean Water Act include **protection of wetlands**, and a requirement the states file **305b reports** on the status of their surface water quality every two years.

The Safe Drinking Water Act

The Safe Drinking Water Act of 1974 (PL 93-523) and its amendments establishes limits or standards for certain constituents in drinking water in order to protect public health. The Safe Drinking Water Act is becoming increasing stringent and important in watershed protection. The Act has relatively new requirements for **source-water assessments**, **source-water proection plans**, and "community-right-to-know" **reports to consumers** on the quality of their drinking water.

Coastal Zone Act Reauthorization Amendments of 1990

Legislation enacted in §6217 of the Omnibus Budget and Reconciliation Act of 1990 (P.L. 101-508) created a coastal nonpoint water pollution program, known as the Coastal Zone Act Reauthorization Amendments (CZARA). Its purpose is to strengthen links between coastal zone management and water quality programs by requiring states to develop a nonpoint water pollution control program to restore and protect coastal waters. It is the only mandatory program in the suite of coastal zone management activities that states undertake; participants who do not meet its requirements risk losing increasing portions of their funding under both the Coastal Zone Management Act and §319 of the Clean Water Act, which funds nonpoint pollution grants. All states have met initial implementation requirements, and the program of one state, Maryland, has been fully approved. This program is jointly administered by USEPA and the National Oceanic and Atmospheric Administration (NOAA).

Other Federal Legislation

The **Endangered Species Act** often controls the establishment of water quality standards which may in turn affect nonpoint sources. A notable example is the Gunnison Basin of Western Colorado, as noted above, which has been identified as a major source of selenium and results in river selenium concentrations that are above those necessary to protect endangered fish species. The TMDL process may be used in the future to regulated nonpoint sources, including agriculture, in the basin.

The **Federal Insecticide, Fungicide and Rodenticide Act**, FIFRA (PL92-516) deals with the registration and labeling of all pesticides, including herbicides, and allows EPA to reduce the risk of ground water contamination by requiring special precautions for the use of certain chemicals (for example restricting use to certain crops or locations or to use by certified applicators only) or by canceling their registration entirely.

The **Resource Conservation and Recovery Act**, RCRA,(PL94-580) controls the management of hazardous wastes to avoid ground water contamination problems.

The **Comprehensive Emergency Response Compensation and Liability Act**, CERCLA (PL 96-510) also known as "Superfund" established a mechanism for the cleanup of uncontrolled hazardous waste sites.

Surface runoff from mines is regulated by the NPDES permit system under the Clean Water Act and state equivalents thereof and also by the **Surface Mining Control and Reclamation Act,** SMRCA (PL95-87). Other laws which may apply in specific instances are the **National Environmental Policy Act**, NEPA (PL 91-190) which requires environmental impact studies for large construction projects such as dams, pipelines, etc. and the **Toxic Substances Control Act,** TOSCA (PL94-469) which controls the manufacture, distribution, and disposal of specific toxic materials. The **Clean Air Act** (PL95-15) regulates the emission of toxic substances to the atmosphere and is particularly important from a water quality standpoint in the management of acid precipitation.

The federal government provides assistance to farmers in controlling agricultural pollution. Technical assistance is provided by the USDA Natural Resources Conservation Service, NRCS, (formerly the Soil Conservation Service, SCS) and cost-sharing on pollution control measures may be available in some cases. The SCS was established in 1935 as a result of the severe erosion problems of the "dust bowl" era. Until 1990, most of the technical and cost-sharing assistance was directed toward the reduction of erosion and sediment loading of rivers. However, since that time programs dealing with nutrients and pesticides have been initiated (but remain very small). Today, the Cooperative Extension System (which has federal, state, and local components) and the NRCS, are cooperating to provide technical assistance to farmers in the area of water quality management.

Colorado Legislation and Regulations

At the state level, the **Colorado Agricultural Chemical and Ground Water Protection Act of 1990 (Senate Bill 126)** begins to address the impacts of agricultural chemicals on ground water quality. The act contains several important requirements including:

- developing best management practices for agricultural chemical use in Colorado and educating farmers and chemical applicators in their use
- monitoring and assessment activities to identify areas in the state which have experienced or are highly vulnerable to ground water pollution from agricultural chemicals
- development of management strategies for such identified critical regions
- opportunity for local development of management strategies and initial emphasis on voluntary adoption of BMPs

- regulatory action to be taken by the Colorado Department of Agriculture if voluntary measures are inadequate to protect ground water quality.

Colorado has adopted legislation establishing a classification system for ground water and a mechanism for setting ground water quality standards based on the use classification.

Colorado has also adopted and implemented legislation (**Colorado "Chemigation Act"**) regulating the application of agricultural chemicals through irrigation systems and requiring permits, inspections and system certain types of backflow prevention hardware. The law is designed to protect wells from backflows and spills of fertilizers and pesticides, but does not deal with percolation of chemicals through the soil to ground water as a result of normal applications.

Colorado has also adopted rather stringent regulations on **confined animal feeding operations or CAFOs** (some enacted recently by citizen initiative) to protect water quality and control odors. These regulations are having a significant impact on hog feeding operations. There are also federal regulations dealing with AFOs.

Water Law

Water Law, governing water quantity, is critical in managing water quality because of the interconnection between water quality and quantity. Western water law is usually based on an **"appropriation doctrine",** while eastern water law is usually based on **"riparian rights",** see pages 68-71 in the text.   In Colorado the legislature has attempted to guarantee that water rights will take precedence over water quality concerns, but numerous court challenges are beginning to occur.