APPENDIX B

Attribute Descriptor Package

The environmental characteristics, or attributes, defined and described in this appendix represent a selected set of elements designed to be used in the environmental assessment process. They may be too generalized for many analyses, but too specific for others. Use them as a guide in classifying the environment into factors that may be affected by the actions of your agency. The manner in which they are incorporated into an analysis is shown in Appendix C.

It should be noted that these descriptions are intended to give the reader an overview of each attribute in the context of its role in impact assessment. None of the descriptions should be considered complete, as indeed, many of the individual subject areas themselves form the basis for complete texts. It is anticipated that familiarity with these 49 attributes can serve to expedite interdisciplinary studies, which frequently encounter difficulties due to lack of communication between disciplines. This communication problem can be overcome when the participants attain some understanding of each other's terminology, problems, and difficulties in achieving solutions to those problems.

The environmental attributes described in this appendix were selected because they have been of primary interest to practitioners over time. Although every one of them will probably not apply to analyzing a given proposed action, this set represents a starting point for consideration when planning the analysis approach for an environmental document. The following attributes are included:

Air

- Diffusion factor
- Particulate matter (PM)
- Sulfur oxides
- Hydrocarbons
- Nitrogen oxides
- Carbon monoxide
- Photochemical oxidants
- Hazardous toxicants
- Odors

Water—physical
- Aquifer safe yield
- Flow variations
- Oil
- Radioactivity
- Suspended solids
- Thermal discharge

Water—chemical
- Acid and alkali
- Biochemical oxygen demand (BOD)
- Dissolved oxygen (DO)
- Dissolved solids
- Nutrients
- Toxic compounds

Water—biological
- Aquatic life
- Fecal coliforms

Land
- Erosion
- Natural hazards
- Land-use patterns

Ecology
- Large animals (wild and domestic)
- Predatory birds
- Small game
- Fish, shellfish, and waterfowl
- Field crops
- Listed species
- Natural land vegetation
- Aquatic plants

Sound
- Physiological effects
- Psychological effects
- Communication effects
- Performance effects
- Social behavior effects

Human aspects
- Lifestyles
- Psychological needs

Physiological systems
Community needs
Economics
Regional economic stability
Public sector revenue and expenditures
Per capita consumption
Resources
Fuel resources
Nonfuel resources
Aesthetics

AIR

Air attributes are factors that indicate the quality of the air. Basically, two kinds of environmental factors relate to air quality:

- Structural elements of the environment
- Inputs to or emissions from human activities

Factors relating to the structural elements of the air environment are stability, temperature, mixing depth, wind speed, wind direction, humidity, precipitation, pressure, and topography. On the other hand, factors relating to inputs from human activity are dust, fumes, gases, vapors, mists, smoke, soot, and compounds of arsenic, aluminum, or other elements.

Nine attributes may be utilized in describing the impact of human activities on the air environment:

- Diffusion factor
- Particulate matter (PM)
- Sulfur oxides
- Hydrocarbons
- Nitrogen oxides
- Carbon monoxide
- Photochemical oxidants
- Hazardous toxicants
- Odors

The first attribute, the diffusion factor, is related to the structural elements of the environment; the remaining attributes are related to the emissions from human activities.

Diffusion Factor

Definition of the Attribute

Diffusion factor is an attribute that is related to various atmospheric and topographic aspects of the environment. For example, vertical temperature structure affects movement of air in the atmosphere. Wind structure in a region determines the scavenging action in the environment as well as the impact of inversions. Topography may change temperature and wind profiles because of the combined effects of surface friction, radiation, and drainage. Valleys are more susceptible to stagnation and to air pollution than are flatlands or hill slopes. The mixing depth, in fact, also determines the intensity of air pollution in a given region. The status of stability or instability of the atmosphere determines to what extent air pollution can build up in a given region. Humidity and pressure also affect the diffusion rate of a given pollutant emitted to the atmosphere. In addition, precipitation is an important scavenger element that can clean up pollutants in the air.

Together, all of the above environmental factors determine the diffusion factor in a given region.

Activities That Affect the Attribute

Generally, most human activities will not affect the diffusion factor. However, since research has shown the possibility of certain activities affecting the weather and other related meteorological factors, it is necessary to consider such activities that are now known (about which limited information is available) which may affect the diffusion factor. For instance, artificial methods for generating storms, seeding clouds, and research and testing of these new and powerful methods can, and will, cause changes in the diffusion factor.

Sources of Effects

As indicated earlier, impacts of certain specialized activities can have a major effect on the diffusion factor. Weather modification, in terms of cloud seeding, hail suppression, or alternate forms may affect precipitation patterns and other atmospheric attributes. The effects must be examined on a case-by-case basis, and where details of these activities are classified, for security reasons, it is not possible to provide detailed information on their potential impacts.

Variables to Be Measured

Variables to be measured to determine the diffusion factor are many; the major ones are stability, mixing depth, wind speed, precipitation, and topography. Various measures of each of these variables indicate the extent and nature of the diffusion factor in a given region.

How Variables Are Measured

Generally, data on stability, mixing depth, wind speed, direction, and precipitation are collected by meteorological survey stations of the National Weather Service. Data on these attributes are readily available from weather service offices across the country. Topography data can be obtained from the United States Geological Survey (USGS), which has maps of the largest available scale.

Data Sources

Primary sources of data for the variables that define diffusion factors are the National Weather Service and the USGS; both have offices in most major cities throughout the country and additional information on their websites.

Skills Required

Collection and analysis of such data require a sophisticated meteorological background. Persons with specialized training in meteorology and trained technicians are required to collect and develop information relating to these variables.

Instruments

A full-scale meteorological laboratory is needed to monitor the selected attributes that define the nature and extent of the air diffusion factor.

Evaluation and Interpretation of Data

The diffusion factor can be classified into three or more major ratings. For example, the diffusion factor can be high, medium, or low. The high rating represents an environmental quality (EQ) value of 1.0; the medium rating represents an EQ value of 0.5; and the low (or poor) rating represents an EQ value of 0.

The environmental impact of selected activities on the diffusion factor is measured by the change in diffusion factor ratings. When a diffusion factor changes only a small amount and its rating remains unaltered, the impact is considered insignificant. When the change in the diffusion factor rating is altered by one step (e.g., between high and medium or medium and poor), the impact is considered to be moderate. When a change in the diffusion factor rating occurs through two steps (e.g., between high and poor), the impact is treated as significant.

called aerosols and raise concern due to their ability to pass through the human respiratory system and cause serious health effects. The Environmental Protection Agency (EPA) classifies PM into two categories, "inhalable coarse particles" which are larger than 2.5 μm and smaller than 10 μm and "fine particles" which are smaller than 2.5 μm.

Activities That Affect the Attribute

Many human activities generate particulates that are emitted to the air. These include construction, operation, maintenance, and repair activities; transportation; and industrial activities. Examples of subactivities are site preparation; demolition, removal, and disposal; excavation; concrete construction; operation and maintenance of aircraft; operation and maintenance of automotive equipment; use of construction equipment; use of explosives; mineral extraction; foundry operation; manufacturing; noninitiating high explosives; and use of transportation vehicles.

Sources of Effects

In general, the atmosphere naturally contains some level of PM. Emissions resulting from various activities are released to the atmosphere causing a higher concentration of particulates. Particulates can cause increased mortality and morbidity in the exposed population by aggravating diseases such as bronchitis, emphysema, and cardiovascular diseases. Particulates can soil clothing and buildings and can cause serious visibility problems. Steel and other metal structures can be corroded as a result of exposure to particulates and humidity. Property values and psychic welfare of people can be undermined.

Variables to Be Measured

Particulate concentration is generally measured as the concentration of all solid and liquid particles averaged over a period of 24 hours. For purposes of impact assessment, particulate concentration is measured as the average annual arithmetic mean of all 24-hour particulate concentrations at a given location.

*How Variables Are Measured**

Particulate concentrations are usually measured by the high-volume method. The air is drawn into a covered housing unit through a filter by a high-low blower at a rate of 35 to 64 feet^3/minute. The particles, ranging

* Variable measurement methods are continually modified by federal and state regulatory agencies. Readers should consult the latest requirements. For air pollution, these requirements are found at 40 CFR 50.

Geographical and Temporal Limitations

There can be substantial variation in the diffusion factor, spatially and temporally, depending upon variations in the determinant variables. It is known, for instance, that wind speed, precipitation, stability, and mixing depth change with time and location in a given region. These variations, therefore, alter the diffusion factor accordingly.

Mitigation of Impact

Generally, the impact of most activities on diffusion has not been adequately defined. The mitigation techniques are also not well established.

Secondary Effects

The diffusion factor can be related to land-use patterns in the vicinity of air pollution sources. The prevailing wind direction can render certain land areas aesthetically undesirable or otherwise environmentally unacceptable during specific times or seasons if the air pollution is not eliminated or satisfactorily dispersed.

Other Comments

Research is needed to identify potential activities, their impacts, and the mitigation strategies relating to potential impacts on the diffusion factor. Also, a mathematical model is needed to relate all of the determinant variables to the diffusion factor. This will help establish a suitable relationship between variables and the diffusion factor.

FURTHER READING

de Nevers N: *Air Pollution Control Engineering*, ed 2, New York, 2000, McGraw-Hill.

Particulate Matter (PM)

Definition of the Attributes

Particulate matter (PM) exists in the form of minute separate particles of solids and liquids suspended in the air. They may be of organic or inorganic composition.

Particulates are finely divided solid and liquid particles suspended in the ambient air. They range from more than 100 micrometers (μm) to less than 0.01 μm in diameter. Particulates of smaller size (less than 10 μm) suspended in air can scatter light and behave like a gas. These smaller particulates are from 100 to 0.1 μm in diameter, are ordinarily collected on fiberglass filters. The concentration of suspended particulates is then computed by measuring the mass of collected particulates in the volume sample in micrograms per cubic meter.

Data Source

Sources of data are generally state pollution control departments, county air pollution control offices, multicounty air pollution control offices, or city air pollution control offices. High-volume samplers may be installed to monitor particulates from specific operations.

Skills Required

Basic paraprofessional training in mechanical or chemical engineering with special training in operating high-volume samplers is adequate to collect particulate concentration data. Specialized supervision is needed to ensure that data are properly collected and analyzed.

Instruments

The apparatus used for sampling particulate concentration is called a high-volume air sampler. The sampler is installed in a shelter to protect it against extremes of temperature, humidity, and other weather conditions. It has a filter medium with a collection efficiency of about 99 percent for particles of 0.3 μm in diameter.

Evaluation and Interpretation of Data

The primary effects of particulates on environmental quality range from visibility problems to health impairments. Visibility problems occur at concentrations as low as 25 $\mu g/m^3$. As the concentration of particulates increases to about 200 $\mu g/m^3$, human health begins to be affected. The concentration levels mentioned earlier refer to 24-hour average annual concentration. Particulate concentration of less than 25 $\mu g/m^3$ is also considered less desirable for the environment, since it provides condensation nuclei upon which fog and cloud droplets settle. From these considerations, a particulate value function was developed, based on a 24-hour average annual concentration, as shown in Figure B.1.

The determination of environmental impact of proposed activities on particulate level is measured by the change in particulates concentration. When the particulate concentration changes to the extent that its rating remains unaltered (e.g., high-quality air remains high quality), the impact may be considered insignificant. When a change in particulate rating occurs through two steps (e.g., between high quality and low quality, or vice versa), the impact is treated as significant; a one-step change is considered moderate.

The particulate value function (Figure B.1) is used for rating air quality in terms of high, moderate, and low quality, based on 24-hour annual geometric mean. For a given value of 24-hour annual geometric mean particulate concentration on the horizontal axis, a point on the curve identifies the environmental quality rating from the vertical axis of Figure B.1 (e.g., 130 μg/m^3 indicates a moderate quality of 0.4).

Geographical and Temporal Limitations

The concentration of particulates does not remain constant over the entire spatial extent of a given region. Also, it will not remain constant over time. As such, substantial spatial and temporal variations in the concentration of particulates can be expected. It is generally claimed that the impact of particulates on the environment and on humans depends on the total amount of exposure over the entire year. Spatial variations can be accounted for by analyzing minuscule units of urbanized regions. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most

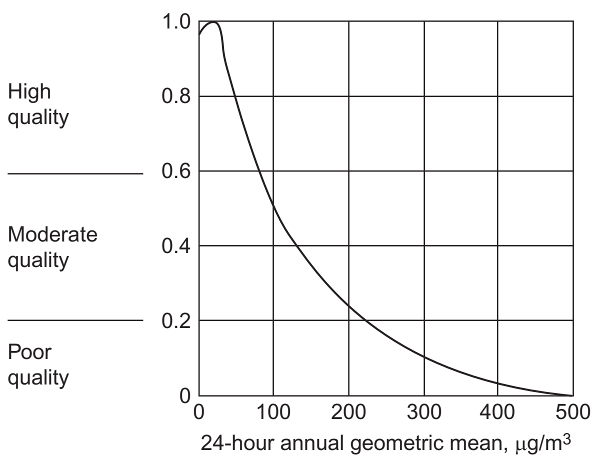

Figure B.1 ***These value functions are provided for conceptual evaluation of air quality impact.*** It should be noted that any time air quality standards established by the governing regulatory agency are exceeded, the impact is significant.

situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

Mitigation of Impact

Particulate pollution impacts can be mitigated by means of four major alternatives:

- Reduction in particulate emission from sources
- Reduction or removal of receptors from the polluted areas
- Particulate removal devices such as cyclones, settling chambers, impactors, scrubbers, electrostatic precipitators, and bag houses
- Use of protected controlled environment (e.g., oxygen masks, enclosed shopping malls)

A combination of the first three alternatives should be considered to provide an optimal strategy for the mitigation of particulate pollution impacts.

Secondary Effects

Particulate emissions are associated with problems of human health—increased mortality and morbidity in the exposed population. In addition to these direct effects, particulates also cause numerous secondary impacts. Particulates soil clothing and structures, resulting in economic loss. In addition to visibility problems and increased accident risk, aesthetic considerations reduce property values and undermine the general psychic welfare of people. Steel and other metal structures can be corroded as a result of exposure to particulates and humidity. Water quality from storm runoff and vegetation can also be deteriorated by the presence of particulate matter.

Other Comments

Particulates are present even in the cleanest air at the most remote locations uncontaminated by humans. Sources of particulate pollution relate to activities such as construction; industrial operation; operation, maintenance, and repair work; and transportation. Automobile emissions are only a minor source of particulate pollution.

Sulfur Oxides

Definition of the Attribute

Sulfur oxides are common air pollutants generated primarily by combustion of fuel. Solid and liquid fossil fuels contain a high degree of sulfur in the form of inorganic sulfides and organic sulfur compounds.

Sulfur oxides are usually a combination of sulfur dioxide, sulfur trioxide, sulfuric acid, and sulfurous acid. Combustion of fossil fuels normally produces about 30 parts sulfur dioxide for 1 part sulfur trioxide. Sulfur dioxide is the most dominant portion of the sulfur oxides concentration; as such, the sulfur oxides attribute is defined in terms of the sulfur dioxide parameter.

Sulfur dioxide is a nonflammable, nonexplosive, transparent gas with a pungent, irritating odor. The concentration of this gas in parts per million (ppm) measures the magnitude of sulfur oxides pollution in a given region.

Activities That Affect the Attribute

Many human activities use fossil fuels. Coal- and oil-fired furnaces, fossil-fueled electricity-generating plants, and industrial uses of fossil fuels appear to be major generators of sulfur dioxide pollution. In addition, operation of various facilities can cause significant sulfur dioxide pollution. Construction work and transportation also create a minor sulfur dioxide problem from the operation of diesel engines.

Sources of Effects

Potential effects of sulfur dioxide pollution include high morbidity; increased mortality; increased incidence of bronchitis, respiratory diseases, and emphysema; and general deterioration of health. It can also cause increased corrosion of metals, chronic plant injury, excessive leaf dropping, and reduced productivity of plants and trees. The effect of sulfur dioxide pollution in the presence of particulates can result in synergistic impacts on the environment. Synergistic impacts of sulfur dioxide in the presence of nitrogen dioxide have also been noted. For example, even low levels of sulfur dioxide, in combination with other contaminants such as particulates, aggravate symptoms of asthma, bronchitis, and emphysema. Sulfur dioxide (SO_2) levels as low as 0.25 parts per million (ppm) may cause attacks in asthmatics participating in exercise (Dickey, 1999).

Variables to Be Measured

The primary variable that measures the extent of the sulfur oxides problem is expressed by the 24-hour annual arithmetic mean concentration of sulfur dioxide present in the ambient air. This variable is used to predict the potential impact of sulfur oxides on the environment.

Here, the use of one variable is not entirely adequate. Concentration of particulates, ozone, and nitrogen oxides affects the impacts of sulfur oxides. However, to take advantage of the simplification, only one variable has been used.

How Variables Are Measured

The sulfur dioxide concentration is commonly measured by the pararosaniline method. In principle, sulfur dioxide is absorbed from air in a solution of potassium tetrachloromercurate (TCM). The resulting complex is added to pararosaniline and formaldehyde to form an intensely colored acid solution that is analyzed spectrophotometrically. The spectrophotometric analysis is a colorimetric method in which the concentration of sulfur dioxide absorption is measured by the intensity of the color produced in the resulting acid solution. The method is recommended by the EPA in the National Primary and Secondary Ambient Air Quality Standards published in 40 CFR 50.4 and 50.5. Test methods are in 40 CFR 50 in Appendix A.

Data Source

Air quality measurements for sulfur oxide are made by air quality monitoring programs established by state pollution control agencies, the EPA, and county, regional, multicounty, or city air pollution control agencies. Generally, the data are compiled annually and are published with summaries by the state agency responsible for air quality monitoring.

Skills Required

The skills required for measuring sulfur dioxide concentration in air can be developed by special technician-level training imparted at a technical school or as part of an on-the-job training program. Technician-level training in mechanical and chemical engineering is adequate to develop the necessary skills to operate a monitoring and recording system for sulfur dioxide.

Instruments

The instruments required for monitoring sulfur dioxide concentration are

- All-glass midget impinger
- Air pump
- Air flow meter
- Spectrophotometer

Evaluation and Interpretation of Data

A review of the literature indicates that the minimum sulfur dioxide concentration for vegetation damage is 0.03 ppm. A sulfur dioxide concentration less than 0.03 ppm should be considered a characteristic of a safe environment. As concentration increases, more damage will be done to the vegetation and materials. Visibility of the atmosphere is also impaired. At a

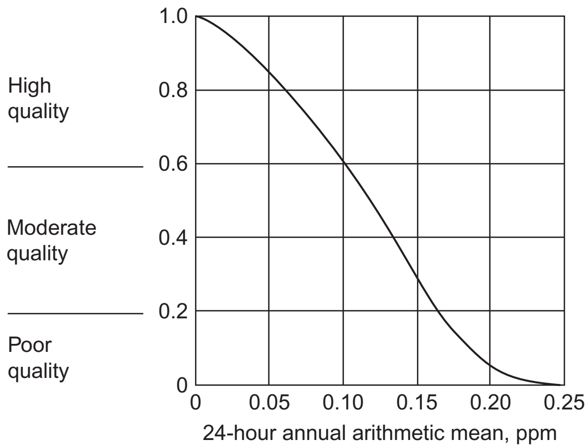

Figure B.2 ***Sulfur dioxide value function.***

concentration of 0.2 ppm of sulfur dioxide, increased mortality rates are observed. This situation should reflect a value function of zero. Based on these considerations, a value function was developed for sulfur oxide, as shown in Figure B.2.

The determination of environmental impact of proposed activities on sulfur dioxide level is measured by the change in sulfur dioxide concentration. When the sulfur dioxide concentration changes to the extent that its rating remains unaltered (i.e., high-quality air remains high quality, and so on), the impact is considered insignificant. If the change in sulfur dioxide concentration is such that its rating changes by one step (i.e., from high quality to moderate quality, etc.), the impact is treated as moderate. Furthermore, when a change in sulfur dioxide rating occurs through two steps (i.e., from high quality to low quality, or vice versa), the impact is treated as significant.

The sulfur dioxide value function (Figure B.2) is used for rating air quality in terms of high, moderate, and low quality based on the 24-hour annual arithmetic mean. For a given value of 24-hour annual geometric mean sulfur dioxide concentration on the horizontal axis, the environmental quality rating can be read for the horizontal axis in Figure B.2.

Geographical and Temporal Limitations

Concentration of sulfur dioxide does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, substantial spatial and temporal variations in the concentration of sulfur dioxide on the environment and on humans depend on the total amount of exposure over the entire year. Spatial variations can be accounted for by taking minuscule units of urbanized regions for purposes of analysis. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial region.

Mitigation of Impact

The impacts can be mitigated by means of four major alternatives or a combination thereof:

- Reduction in sulfur dioxide emissions from sources
- Reduction or removal of receptors from the polluted areas
- Gas removal devices using absorption (liquid as a medium), adsorption (molecular sieve), and catalytic converters
- Use of protected, controlled environment, such as oxygen masks, enclosed athletic facilities, and the like

Secondary Effects

Secondary effects of sulfur oxides include economic and resource loss through damage to material surfaces and vegetation, water quality deterioration through the natural "cleansing" of the atmosphere through precipitation, and aesthetic and general welfare quality reduction that accompanies the degradation of a vital resource. Land-use patterns and community needs may be affected in localized areas with point-source emissions.

Other Comments

Sulfur dioxide is generally harmful to the health and welfare of a community. Its impact can be substantially increased by the presence of suspended particulates due to the synergistic relationship of the two pollutants. Despite this, the value function is based only on the concentration of sulfur dioxide. This is done to simplify the value function. However, the impacts have been adjusted for the concentrations of particulates that generally accompany given levels of sulfur dioxide in the ambient air.

Hydrocarbons

Definition of the Attribute

Hydrocarbon is a general term used for several organic compounds emitted when organic materials such as petroleum fuels are burned. Automobile exhaust accounts for over half of the complex mixture of hydrocarbons emitted to the atmosphere. The remaining hydrocarbons arise from natural sources like decomposable organic matter on land, swamps, and marshes; hydrocarbon haze from plants and forest vegetation; geothermal areas; coal fields, natural gas, and petroleum fields; and forest fires. Usually, hydrocarbons consist of methane, ethane, propane, and derivatives of aliphatic and aromatic organic compounds.

The hydrocarbons attribute is defined as the total hydrocarbon concentration present in the ambient air. Hydrocarbons are organic compounds consisting of carbon and hydrogen; their concentration is measured in parts per million by volume or in micrograms per cubic meter of air. For most U.S. cities, except Los Angeles, the peak hydrocarbon concentration occurs between 6:00 and 9:00 a.m.

Activities That Affect the Attribute

Many activities emit high levels of hydrocarbons into the environment. For example, industrial operations, home heating, and vehicle operations involve substantial combustion of fuel, causing hydrocarbon emissions due to inefficient combustion processes. Gasoline and diesel engines are used for purposes of construction, operation, maintenance, repair, and transportation. In addition, many industrial activities have petroleum and petrochemical operations that emit high levels of hydrocarbons. Areas with natural vegetation and forests also generate high levels of hydrocarbon concentration.

Sources of Effects

Hydrocarbons are of concern primarily for their role in the formation of photochemical oxidants and smog. Direct health effects of gaseous hydrocarbons in the ambient air have not been demonstrated. Health effects occur only at high concentrations (about 1000 ppm or more) that interfere with oxygen intake. Hydrocarbons in the atmosphere have been found to cause lacrimation, coughing, sneezing, headaches, laryngitis, pharyngitis, and bronchitis, even at low concentrations. In addition, hydrocarbons may cause breathing problems and eye irritation. In combination with nitrogen oxides, hydrocarbon impacts can be significantly increased.

Variables to Be Measured

The variable expressing the impact of hydrocarbons is measured by the 3-hour average annual concentration of ambient hydrocarbons, expressed in parts per million. The time concentration is measured from 6:00 to

9:00 a.m., at which time peak hydrocarbon concentration is expected to occur in most U.S. cities except Los Angeles.

Nitrogen oxide variables interact synergistically with the concentration of hydrocarbons. Nitrogen oxides combined with hydrocarbons generate oxidants causing smog. The impact of smog is significantly greater than that of hydrocarbons alone. However, for purposes of simplicity, nitrogen oxides are treated as a separate variable.

How Variables Are Measured

There are two different methods of analysis for the total hydrocarbons:

- Flame ionization method
- Spectrophotometric method

The EPA, in its national primary and secondary ambient air quality standards document, has recommended use of the hydrogen flame ionization method to measure total hydrocarbon concentration. The flame ionization technique uses a measured volume of ambient air delivered semicontinuously (about 4 to 12 times per hour) to a hydrogen flame ionization detector (FID). A sensitive electrometer detects the increase in ion concentration that results from the interaction of the hydrogen flame with a sample of air contaminated with organic compounds such as hydrocarbons, aldehydes, and alcohols. The ion concentration response is approximately proportional to the number of organic carbon atoms in the sample. The FID serves as a carbon atom counter.

The measurement can be made by two modes of operation:

- A complete chromatographic analysis showing continuous output from the detector
- Programming the system to display selected output from the detector

The latter is adequate for recording hydrocarbons system concentration values from 6:00 to 9:00 a.m. only.

Data Sources

Hydrocarbon data are generally collected by state air quality monitoring programs. Other potential sources include the federal EPA and city or county monitoring agencies.

Skills Required

Basic paraprofessional training in mechanical or chemical engineering with special training in operating air pollution samplers is adequate to collect data relating to hydrocarbons. Specialized supervision is needed to ensure that the instruments are correctly operated and recorded. This requires either experienced personnel or experienced consultants specializing in air quality monitoring.

Instruments

Instruments used for measuring hydrocarbons are the following:
- Commercial total hydrocarbon concentration analyzer
- Sampler introduction system (including pump, flow control, valves, automatic switching valves, and flow meter)
- In-line filter (a binder-free glass-fiber with a porosity of 3 to 5 μm)
- Stripper or per column (the column should be repacked or replaced every 2 months of continuous use)
- Oven (containing analytical column and analytical converter)

The instruments are installed and connected in accordance with the manufacturer's specifications.

Evaluation and Interpretation of Data

The extent of hydrocarbon impact is measured by the degree to which it affects smog intensity. Hydrocarbon criteria are, therefore, keyed to the 6:00 to 9:00 a.m. average annual concentration. At low concentrations, hydrocarbons are relatively harmless and unimportant. The quality of the environment deteriorates rapidly as conditions for smog development approach (i.e., 0.15 to 0.25 ppm). A sharp decrease in environmental quality is noted within this range. Above a 0.25-ppm hydrocarbon concentration, the value function gradually levels off to zero, since the marginal impact of increases in hydrocarbons concentration is small. The value function is thus a flat S curve. On the basis of these considerations, the hydrocarbons value function shown in Figure B.3 was developed.

The determination of environmental impact of proposed activities on hydrocarbon levels is measured by the change in hydrocarbon concentration. When the hydrocarbon concentration changes to the extent that its rating remains unaltered (e.g., high-quality air remains high quality), the impact is considered insignificant. When the change in hydrocarbons concentration is such that its rating changes by one step (e.g., between high quality and moderate quality), the impact is treated as moderate. When a change in hydrocarbons rating occurs through two steps (e.g., from high quality to low quality, or vice versa), the impact is considered significant.

The hydrocarbons value function (Figure B.3) is used for rating air quality in terms of high, moderate, and low quality based on the 3-hour average

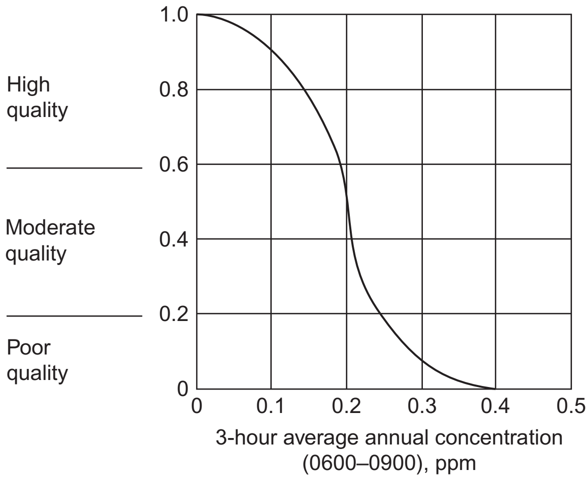

Figure B.3 ***Hydrocarbons value function.***

annual concentration. For a given value of 3-hour average annual concentration on the horizontal axis, a point on the curve identifies the environmental quality rating from the vertical axis of Figure B.3 (e.g., 0.3 ppm indicates a poor quality of 0.15).

Geographical and Temporal Limitations

Concentration of hydrocarbons does not remain spatially constant in a given region. Also, it will not remain constant over time. As such, a substantial spatial and temporal variation in the concentration of hydrocarbons can be expected. It is generally claimed that the impact of hydrocarbons on the environment and humans depends upon the total exposure during peak periods. Spatial variations can be accounted for by taking small units of urbanized regions for analysis. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

Mitigation of Impact

The four major strategies for the mitigation of impacts of hydrocarbons on the environment are:

- Control of motor vehicle emissions
- Control of stationary source emission (including evaporation, incineration, absorption, condensation, and material substitution)

- Reduction or removal of receptors from polluted areas
- Creation of a controlled environment to avoid pollution (including use of oxygen masks)

These strategies can be used in an optimal combination in order to get the best results from an abatement program.

Secondary Effects

Production of hydrocarbons beyond acceptable levels may result in secondary impacts through reduction of property values, shifts in land-use patterns, and adverse effects on vegetation. Increased accident occurrence can accompany the reduction in vision and other human health aspects.

Other Comments

Hydrocarbon concentration is one of the parameters that defines the extent of smog development in an environment. In selecting attributes, the ozone parameter was avoided, since the formation of ozone is determined by the interaction of hydrocarbons and nitrogen oxides in the presence of sunlight. The environment receives many different kinds of hydrocarbon emissions; as such, these emissions are an important indicator of environmental impact.

Nitrogen Oxides

Definition of the Attribute

Many nitrogen oxides are found in the urban environment. The most important are nitric oxide (NO) and nitrogen dioxide (NO_2). In addition, nitrous oxide (N_2O) is another oxide of nitrogen present in the atmosphere in appreciable concentration. The term NO_2 is often used to represent the composite atmospheric concentration of nitrogen oxides in the environment.

Nitrogen oxides are emitted by exhausts from high-temperature combustion sources. They result from the reaction of nitrogen with oxygen; with hydrocarbons they produce photochemical smog. Nitrogen oxide concentrations are measured in parts per million by volume.

Activities That Affect the Attribute

Many human activities generate nitrogen oxides which are emitted to the air. Industrial operations; research, development, and testing operations; operation and maintenance of motor vehicles; and stationary combustion sources (like power plants, natural gas burners, diesel-operated construction machineries) are some of the sources of nitrogen oxides. However, a large portion of nitrogen oxides is produced by natural sources, such as bacterial action in forests, swamps, and parks.

Sources of Effects

There is very little documented information on the health effects of nitrogen oxides at concentrations normally found in ambient air. The human threshold for sensing the odor of nitrogen dioxide is about 0.12 ppm. Data from human and animal studies indicate that nitrogen oxides have adverse effects on human health. Nitrogen dioxide is about four times more toxic than nitric oxide.

In addition, nitrogen oxides can affect vegetation, causing acute (chronic) injury to leaves as well as to productivity of certain plants. Nickel alloys are subject to corrosion in the presence of nitrogen oxides; synthetic fibers fade and white clothes yellow in the presence of nitrogen oxides.

Variables to Be Measured

The variable measuring the extent of pollution from nitrogen oxides is the average annual concentration of nitrogen oxides in the ambient air. The nitrogen oxides level is measured in parts per million (ppm).

Other variable factors that might interact with nitrogen oxides are hydrocarbons and particulates. These variables are considered separately in defining air quality impacts, even though they interact synergistically.

How Variables Are Measured

Nitrogen dioxide is the only atmospheric nitrogen oxide which can be measured directly with current techniques.* Measurement of nitrogen oxides, therefore, must rely on some type of converter that oxidizes nitric oxide to nitrogen dioxide.

The reference method for the determination of nitrogen dioxide is the Griess–Saltzman technique, modified by the EPA. It is a 24-hour continuous sampling method. In principle, nitrogen dioxide–contaminated air is bubbled through a sodium nitrite. The nitrite concentration in the sample solution is measured colorimetrically by the reaction of an exposed absorbing agent with phosphoric acid, sulfanilamide, and NEDA (N-[1-Naphthyl]-ethylenediamine dihydrochloride) solution.

* Nitrogen oxides pollution is measured by the concentration of nitrogen dioxide expressed in terms of annual arithmetic mean concentration.

Data Sources

Sources of data are generally state pollution control departments and county, multicounty, or city air pollution control offices. They can also install monitoring samplers at critical distances from emission sources to determine the level of nitrogen oxides generated by the particular activities.

Skills Required

Basic paraprofessional training in mechanical or chemical engineering, with special training in operating air quality sampling devices, is adequate to collect data relating to nitrogen oxides. Specialized supervision is needed to ensure that the data are properly collected and analyzed. Specialized supervision should include personnel or experienced consultants trained in the field of air quality monitoring.

Instruments

Nitrogen dioxide is measured with an apparatus consisting of the following components:

- Absorber tubes
- Probe with membrane filter, glass funnel, and trap
- Flow-control device with a calibrated 27-gauge hypodermic needle and a membrane filter protection
- Air pump capable of maintaining a flow of 0.2 1/min and a vacuum of 0.7 atmospheres
- Calibration equipment

Evaluation and Interpretation of Data

Generally, nitrogen oxides concentrations below 0.05 ppm (on average annual basis) do not pose health problems. Exposure above this level can be correlated with a higher incidence of acute respiratory problems. At levels higher than those normally present in ambient air (i.e., about 0.05 ppm), nitrogen dioxide acts as a toxic agent. Based on these considerations, a nitrogen dioxide value function has been developed, as shown in Figure B.4.

The determination of environmental impact of proposed activities on nitrogen oxides level is measured by the change in nitrogen oxides (NO_x) concentration. When the NO_x concentration changes to the extent that its rating remains unaltered (e.g., high-quality air remains high quality), the impact is considered insignificant. When the change in NO_x concentration is such that its rating changes by one step (e.g., between high quality and moderate quality), the impact is treated as moderate. When a change in NO_x

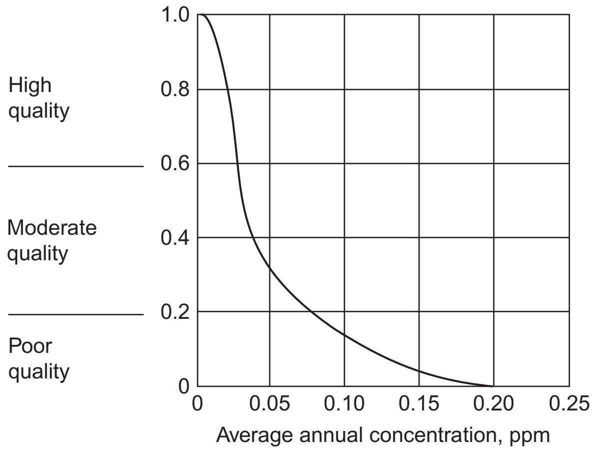

Figure B.4 ***Nitrogen oxides value function.***

ratings occurs through two steps (e.g., from high quality to low quality, or vice versa), the impact is considered significant.

The nitrogen oxides value function (Figure B.4) is used for rating air quality in terms of high, moderate, and low quality, based on average annual concentration. For a given value of average annual concentration on the horizontal axis, a point on the curve identifies the environmental quality rating from the vertical axis of Figure B.4 (e.g., 0.1 ppm indicates a poor quality of 0.1).

Geographical and Temporal Limitations

Concentration of nitrogen dioxide does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, substantial spatial and temporal variations in the concentration of nitrogen dioxide can be expected. It is generally claimed that the impact of nitrogen dioxide on the environment and humans depends on the total amount of exposure over the entire year. Spatial variations can be accounted for by analyzing small units of urbanized regions. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

Mitigation of Impact

The five major strategies for the mitigation of impacts of nitrogen dioxide on the environment are:

- Control of motor vehicle emissions
- Control of stationary-source emissions (including incineration and evaporation)
- Reduction or removal of receptors from polluted areas
- Gas removal devices using absorption (liquid as a medium), adsorption (molecular sieves), and catalytic converters
- Creation of a controlled environment to avoid pollution (such as the use of oxygen masks)

These strategies can be used in an optimal combination to get the best results from an abatement program.

Secondary Effects

Secondary effects due to nitrogen oxide production include economic losses ranging from damage to vegetation to deterioration of building materials. Shifting land-use patterns, reduced property values, and increased accident occurrence can accompany the formation of smog and other direct effects.

Carbon Monoxide

Definition of the Attribute

Carbon monoxide (CO) is the most widely distributed and most commonly occurring air pollutant. The majority of atmospheric CO is produced by the incomplete combustion of carbonaceous materials used for fuels for vehicles, space heating, industrial processing, and the burning of refuse.

Activities That Affect the Attribute

All activities that involve the combustion of organic materials are sources of CO. In addition, industrial operations contribute to the CO burden in the air. CO is also formed by explosions and the firing of weapons, and it can occur naturally.

Sources of Effects

Adverse health effects on humans have been observed for exposures of 8 hours or more at CO concentrations of 12 to 17 mg/m^3 (10 to 15 ppm). Adverse health effects include impaired time-interval discrimination and physiologic stress on heart patients.

Variables to Be Measured

The concentration of CO is measured in micrograms per cubic meter. The variable measuring the extent of carbon monoxide pollution is the maximum 8- and 1-hour concentration.

How Variables Are Measured

The reference method for the continuous measurement of carbon monoxide is nondispersive infrared spectrometry. The measurement technique is based on the absorption of infrared radiation by carbon monoxide. By comparing absorption of infrared radiation passing through a reference cell and a test cell electronically, the concentration of CO in the test cell can be measured.

Instruments are available that measure in the range of 0 to 58 mg/m^3. The sensitivity is 1 percent of full-scale response per 0.6 mg CO per m^3 (0.5 ppm). See 40 CFR 50 Appendix C for test methods and 40 CFR 50.8 for standards.

Data Sources

Sources of data are generally the State Pollution Control Department, the County Air Pollution Control Office, or the City Air Pollution Control Office. Monitoring equipment can be installed at critical locations near specific operations to determine the level of carbon monoxide generated.

Skills Required

Basic paraprofessional training in mechanical or chemical engineering with special training in operating the air quality instruments is adequate to collect data relating to carbon monoxide. Specialized supervision will be needed to ensure that the data are properly collected and analyzed. Specialized supervision should include trained and experienced personnel or experienced consultants in the field of air quality monitoring.

Instruments

Instruments recommended for measuring carbon monoxide are:

- Commercial nondispersive infrared spectrometer
- Sample introduction system (including pump, flow control valve, and flow meter)
- In-line filter (use a filter with a porosity of 2 to 10 μm to trap large particles)
- Moisture controller (refrigeration units or drying tubes)

The instruments are installed and connected in accordance with the manufacturer's specifications.

Evaluation and Interpretation of Data

Generally, carbon monoxide does not pose a health problem to the general public. Continuous exposure to CO concentrations of 10 to 15 ppm, however, can cause impaired time-interval discrimination. CO levels of 30 ppm have caused physiologic stress in patients with heart disease, while concentrations of 8 to 14 ppm have been correlated with increased fatality rates in hospitalized myocardial infarction patients.

Geographical and Temporal Limitations

The concentration of carbon monoxide does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, substantial spatial and temporal variations in the concentration of carbon monoxide can be expected. It is generally claimed that the impact of carbon monoxide on the environment and humans depends on the total amount of exposure over the entire year. The spatial variations can be accounted for by taking small units of urbanized regions for purposes of analysis. This would require extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

Mitigation of Impact

The three major strategies for the mitigation of impact of carbon monoxide on the environment are:

- Control of motor vehicle emissions
- Control of stationary source emission
- Reduction or removal of receptors from polluted areas

Secondary Effects

Presently identifiable specific secondary impacts due to increased carbon monoxide emissions are those related to human health effects, including economic loss and increased accident rate. Long-term secondary effects on the ecosystem due to increased carbon monoxide levels are not yet understood.

Photochemical Oxidants

Definition of the Attribute

Products of atmospheric reactions between hydrocarbons and nitrogen oxides which are initiated by sunlight are called photochemical oxidants. The product of these reactions, which is most commonly found and measured in the atmosphere, is *ozone*. Other oxidants of interest include peroxyacetyl nitrate and acrolein. Atmospheric measurement techniques measure the net oxidizing properties of atmospheric pollutants and report these photochemical oxidant concentrations as equivalent ozone concentration. Photochemical oxidants can be found anywhere hydrocarbons and nitrogen oxides interact in the presence of sunlight.

Activities That Affect the Attribute

All activities that generate oxides of nitrogen and hydrocarbons simultaneously contribute to the generation of photochemical oxidants. Industrial activities and the operation and maintenance of motor vehicles and stationary combustion sources are major sources of nitrogen oxides and hydrocarbons. In addition, many other activities have petroleum and petrochemical operations that emit high levels of hydrocarbons.

Sources of Effects

The data from animal and human studies are sparse and inadequate for determining the toxicological potential of photochemical oxidants. Injury to vegetation is one of the earliest manifestations of photochemical air pollution. The oxidants can cause both acute and chronic injury to leaves. Leaf injury has occurred in certain sensitive species after a 4-hour exposure to 100 $\mu g/m^3$ (0.05 ppm) total oxidants. Photochemical oxidants are known to attack certain materials. Polymers and rubber are important materials that are sensitive to photochemical oxidants.

Variables to Be Measured

The concentration of ozone is measured in micrograms per cubic meter, as a maximum hourly average concentration. The standard is found in 40 CFR 50.9, and the test method in 40 CFR 50 in Appendix D.

How Variables Are to Be Measured

Since ozone is the major constituent contributing to photochemical oxidants, it is used as the reference substance in reporting levels of photochemical oxidants.

Ambient air and ethylene are delivered simultaneously to a mixing zone, where the ozone in the air reacts with the ethylene to emit light, which is detected by a photomultiplier cell. The resulting photocurrent is amplified and displayed on a recorder. The range of most instruments is from 0.005 ppm to greater than 1 ppm of ozone. The sensitivity is 0.005 ppm of ozone.

Data Sources

Sources of data are generally the State Pollution Control Department, the County Air Pollution Control Office, or the City Air Pollution Control Office. They can also install monitoring equipment at critical locations near their operations to determine the level of photochemical oxidants generated by activities.

Skills Required

A basic paraprofessional training in mechanical or chemical engineering with special training in operating the air quality instruments is adequate to collect data relating to photochemical oxidants. Specialized supervision will be needed to ensure that the data are properly collected and analyzed. Specialized supervision should include trained and experienced personnel or experienced consultants in the field of air quality monitoring.

Instruments

Instruments for carrying out photochemical oxidant measurements include:

- Detector cell
- Air flow meter capable of controlling air flows between 0 and 1.5 L/min
- Ethylene flow meter capable of controlling ethylene flows between 0 and 50 mL/min
- Air inlet filter capable of removing all particles greater than 5 μm diameter
- Photomultiplier tube
- High-voltage power supply (2000 V)
- Direct current amplifier and a recorder

Evaluation and Interpretation of Data

Photochemical oxidants are keyed to the 6:00 to 9:00 a.m. concentration values. At low concentrations, photochemical oxidants do not pose a problem. The quality of the environment, however, rapidly deteriorates as conditions for smog development approach (i.e., hydrocarbon concentration of

0.15 to 0.25 ppm). The values of the oxidant levels during the early morning determine the intensity of the oxidants to be expected later in the day. After sunset, the oxidant concentrations are reduced to low levels.

Geographical and Temporal Limitations

The concentration of photochemical oxidants does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, a substantial spatial and temporal variation in the concentration of photochemical oxidants can be expected. It is generally claimed that the impact of photochemical oxidants on the environment and humans depends on the total amount of exposure during the peak periods. The spatial variation can be accounted for by taking small units of urbanized regions for purposes of analysis. This would require extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict the air quality values over the entire spatial area.

Mitigation of Impact

All strategies for mitigating hydrocarbons and oxides of nitrogen are applicable to photochemical oxidants.

Secondary Effects

Sensitivity of plants to photochemical oxidants results in economic loss, as well as other secondary impacts on ecological balance. Other economic loss occurs with material deterioration and reduced property values.

Hazardous Toxicants

Definition of the Attribute

Many kinds of hazardous air pollutants may be released to the environment. Some of these toxic elements or compounds are arsenic, asbestos, barium, beryllium, boron, cadmium, chromium, copper, lead, molybdenum, nickel, palladium, titanium, tungsten, vanadium, zinc, zirconium, radioactive wastes, mercury, and phenols. These toxic substances at certain concentrations may cause serious damage to the health and welfare of an exposed community.

Hazardous toxicants are substances like asbestos, beryllium, mercury, and other harmful elements and their compounds. Exposure to these toxicants can cause serious health hazards and diseases. These health impairments can result in increased mortality, morbidity, susceptibility to diseases, and loss of productivity.

Activities That Affect the Attribute

Hazardous toxicants may be generated by human activities such as construction; operation, maintenance, and repair of existing systems; industrial operations; research, development, and testing operations; and demolition of structures. For example, the surfacing of roadways with asbestos tailings can cause serious asbestos hazards.

The manufacture of clocks, cord, wicks, tubing, tape, twine, rope, thread, cement products, fireproofing and insulating materials, friction products, paper, mill board, felt, floor tile, paints, coatings, caulks, adhesives, sealants, and plastics may produce visible emissions of asbestos. Also, construction emissions produce substantial amounts of asbestos dust.

Sources of Effects

Hazardous toxicants can create serious health hazards and diseases of a chronic nature. For instance, exposure to asbestos dust at high concentrations and for longer durations can cause asbestos and bronchial cancer. In addition, asbestos is a cause of mesotheliomas; tumors; and membrane, intestine, and abdomen cancers. Most asbestos diseases have a latency period of 30 years.

Today, research has failed to establish an emission limit or concentration range above which asbestos dust can be harmful to human health. The EPA, however, recommends that no visible emissions be permitted from asbestos-generating activities.

Beryllium is another hazardous air pollutant that can seriously affect human health. Its effects are acute and chronic lethal inhalation, skin and conjunctival effects, cancer induction, and other beryllium diseases. The lowest beryllium concentration producing a beryllium disease was found to be greater than 0.01 $\mu g/m^3$. At a concentration of 0.10 $\mu g/m^3$ or more, the majority of exposed persons will develop beryllium diseases.

Variables to Be Measured

The variable measuring the extent of impact of a specific hazardous toxicant varies with the toxicant. For example, beryllium concentrations are required not to exceed 10 g over a 24-hour period, while radionuclide emissions must not exceed the amount that would cause a member of the public to receive a specified dose equivalent per year.

How Variables Are Measured

There are many different methods of measuring various hazardous toxicants. See 40 CFR 61 for the method required for each toxicant.

Data Sources

Only a few city, county, regional, and state agencies monitor hazardous toxicants and emissions. Monitoring of selected hazardous toxicants is occasionally done by the EPA in cooperation with state or local agencies for selected periods at critical locations. Such monitoring is done only when a special hazardous toxicant is identified in a given region. Data on toxicant monitoring are available from state and local air pollution control agencies when collected.

Skills Required

Skills required for various hazardous toxicant–measuring techniques are not well defined in the literature and require specialized supervision for use. Specialized consulting services are needed to implement these measurement techniques.

Instruments

Complex sampling trains have to be designed on a case-by-case basis for each hazardous toxicant in the environment. The full range of instrumentation necessary for measurement of each hazardous toxicant is described in some of the standard documents mentioned earlier.

Evaluation and Interpretation of Data

There are no well-defined value functions available for the hazardous toxicants identified in the environment. Generally, for each hazardous toxicant, it is possible to establish the upper and lower concentration limits of acceptability for the environment. The upper limit of acceptability is called the permissible level, the excess of which is considered highly undesirable and damaging to human health. On the other hand, the lower concentration limit of acceptability is called the desirable level, below which concentrations the quality of air can be considered acceptable; that is, the value function equals 1.

Emission limits have not been established for all the known hazardous toxicants. The EPA has established standards for major hazardous toxicants. These are found in 40 CFR 61.

The environmental impact of proposed activities on hazardous toxicant level is measured by the change in the hazardous toxicant concentration (HTC). When the HTC changes to the extent that its rating remains unaltered (e.g., high-quality air remains high quality), the impact is considered insignificant. When a change in HTC is such that the rating changes by one step (e.g., between high quality and moderate quality), the impact is treated as moderate. When a change in HTC rating occurs through two steps (e.g., from high quality to poor quality, or vice versa), the impact is considered significant.

Geographical and Temporal Limitations

Concentrations of hazardous toxicants do not remain constant over the entire spatial extent in a given region. Also, they will not remain constant over time. As such, substantial spatial and temporal variations in the concentrations of hazardous toxicants can be expected. It is generally claimed that the impact of hazardous toxicants on the environment and humans depends on the total amount of exposure over the entire day. Spatial variations can be accounted for by analyzing small units of urbanized regions. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring program is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

Mitigation of Impact

The five major strategies for the mitigation of impacts resulting from hazardous toxicants are:

- Use of materials that do not generate hazardous toxicants
- Use of processes that do not generate hazardous toxicants
- Avoiding or reducing activities that generate hazardous toxicants
- Removal of hazardous emissions
- Moving people from contaminated areas

Secondary Effects

Secondary effects of hazardous toxicants include the economic losses that accompany lowered health standards and decreased productivity. Deterioration of water quality may result as these toxicants are cleansed from the air by natural processes. Effects on plant and animal life (aquatic and terrestrial) would vary with the toxicants and the levels present.

Other Comments

Hazardous toxicants are powerful damaging agents for a community. Any industry can ill afford to be negligent about such emissions. Any attempt on the part of industry to compel communities to endure dangerous levels of toxicants resulting from its activities should be strongly discouraged. The use of this parameter will help to identify potential hazardous toxicant problems resulting from various operations.

Odors

Definition of the Attribute

Industrial malodors are generally considered harmless, even though they frequently cause loss of personal and community pride, loss of social and economic status, discomfort, nausea, loss of appetite, and insomnia. It is true that odor effects on human health and welfare have been recognized only recently, and it seems that very little attention has been given in the literature to this air contaminant.

Malodors are generally caused by organic and sulfur compounds. The resulting odor characteristics are described by commonly accepted odor descriptors. Some common odor descriptors and their odor contaminants are indicated in Table B.1. For each odor contaminant, a concentration can be defined for which there can be no perception of the odor by a panel of

Table B.1 Selected Malodors and Contaminants

Chemical compound or type of material	Commonly accepted description of odor types
Acetylaldehyde	Fruity
Acetic acid	Vinegar
Acetone	Nail polish remover
Acetylene	Ethereal, garlic
African fiber	Musty, sour
Banana oil	Nail polish remover
Burnt protein	Burnt toast, scorched grain
Cannery waste	Rotten egg

Continued

Table B.1 Selected Malodors and Contaminants—cont'd

Chemical compound or type of material	Commonly accepted description of odor types
Carbon disulfide	Rotten egg
Carbon tetrachloride	Cleaning fluid
Cresol	Creosote
Decayed fish	Rendering
Dimethyl sulfide	Rotten vegetables
Enamel coatings	Fatty linseed oil
Fatty acids	Grease, lard
Fermentation	Yeast or stale beer
Foam rubber curing	Sour sulfides
Gas house	Gas odors
Hydrogen sulfide	Rotten egg
Indole	Rest room
Iodoform	Iodine
Medicinal	Iodoform
Methyl ethyl ketone	Nail polish remover
Mercaptans (methyl)	Rotten cabbage
Oils: castor, coconut, soya, linseed	Rancid grease
Phenolic	Carbolic acid
Phenolic resins	Carbolic acid
Pig pen	Waste lagoons
Pyridine	Acrid, goaty
Septic sewage	Rotten egg
Skatole	Rest room
Sludge drying	Burnt grain
Sulfur dioxide	Irritating, strong, suffocating

Sources: Weisburd (1972) and Post (1968).

individuals. This concentration is generally known as olfactory threshold or odor threshold. The odor thresholds of a few selected gaseous sulfur compounds in the air are shown in Table B.2.

The odor intensity is a measure of the stimulus resulting from the olfactory sensation of a given concentration of odorant. According to the Weber–Fechner law, odor intensity increases logarithmically with the increase in concentration of the odor.

Table B.2 Typical Odor Recognition Thresholds

Compound	ppm by volume
Acetaldehyde	0.2
Acetic acid	1
Acetone	100
Acrolein	0.2
Acrylonitrile	20
Allyl chloride	0.5
Ammonia	50
Aniline	1
Benzene	5
Benzyl chloride	0.05
Benzyl sulfide	0.002
Bromine	0.05
Butyric acid	0.001
Carbon disulfide	0.2
Carbon tetrachloride	20
Chloral	0.05
Chlorine	0.3
o-Cresol	0.001
Dimethylacetamide	50
Dimethylformamide	100
Dimethyl sulfide	0.001

Continued

Table B.2 Typical Odor Recognition Thresholds—cont'd

Compound	**ppm by volume**
Diphenyl sulfide	0.005
Ethanol	10
Ethyl acrylate	0.0005
Ethyl mercaptan	0.001
Formaldehyde	1
Hydrochloric acid	10
Hydrogen sulfide	0.0005
Methanol	100
Methylene chloride	200
Methyl ethyl ketone	10
Methyl isobutyl ketone	0.5
Methyl mercaptan	0.002
Methyl methacrylate	0.2
Monochlorobenzene	0.2
Nitrobenzene	0.005
Perchlorethylene	5
Phenol	0.05
Phosgene	1
Phosphine	0.02
Pyridine	0.02
Styrene	0.05
Sulfur dichloride	0.001
Sulfur dioxide	0.5
Toluene	5
Trichloroethylene	20
p-Xylene	0.5

Source: Corbitt (1990).

Activities That Affect the Attribute

In general, industrial operations; research, development, and testing operations; and operation and maintenance activities are potentially capable of emitting odor contaminants to the air.

Specific examples include metallurgical, chemical, petroleum, and food processing operations, feedlots, and burning activities.

Sources of Effects

Malodors can affect both the health and welfare of a community. These effects result from the loss of personal and community pride, reducing property values, tarnishing silver and paints, corroding steel, reducing appetite, producing nausea and vomiting, causing headache, and disturbing sleep, breathing, and olfactory sensations. These result in significant impacts, causing major public concern.

Variables to Be Measured

There are two major variables that measure the extent of odor problems. First, the average annual concentration of selected odor contaminants in parts per million (ppm) by volume is a useful measure of the extent of odor pollution at a given receptor point in a community. Second, the odor intensity, determined by an "odor jury" consisting of a panel of eight persons, is another measure of odor problems. The odor intensity scale has the following levels:

Levels	Descriptors
0	No odor
1	Odor threshold (or very slight odor)
2	Slight odor
3	Moderate odor
4	Strong odor

The concentration and intensity variables are used interchangeably for odor measurements.

How Variables Are Measured

Two distinct methods for measuring malodors are:

- Scentometer method
- Odor judgment panel

A scentometer can be used to measure ambient odor intensities when traveling through dusty areas. Strong, constant odors are measured by a scentometer over a square mile of area. It is a useful routine surveillance device that can identify threshold levels, possible odor problem areas, patterns of peak odor intensity, and other factors over a given region.

On the other hand, an odor judgment panel can be used to verify the source of an unidentified odor, odor intensity, and damage potential of a given odor.

Data Sources

The federal government has not yet established standards for potential odorants. No systematic monitoring and data collection are done with regard to odorants or odor contaminants by state and local agencies. Only in isolated cases will it be possible to find data on odor contaminants for selected periods and monitoring stations operated by state or local agencies.

Skills Required

The use of a scentometer requires at least technician-level training and about a year's experience in using the equipment. The odor panel approach does not require any specific qualifications or formal training. It requires careful selection of juries based on olfactory sensation and continuous training of the jurors to develop proper perception of different types of odors.

Instruments

The scentometer is the only equipment that is required in the first method of measuring odor problems. The second method (i.e., odor panel approach) does not require any equipment whatsoever.

Evaluation and Interpretation of Data

An environment with no odor at all is considered to be an ideal environment, with an environmental quality value of 1.0. Odor threshold concentration represents a tolerable level of odor contamination in the air; as such, it has an environmental quality value of 0.6. The value function falls rapidly with the occurrence of slight odor, and to 0 with a strong odor. Based on the above considerations, the value function for various odorants is presented in Figure B.5. For practical purposes, the odor threshold of any odorant is the odorant concentration that can be detected only by 5 to 10 percent of the panelists. The slight odor is detected by about 20 to 25 percent of the panelists. The moderate odor is detected by about 40 percent of the panelists, and the strong odor is detected by about 100 percent of the panelists.

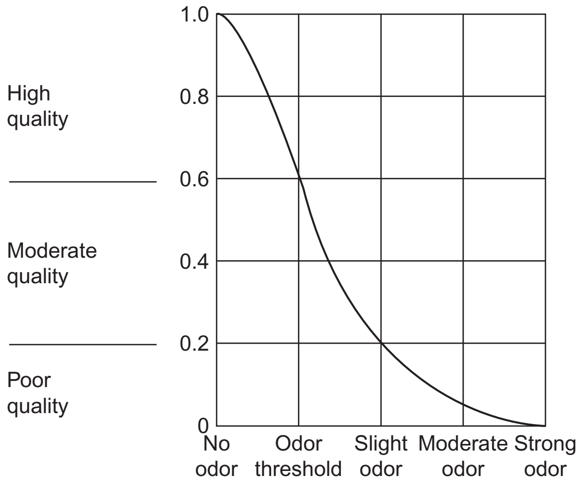

Figure B.5 ***Odor value function.***

Geographical and Temporal Limitations

Concentration of malodors does not remain constant over the entire spatial extent in a given region. Also, it will not remain constant over time. As such, substantial spatial and temporal variations in the concentration can be expected. Spatial variations can be accounted for by analyzing small units of urbanized regions. This requires extensive calculations based on a diffusion model or a large-scale monitoring program. Since the use of a large-scale monitoring network is infeasible in most situations, the problem can be adequately addressed using diffusion models to predict air quality values over the entire spatial area.

The environmental impact of proposed activities on odor level is measured by the change in odor intensity. When the odor intensity changes to the extent that its rating remains unaltered (e.g., high-quality air remains high quality), the impact is considered insignificant. When the change in odor intensity is such that its rating changes by one step (e.g., between high quality and moderate quality), the impact is treated as moderate. When a change in odor rating occurs through two steps (e.g., from high to low quality, or vice versa), the impact is considered significant.

The odor value function (Figure B.5) is used for rating air quality in terms of high, moderate, and low quality, based on measured odor intensity. For a given value of odor intensity on the horizontal axis, a point on the curve can be found which identifies the environmental quality rating from the vertical axis of Figure B.5 (e.g., odor intensity of slight odor indicates a moderate quality of greater than 0.2).

Mitigation of Impact

The many different methods of abating potential impacts of odorous contaminants include:

- Dilution of odorant (dilution can change the nature as well as the strength of an odor)
- Odor counteraction or neutralization (certain pairs of odors in appropriate concentrations may neutralize each other)
- Odor masking or blanketing (certain weaker malodors may be suppressed by a considerably stronger good odor)
- Reduction in odor emissions
- Removal of receptors from polluted areas and/or from downwind odor path
- Fatigued olfactory odor perception (certain levels of odor can be tolerated as a result of perception fatigue due to long-term exposure to the odor)

Planning can help establish optimal combinations of these mitigation alternatives to ensure that the best solution is made available to a community.

Secondary Effects

Additional effects of malodors include the lowering of socioeconomic status, damaging community reputation, discouraging capital investment in a community, and discouraging tourism. Effects on the ecosystem and animal populations are not well understood.

WATER

Water assumes different meaning and significance to different people. A particular definition depends, in large measure, on the personal uses to which water is put by the definer. Water may be considered an absolute necessity to sustain life and a necessary resource for all economic activity by some, and yet a refuge for biological pests and nuisances by others.

Pollution of water may be defined as a reduction in water quality by activities causing an actual hazard to public health or impairment of beneficial use of water.

The water environment is an intricate system of living and nonliving elements. Physical, chemical, and biological factors influencing water quality are so interrelated that a change in any water quality parameter triggers other changes in a complex network of interrelated variables. Often it is difficult to categorize the nature of these interrelationships that may result from human activity and influence the entire water system.

To simplify analysis in the area of water, attributes of similar nature have been grouped together. This grouping was done with the following objectives. The list of selected attributes should be:

1. As compact as possible
2. Equally applicable to surface and groundwater quality
3. Representative of comprehensive water quality indicators
4. Measurable in the field
5. Relevant to the spectrum of major activities
6. Capable of being measured on a project scale

Self-Purification of Natural Waters

All natural waters have the capability to assimilate certain amounts and types of waste without apparent effect upon the environment. The process by which self-purification is achieved is different for surface water and groundwater systems. Processes associated with both types of water systems are briefly described here.

Surface Water System

Some minor degradation of surface water quality may be overcome by the natural capacity of water bodies for withstanding certain insults. Such natural waste assimilation capacity is a result of dilution, sedimentation, flocculation, volatilization, biodegradation, aeration, aging, and uptake by organisms. The effects of relatively small amounts of waste are mitigated, and the water system recovers itself. If the waste load exceeds waste assimilation capacity, even for a short period, the effects may be devastating. The process of self-purification in surface waters is a complex phenomenon.

Groundwater System

Pollution of groundwater systems is a serious problem. Fortunately, contaminants typically must travel through the soil column before reaching the water table. Many soils have the capacity to mitigate manifold types of wastes. The processes by which waste is removed or purified in the soil column include aerobic and anaerobic decomposition, filtration, ion exchange, adsorption, and absorption. The process of dilution also reduces the concentration of contaminants.

Certain contaminants undergo significant removal during movement of water through the soil (unless the groundwater is directly contaminated by fissure cracks, leaks, abandoned or improperly constructed wells, pipes, or holes). Examples of such contaminants are microorganisms, organic matter, and turbidity. Dissolved solids, gases, and colloids are also important in assessing potential groundwater pollution. These contaminants, as discussed later, cause taste, odor, and physiological effects.

When groundwater becomes contaminated, remediation may be difficult and expensive. Due to the relatively low flow-rate characteristic of groundwater systems, pollutants are not readily diluted and thus tend to remain localized problems for extended periods of time. There may also be a considerable lag in time before pollution becomes noticeable in a groundwater system. As a result, today's activity may result in a significant impact only after several years, and today's problems are often traced to discharges of 10 to 30 years ago.

Description of Selected Water Attributes

Fourteen attributes are used to define potential effects on water from the basic activities associated with various programs. These attributes—in three major categories, physical, chemical, and biological—are outlined here:

1. Physical
   - **a.** Aquifer safe yield
   - **b.** Flow variation
   - **c.** Oil
   - **d.** Radioactivity
   - **e.** Suspended solids
   - **f.** Thermal discharge
2. Chemical
   - **a.** Acid and alkali
   - **b.** Biochemical oxygen demand (BOD)
   - **c.** Dissolved oxygen (DO)
   - **d.** Dissolved solids
   - **e.** Nutrients
   - **f.** Toxic compounds
3. Biological
   - **a.** Aquatic life
   - **b.** Fecal coliforms

Table B.3 is a summary table indicating the 14 water quality attributes, conditions contributing to each, and a useful scale of impacts.

Aquifer Safe Yield

Definition of the Attribute

The safe yield of an aquifer is exceeded when the rate of withdrawal surpasses the rate of recharge. Aquifer safe yield describes the general availability of the total groundwater system to supply water for human uses without the ultimate depletion of the aquifer. Aquifer safe yield incorporates physical attributes of the aquifer, which are porosity, permeability, transmissibility (which is permeability times thickness of the aquifer), and the storage coefficient.

Activities That Affect the Attribute

Many human activities affect the aquifer yield. The aquifer safe yield (available water resource) may decrease due to overpumping or by restricting this movement of water into or through the aquifer. During overpumping, as a result of turbulence in the well bore, fine-grained material moving near the well may cause a decrease in water movement toward the well. Land-use patterns may significantly reduce the water percolation into the ground. Also, improper waste injection may cause clogging of the formation due to suspended solids or bacterial action.

Leaching of landfills may also clog the pores. All these factors decrease transmissibility of an aquifer and result in decreased aquifer safe yield. In regions dependent upon groundwater for water supplies, a decrease in safe yield could be highly undesirable. Lowering of the water table may cause public controversy, even in regions almost wholly dependent upon surface waters as a water supply. In coastal regions, uncontrolled water pumping from the ground may reverse the normal seaward gradient of the water table and permit salt water to move inland and contaminate the aquifer.

Many activities may increase water availability due to increased water entering the system, which may result in the raising of the water table accompanied by increased aquifer safe yield. Examples of such activities are water impoundment and reservoir construction and changes in topography to increase percolation. High water table is often accompanied by waterlogging problems in soils and water problems during excavation.

Table B.3 Selected Attribute and Environmental Impact Categories

		Environmental impact category*				
Selected attributes	*Observed condition*	**1** *(most desirable)*	**2**	**3**	**4**	**5** *(least desirable)*
Physical						
Aquifer safe yield†	Changes occurring in physical attributes of aquifer (porosity, permeability, transmissibility, storage coefficient, etc.)	No change	No change	Slight change	Significant change	Extensive change
Flow variation‡	Flow variation attributed to activities (Q_{max}/Q_{min})	None	None	Slight	Significant	Extensive
Oil§	Visible silvery sheen on surfaces, oily taste and odor to water and/or to fish and edible invertebrates, coating of banks and bottom or tainting of attached associated biota	None	None	Slight	Significant	Extensive
Radioactivity§	Measured radiation limit, 10^{-7} microcurie/mL	Equal to or less	Equal to or less	Exceed limit	Exceed limit	Exceed limit
Suspended solids‡	1. Sample observed in a glass bottle 2. Turbidity in net transfer units 3. Suspended solids mg/L	Clear 3 or less 4 or less	Clear 10 10	Fairly clear 20 15	Slightly turbid 50 20	Turbid 100 35
Thermal discharge‡	Magnitude of departure from natural condition, °C	0	2	4	6	10

Continued

Table B.3 Selected Attribute and Environmental Impact Categories—cont'd

Selected attributes	*Observed condition*	Environmental impact category* 1 *(most desirable)*	2	3	4	5 *(least desirable)*
Chemical						
Acid and alkali§ pH units	Departure from natural condition	0	0.5	1	1.5	2
BOD§	mg/L	1	2	3	5	10
DO‡	% saturation	100	85	75	60	Low
Dissolved solids§	mg/L	500 or less	1000	2000	5000	High
Nutrients‡	Total phosphorus mg/L	0.02 or less	0.05	0.10	0.20	Large
Toxic compounds§	Concentration mg/L	Not detected	Traces	Small	Large	Large
Biological						
Fecal coliform§	Number per 100 mL	50 or below	5000	20,000	250,000	Large
Physical						

Aquatic life[‡]	Green algae	Scarce	Moderate quantities in shallows	Plentiful in shallows	Abundant	Abundant
	Gray algae	Scarce	Scarce	Scarce	Present	Plentiful
	Delicate fish; trout, grayling	May be plentiful	Plentiful	Probably absent	Scarce	Absent
	Coarse fish; chub, dace, carp, roach	May be present	Plentiful	Plentiful	Scarce	Absent
	Mayfly naiad, stonefly nymph	May be plentiful	Plentiful	Scarce	Absent	Absent
	Bloodworm, sludge worm, midge larvae, rat-tailed maggot, sewage fly larvae and pupa	May be absent	Scarce	May be present	Plentiful	Abundant

*Environmental impact category: category 1 indicates most desirable condition; category 5 indicates extensive adverse condition. Because all attributes are related to environmental quality between 0 and 1, it is possible to compare different attributes and five categories on a common base. Each category is equivalent to approximately 20 percent of overall environmental quality. In the physical sense, water quality for five categories will be very clean, clean, fairly clean, doubtful, and bad. Environmental impact may be adverse or favorable. Adverse impact will deteriorate the environmental quality while favorable impact will improve the quality. Proper signs and weights must be used to achieve overall effects.
[†]Applies to groundwater systems only.
[‡]Applies to surface water systems only.
[§]Applies to both the groundwater and surface water.

Sources of Effects

As discussed earlier, many activities may upset the aquifer yield by directly or indirectly altering physical factors such as permeability, porosity, and ground surface conditions. The effects may be damaging and reduce potential groundwater resources.

Variables to Be Measured; How Variables Are Measured

Maximum safe yield is measured in thousands of acre-feet of water withdrawn in a unit of time (usually 1 year); the method of measurement is based upon several techniques which all utilize extensive pumping tests.

Evaluation and Interpretation of Data

Knowledge concerning the relationship between degree of change in aquifer safe yield and environmental impact is extremely limited. It would not be possible at this time to make any quantitative judgment. However, since the reasonable environmental goal is to minimize the impact, a qualitative judgment can be made relating to deviation from the natural condition. Table B.3 summarizes five degrees of environmental impact based upon the qualitative judgments, and Table B.4 provides National Primary Drinking Water Standards.

Geographical and Temporal Limitations

Impacts related to aquifer safe yield are most likely to occur in areas with: 1) high dependency on groundwater for supply, 2) a high water table, or 3) significant seasonal precipitation and subsequent infiltration. Local USGS offices and state water agencies are excellent data sources for groundwater information.

Mitigation of Impact

All activities likely to change the physical nature of the aquifer, to affect land surface runoff and percolation, and, in general, to increase or decrease water availability to the aquifer should be carefully controlled. Included are changing land-use patterns, landfilling, lagooning, reservoir construction, deep well injection, and pumping rate modifications. Complete tests should be made to investigate the existing groundwater hydrology, and correctional techniques should be selected to minimize adverse effects. These may relate to land slope and topography; surface area; reservoir, lagoon, and landfill lining; and deep well injection. Pumping rates may be adjusted to minimize the impact. Artificial recharge may also be employed.

Table B.4 2009 National Primary Drinking Water Regulations, EPA

Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0	0.01	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass and electronics production wastes
Asbestos (fiber > 10 micrometers)	7 million fibers per liter (MFL)	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposit
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT*; Action level = 1.3;	Short-term exposure: gastrointestinal distress Long-term exposure: liver or kidney damage Those with Wilson's Disease should consult their personal doctor if their water systems exceed the copper action level.	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories

Fluoride	4	4	Bone disease (pain and tenderness of the bones); children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead	0	TT*; Action level = 0.015	Infants and children: delays in physical or mental development Adults: kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as nitrogen)	10	10	Infants below the age of 6 months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Nitrate (measured as nitrogen)	1	1	Infants below the age of 6 months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in ringers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and pharmaceutical companies

Organic chemicals	MCLG (mg/L)	MCL (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short term)	Sources of contaminant in drinking water
Acrylamide	0	TT*	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	0	0.002	Eye, liver, kidney, or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Benzene	0	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas, storage tanks, and landfills
Benzo(a)pyrene (PAHs)	0	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood or nervous system; reproductive difficulties	Leaching of soil fumigant used on rice and alfalfa

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Carbon tetrachloride	0	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	0	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on row crops
l,2-Dibromo-3-chloropropane (DBCP)	0	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories

p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney, or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	0	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-l,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	0	0.005	Liver problems; increased risk of cancer	Discharge from pharmaceutical and chemical factories
1,2-dichloropropane	0	0.005	Increased risk of cancer	Discharge from industrial chemical factories
Di(2-ethylhexyl)adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties	Discharge from chemical factories
Di(2-ethylhexyl)phthalate	0	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Dioxin (2,3,7,8-TCDD)	0	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	0	TT*	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidney problems	Discharge from petroleum refineries
Ethylene dibromide	0	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries

Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	0	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	0	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	0	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes
Polychlorinated biphenyls (PCBs)	0	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Pentachlorophenol	0	0.001	Liver or kidney problems; increased risk of cancer	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	0	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	0	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories

1,1,1-Trichloroethane	0.2	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	0	0.005	Liver problems; increased risk of cancer	Discharge from petroleum refineries
Vinyl chloride	0	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories
Disinfectants	MCLG (mg/L)	MCL (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as shortterm)	Sources of contaminant in drinking water
Chloramines (as Cl_2)	Maximum residual disinfectant level goal (MRDLG) = 4	Maximum residual disinfectant level (MRDL) = 4	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes
Chlorine (as Cl_2)	MRDLG = 4	MRDL = 4	Eye/nose irritation; stomach discomfort	Water additive used to control microbes

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd

Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Chlorine dioxide (as ClO_2)	MRDLG = 0.8	MRDL = 0.8	Anemia; infants and young children: nervous system effects	Water additive used to control microbes
Disinfection Byproducts	MCLG (mg/L)	MCL (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short term)	Sources of contaminant in drinking water
Bromate	0	0.01	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	0.8	1	Anemia; infants and young children: nervous system effects	Byproduct of drinking water disinfection
Haloacetic acids (HAA5)	N/A	0.060	Increased risk of cancer	Byproduct of drinking water disinfection
Total Trihalomethanes (TTHMs)	N/A	0.08	Liver, kidney, or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection

Radionuclides	MCLG (mg/L)	MCL (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short term)	Sources of contaminant in drinking water
Alpha particles	None	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	None	4 millirems per year	Increased risk of cancer	Decay of natural and manmade deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	None	5pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	0	30 μg/L	Increased risk of cancer, kidney toxicity	Erosion of natural deposits
Microorganisms	MCLG (mg/L)	MCL (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short term)	Sources of contaminant in drinking water
Cryptosporidium	0	TT*	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

Continued

Table B.4 2009 National Primary Drinking Water Regulations, EPA—cont'd
Contaminants

Inorganic chemicals	Maximum contaminant level goal (MCLG) (mg/L)	Maximum contaminant level (MCL) (mg/L)	Potential health effects from long-term exposure above the MCL (unless specified as short-term)	Sources of contaminant in drinking water
Giardia lamblia	0	TT*	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count (HPC)	N/A	TT*	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment
Legionella	0	TT*	Legionnaire's disease, a type of pneumonia	Found naturally in water; multiplies in heating or air conditioning systems
Total coliforms (including fecal coliform and *E. Coli*)	0	5.0%	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste

Turbidity	N/A	TT*	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff
Viruses (enteric)	0	TT*	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

*Treatment technique (TT). An enforceable procedure or level of technical performance which public water systems must follow to ensure control of a contaminant.
Source: EPA, Office of Water, May 2009.
Note: MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to human health. "None" indicates no goal has been established. MCLGs are nonenforceable goals. MCL is the highest level of a contaminant that is allowed in drinking water and is set as close to the MCLG as possible. MCLs are enforceable standards. MRDLG is the level of a drinking water disinfectant below which there is no known or expected risk to health. MRDL is the highest level of a disinfectant allowed in drinking water.

Secondary Effects

Alterations in aquifer safe yield can be related to other attributes in terms of secondary impacts. Aside from being a community need, a safe, dependable water supply is necessary for community and regional economic stability. It can affect land-use patterns as well, since it is a factor in domestic, industrial, and agricultural requirements.

Flow Variations

Definition of the Attribute

The velocity of flow and rate of discharge are extremely important to aquatic organisms in a number of ways, including the transport of nutrients and organic food past those organisms attached to stationary surfaces; the transport of plankton and benthos as drift, which in turn serve as food for higher organisms; and the addition of oxygen to the water through surface aeration. Silts are moved downstream, and sediments may be transported as bed load. These, in turn, are often associated with major nutrients, such as nitrogen and phosphorus, which may be released at some point downstream.

Natural flow variations are, therefore, critical factors governing the type of ecological system that will develop and survive in a given watercourse. If the pattern of stream flow variation is changed markedly from what is natural, subsequent disruption of the natural ecology may result.

Activities That Affect the Attribute

Major activities that may influence stream flow include water resource projects and changing the ground surface and topography for different types of land-use projects. This may include site clearing, earthwork and borrowing, paving of land areas, and building construction. Other activities include modification of vegetation, which can lead to altered runoff patterns, and water use changes in withdrawal and return flow rates.

Sources of Effects

Water resource projects may be for flood control (that reduces high flows), power generation (that minimizes low-flow conditions), or any desired use that alters the flow pattern of the stream. The land-use project alters the runoff, percolation, and evaporation in the drainage basin. These changes may increase or decrease the runoff. Other attributes affected by such activities are suspended solids and nutrients in the watercourses; they may, in turn, affect the population of photosynthetic organisms and, thus, the food chain. Direct flow variations are caused by fluctuating municipal, industrial, and/or agricultural demands and the return flows from these uses.

Variables to Be Measured; How Variables Are Measured

Flow measurement is relatively simple. Many types of automatic flow measurement devices that can be installed in a selected reach of a watercourse are commercially available. The typical unit of flow measurement is cubic feet per second (ft^3/s). Velocity measurement may be accomplished by current meters, which register in feet per second (ft/s).

Evaluation and Interpretation of Data

If flow variations are rapid and extensive, more disruption to natural ecology results. However, due to lack of information, classification of water cannot be made on the basis of qualitative measurement. Five degrees of environmental impact are summarized in Table B.3. This classification is based upon qualitative or observed conditions.

Special Conditions

Flow variations become most significant at the extreme conditions—low flows and high flows. Under low-flow conditions, the natural assimilative capacity of a given stream is greatly reduced, and the adverse effects of natural and human-induced waste loads are most critical. At high flows, physical damage due to flooding and inundation of vegetation becomes a major concern.

Geographical and Temporal Limitations

Low-flow considerations are of importance on all streams; however, they warrant particular consideration in areas that typically experience prolonged periods of drought. These periods frequently coincide with summer, when biological activity is high and dissolved oxygen content in streams is at a minimum, thus compounding the significance of the problem.

Impacts associated with high-flow conditions are most likely to occur in areas and climates with conditions conducive to flooding.

Mitigation of Impact

All activities such as land-use projects and water impoundment and operation should be given consideration to minimize flow variations from the mean natural flow.

Secondary Effects

Human-induced flow variations may have secondary impacts in ecology, land-use patterns, and the socioeconomic realm. Many species of plant and animal life are sensitive to flow variations and require specific ranges of flow conditions. Floodplain development can be a function of the degree of control over flow variations. Economic losses are felt through flooding of agricultural as well as built-up areas, and adverse psychological effects are apparent when there are threats of flood.

Oil

Definition of the Attribute

Oil (i.e., petroleum) slicks on water are barely visible at a concentration of about 25 gal/mi^2. At about 50 gal/mi^2, an oil film is about 3.0×10^{-6} inches thick and is visible as a silvery sheen on the surface of a body of water. Oil is destructive to aquatic life in the following ways:

- Free oil and emulsions may coat and destroy algae and plankton.
- Heavy coating may interfere with the natural processes of reaeration and photosynthesis.
- Water-soluble fractions may exert a direct toxic action.
- Settleable oil substances may coat the floor of the water body, destroy benthic organisms, and interfere with spawning areas.

Activities That Affect the Attribute

Major activities responsible for oil pollution include bilge and ballast waters discharged from ships; oil refinery wastes; industrial plant wastes, such as oil, grease, and fats, and lubrication of machinery; gasoline filling stations; bulk stations; and accidental spills.

Sources of Effects

Oil may reach natural waters by direct discharge or by surface runoff. Direct discharge may occur from bilge and ballast waters or by accidental spill from barges or tankers. Indirect oil release may occur from surface runoff or storm sewers or combined sewer overflows. In all cases, damage could be severe and long lasting. Water quality parameters affected by oil discharge are dissolved oxygen, general appearance, and taste and odor.

Variables to Be Measured; How Variables Are Measured

Dissolved or emulsified oil or grease is extracted from water by intimate contact with various organic solvents. The results are expressed in milligrams per liter of oil or grease. Other measurements are qualitative and include: 1) visible oil slick, 2) oily taste and odor in fish and edible invertebrates, and 3) coating of banks and bottom or tainting of associated biota. Quantitative measurement of oil and grease is by extraction in a separating funnel with either trichlorotrifluoroethane or petroleum ether. This technique is routinely used in water and wastewater analysis.

Evaluation and Interpretation of Data

Due to lack of information, classification of water cannot be made on the basis of quantitative measurement or concentrations. Five degrees of water impacts are summarized in Table B.3 on the basis of qualitative or observed conditions.

Mitigation of Impact

Oil pollution can be minimized by controlling all direct discharge into natural waters. Surface runoff from oil-handling areas should be treated for oil separation before discharge into the environment. If oil wastes are combined with sanitary sewage, oil separation will be necessary at the wastewater treatment facility. Lagooning of oil wastes and land disposal of oily sludges should be restricted in order to avoid possible contamination of the groundwater system.

Secondary Effects

Secondary effects of oil discharges are manifested through impacts on aquatic ecology and waterfowl, economic loss through decreased recreational desirability, and lowered property values if the discharges become frequent. Increased activity in exploration, production, and transportation of petroleum can increase controversy, divide communities, alter land-use patterns, and indirectly affect public and private land markets—whether or not any actual spills take place.

Radioactivity

Definition of the Attribute

Ionizing radiation, when absorbed in living tissue in quantities substantially above that of natural background, is injurious. It is therefore necessary to prevent excessive levels of radiation from reaching any organism, such as humans, fish, or invertebrates.

Activities That Affect the Attribute

Human activities responsible for radiation hazards are application of nuclear methods in power development, industrial operation, medical laboratories, research and development, nuclear weapons testing, and radiation warfare.

In all applications, radioactive substances may be released accidentally, by inadequately planned and controlled activity, or by disposal of radioactive wastes.

Sources of Effects

Radioactivity, once released to the aquatic environment, may: 1) remain in solution or in suspension, 2) precipitate and settle to the bottom, or 3) be taken up by plants and animals. Immediately upon introduction of radioactive materials into the water, the wastes may become diluted by dispersion or may become concentrated by the process of biological magnification.*

Variables to Be Measured; How Variables Are Measured

The measure of radioactivity is the curie (Ci), the quantity of any radioactive material in which the disintegrations per second are 3.7×10^{10}; this is a large amount of radioactivity. Two smaller units, the microcurie (μCi, 10^{-6} Ci) and the picocurie (pCi, 10^{-12} Ci or 2.22 disintegrations per minute), are often used. Radioactive waste can be diluted in water to below the allowable limit. The allowable limit of radiation in natural water is taken as 10^{-7} μCi/mL when the activity is caused by an unknown mixture of beta- and gamma-emitting isotopes.

Measurement techniques are not difficult because radiation-counting equipment of high sensitivity and stability is commercially available.

Evaluation and Interpretation of Data

It is difficult to determine the long-term effects of radiological wastes upon aquatic life. For this reason, and as a practical matter, radioactivity exceeding the allowable limit of 10^{-7} μCi/mL may be considered detrimental to human health and aquatic life. Five classes of water impacts are given in Table B.3.

Special Conditions

Special precautions should be taken to prevent radioactive materials from entering ground or surface waters to be used for drinking water supply, fish production, or recreation. Table B.4 provides national primary drinking water standards that should be consulted for water that is to be used as a drinking water supply.

* Biological magnification, or bioaccumulation, is a process in which some substances become concentrated as they pass through the food chain.

Mitigation of Impact

Release of radioactive wastes from radiation facilities must be monitored and controlled. Radioactivity in sewage after treatment is likely to be concentrated in sludge; thus sludge disposal becomes a difficult problem. Therefore, waste containing radioactivity should be treated separately by means of dewatering procedures, and solids or brine should be disposed of by special care (deep well injection or containment). Fallout of radioactive dust will induce radioactivity in surface runoff, the treatment of which is a difficult task. All efforts should therefore be made to minimize release of radioactivity into the environment.

Secondary Effects

While it is generally understood that aquatic organisms are relatively tolerant of radioactive materials, little is known of the mechanism of concentrating radioactive elements by these organisms and the effect this might have on human or other consumer organisms. Although there have been few cases of actual radioactive contamination of water resources, the fear of such contamination has had much greater impact. These fears have resulted in controversy and altered land-use patterns and have had other socioeconomic effects.

Suspended Solids

Definition of the Attribute

Suspended solids are solids contained in water that are not in solution. They are distinguished from dissolved solids by laboratory filtration tests. Suspended solids comprise settleable, floating (specific gravity lower than water), and nonsettleable (colloidal suspension) components. These may contain organic (volatile suspended solids) or inert (nonvolatile) substances. Turbidity may be caused by a wide variety of suspended materials, ranging in size from colloidal particles to a coarse dispersion, depending upon the turbulence and light-scattering properties of suspended materials.

Suspended solids are perhaps of greatest significance from the standpoint of aesthetics. Natural waters may contain wide variations of suspended solids. These may be due to clay, silt, silica, organic matter, microorganisms, or sewage. Suspended solids may be undesirable in many ways. In public water supplies, turbid water is difficult and costly to filter. Disinfection may require higher chemical dosages if the water is turbid. Also, excessive suspended solids can be harmful to fish and other aquatic life by coating gills, blanketing bottom organisms, reducing solar radiation intensity, and, thus, affecting the natural food chain. In stream pollution-control work, all suspended solids are considered to be settleable solids, because eventually (by bacterial decomposition and chemical flocculation) those solids are deposited.

Activities That Affect the Attribute

Activities directly responsible for suspended-solids release are dredging, wastewater discharge, construction of hydraulic structures, and gravel washing. Activities that indirectly affect suspended solids result from land use: site clearing, surface paving, building construction, landscaping, and mine tailings. All change the surface runoff pattern, which increases the storm flow in most cases. Suspended-solid load in the surface runoff may change considerably due to erosion. Also, flow variations in streams may change the bed load and solids transport.

Sources of Effects

As discussed earlier, many activities will increase or decrease the suspended-solid condition in natural waters. Many times this effect may be temporary. For example, dredging may increase suspended solids during operation. After completion of dredging, the channel may become deeper and wider; thus, dredging may actually reduce velocity and encourage settling. Likewise, many other activities, such as construction, site clearing, and excavation, may have effects that should be evaluated as long or short term.

Many water quality attributes may be affected by change in suspended-solid condition. These include dissolved oxygen (DO) (due to increase in photosynthesis), nutrient enrichment, and direct deleterious effects on fish and other aquatic life by coating gills or blanketing bottom organisms, for example.

Variables to Be Measured; How Variables Are Measured

Readily settleable suspended solids are measured in milliliters per liter of settled water. Suspended solids are measured by filtering a sample through a membrane filter or a glass fiber mat in a Gooch crucible. Turbidity is measured in net transfer units equivalent to the interference to light transmission caused by 1 mg/L of a standard suspension.

Many types of commercially available instruments can continuously measure and record the turbidity and the suspended solids in water. They rely upon transmission, diffraction, and absorption of light through a standard light path.

Evaluation and Interpretation of Data

Water quality is considered lower with increasing turbidity and suspended solids. Table B.3 summarizes the five classes of water impact based upon turbidity, suspended solids, and visual consideration.

Mitigation of Impact

The impact due to suspended solids may be minimized by controlling discharge of wastes that contain suspended solids; this includes sanitary sewage and industrial wastes. Also, all activity that increases erosion or contributes nutrients to water (thus stimulating algae growth) should be minimized.

Gravel-washing activities, mine tailings, and anything causing dust may be controlled by utilizing available technology.

Secondary Effects

Increase in suspended solids content may have secondary impact on socioeconomic attributes as a result of loss of productivity (e.g., decline in fish harvest) and reduction in various recreation-oriented activities. Additionally, increased costs to remove suspended solids for domestic or industrial water use may occur as a result. Long-term effects include siltation of reservoirs, reducing useful capacity, and filling of marsh areas in estuaries, reducing productive habitat.

Thermal Discharge

Definition of the Attribute

Temperature is a prime regulator of natural processes within the water environment. In addition to affecting the rate of chemical reactions, it governs physiological function in organisms and, acting directly or indirectly in combination with other water quality constituents, affects aquatic life with each change. Water temperature controls spawning and hatching, regulates activity, and stimulates or suppresses growth; it can kill when the water becomes heated or chilled too suddenly. Colder water generally suppresses development; warmer water generally accelerates activity.

Activities That Affect the Attribute

Human activities affecting the attribute are discharges with temperatures above or below that of the receiving waters. Heated discharge may result from sources such as thermal power generation, heavy machine operations, and industrial operations.

Cold water discharges may result from flows from large, deep reservoirs.

Sources of Effects

Heated wastes, when discharged into the water environment, raise the temperature of the water. The extent to which the temperature is raised depends upon the quantity of waste heat discharged and the amount of diluting water available. As water temperature increases, the solubility of oxygen decreases. Furthermore, the accelerated biological activity imposes higher oxygen demand. The net result is a decrease in DO level, which can reach critical levels.

Water released from lower depths of stratified reservoirs may be significantly lower in temperature and DO content than would prevail in normal ambient stream conditions. Thus, release depths can have a pronounced effect upon the aquatic life below reservoirs.

Variables to Be Measured; How Variables Are Measured

Temperature measurement is simple and accurate. Many types of automatic temperature recording devices are commercially available. Measurement scale is either degrees Celsius or degrees Fahrenheit. Prediction of the effects of projects on ambient water temperatures is a complex problem that may be addressed through the use of mathematical models for mixing and heat exchange in the aquatic environment.

Evaluation and Interpretation of Data

In environmental quality assessment, temperature effects are best handled in terms of the magnitude of departure from natural conditions. Table B.3 summarizes five classes of water impacts, based upon temperature rise above natural conditions. Allowable departures from ambient temperatures may vary with location, so state water quality regulations should be consulted.

Geographical and Temporal Limitations

Fogging problems may be associated with warm water discharges in cold regions or under special climatic conditions.

Mitigation of Impact

Cooling towers can be used to convert once-through systems into closed systems. A very efficient way is to utilize treated wastewaters (such as sewage, industrial wastes, or stored surface runoffs) as cooling water makeup. Many industrial plants are considering this type of closed system. Chromium may be recovered from cooling tower blowdown before treatment and disposal of tower blowdown. Selective withdrawal may be employed to control the temperature of water released from stratified reservoirs.

Secondary Effects

Effects on the aquatic environment resulting from temperature alteration may, in turn, have other biophysical and socioeconomic consequences. Increased heat to water bodies accelerates evaporation, and thus the suspended solids content of the water. This and other impacts on the biological activity may alter the aesthetic and recreational desirability of a given area. Depending upon the circumstances, these effects may be of a positive or a negative nature. On the one hand, heat addition may speed the eutrophication process and reduce recreational use. In other instances, this effect has increased recreational benefit through increased productivity. Aquaculture, or "fish farming," has been investigated as a possible beneficial secondary result of heated discharges.

Acid and Alkali

Definition of the Attribute

Acid and alkaline wastes discharged into waters may change the natural buffer system. The pH of the water may significantly change, depending upon the extent of acid or alkali discharged. Change in the pH of natural water is hazardous for fish and other aquatic life. Below a pH of 5.0 and above 9.0, fish mortalities may be expected.

Activities That Affect the Attribute

Activities which may contribute acid and alkali waste to the environment are industrial wastes such as pickling liquors, tanning, metal finishing, food processing, accidental spills of chemicals, and mining operations.

Sources of Effects

Acid and alkali wastes can be extremely damaging to aquatic life. Toxicity due to the solubility or precipitation of heavy metals is increased by synergism. Also, the capacity of natural waters to assimilate organic wastes is significantly reduced by these wastes.

Variables to Be Measured; How Variables Are Measured

The pH is considered to be an important measure of environmental quality. High pH reflects an alkaline situation, and low pH reflects an acid condition (a neutral solution has a pH equal to 7.0).

The pH measurement is simple. Many types of continuous measuring and recording instruments are commercially available for this purpose.

Evaluation and Interpretation of Data

Since the natural pH of aquatic ecosystems varies from one locale to another, the best measure of pH is in terms of departure from natural levels. Table B.3 summarizes five classes of water impacts, based upon pH departure from the normal. It has been assumed that both positive and negative departures are equally damaging to the environment. This may not be strictly true in normal cases, but due to lack of evidence, such assumptions may be considered valid.

Special Conditions

In some cases, alkaline or acid wastes actually may help to balance a pH problem. Acid mine drainage is an example of a problem which would be neutralized by an alkaline discharge; however, these are more productively controlled through treatment processes.

Secondary Effects

Secondary effects of impacts on the acidity or alkalinity of waters follow as a result of any condition that deteriorates the quality of water. Social and economic losses in terms of reduced productivity, decline in recreational benefits, and additional costs of treatment to correct problems related to pH are a few examples.

Biochemical Oxygen Demand (BOD)

Definition of the Attribute

BOD of water is a direct bioassay to measure the amount of oxygen required to biologically degrade the organic material present. It is thus an indication of the amount of DO that will be depleted from water during the biological assimilation of organic pollutants. The BOD test is widely used to determine the organic strength of sewage and industrial wastes in terms of oxygen that would be required to oxidize organics if these wastes were discharged into natural waters in which aerobic conditions exist. The test is one of the most important in stream pollution-control activities. By its use, it is possible to determine the degree of organic pollution in natural waters at any time. This test is also of prime importance in regulatory work and in studies designed to evaluate purification capacity of receiving bodies of water.

Activities That Affect the Attribute

Activities associated with normal municipal and industrial operations may contribute to BOD wastes. These human activities (e.g., sanitary sewage; wastewaters from hospitals, food-handling establishments, and laundry facilities; and floor washing from shops) constitute BOD wastes. If all wastes are collected by a network of sewers to a central location, adequate treatment must be provided to minimize impact upon the surface water system. If cesspools, septic tanks, and soakpits are utilized, groundwater in the vicinity may become adversely affected.

Sources of Effects

The discharge of wastes containing organic material imposes oxygen demand in the natural body of water and reduces the DO level. If wastewaters are treated, the combined sewer overflows and surface runoffs may also exert effects under wet weather conditions. All parameters directly or indirectly related to DO also affect the organic waste assimilation. These parameters include depth of water, velocity of flow, temperature, and wind velocity (see section on DO for general discussion).

Variables to Be Measured; How Variables Are Measured

BOD values are generally expressed as the amount of oxygen consumed (mg/L) by organisms during a 5-day period at 20°C. Several other parameters, such as chemical oxygen demand (COD) and total organic carbon (TOC), are also used to represent the organic matter in water and wastewater. The COD value indicates the total amount of chemically oxidizable material present and is normally greater than BOD. TOC is a measure of bound carbon. Both these tests are closely related to BOD and are used in water and wastewater monitoring programs.

Routine BOD measurements are made in laboratories by dilution techniques; results are obtained in 5 days. Some modifications of BOD tests may require less time. COD measurements take a few hours, and TOC takes only seconds. Several types of instruments that measure TOC on a continuous basis are commercially available.

Evaluation and Interpretation of Data

Table B.3 indicates five classes of water: very clean, clean, fairly clean, doubtful, and bad, depending upon the BOD of water. It may be mentioned, however, that this classification must be used on relative terms. As an example, a sluggish stream, reservoir, or lake may show undesirable conditions at BOD of 5 mg/L, whereas a swift mountain stream may easily handle 5 mg/L of BOD without significant deleterious effects.

Mitigation of Impacts

All wastes containing organic material should be processed by treatment methods. The treatment methods may include biological and/or chemical processes. Also, several types of packaged treatment units are commercially available that can be installed for desired applications.

Secondary Effects

By virtue of the biologic and aesthetic effects of BOD on aquatic environments, secondary impacts are manifested in terms of additional impacts on aesthetics, reduced recreational benefits, and costs to alleviate the direct consequences of BOD on waters scheduled for reuse. The success of land-use planning efforts in areas where water is an integral part of the planning effort (e.g., recreational areas and industrial siting) is dependent upon the quality of those waters. BOD is a parameter of importance.

Dissolved Oxygen (DO)

Definition of the Attribute

Almost all living organisms depend upon oxygen in one form or another for their metabolic process. Aerobic organisms require DO and produce innocuous end products. Anaerobic organisms utilize chemically bound oxygen, such as that from sulfates, nitrates, and phosphates, and the end products are odorous. For a diversified warm-water biota, including game fish, DO concentration should remain above 5 mg/L. Absence of DO will lead to the development of anaerobic conditions with odor and aesthetic problems. In surface waters, DO is measured frequently to maintain conditions favorable for the growth and reproduction of fish and other favorable aquatic life.

Activities That Affect the Attribute

The activities discussed in BOD also apply to DO. Other activities that may influence DO include site preparation demolition, dredging, and excavation, all of which may cause turbidity and nutrient release. Routine operations, such as operation and maintenance of aircraft, watercraft, and automotive equipment, may cause oil release. Oil film interferes with the natural process of reaeration.

Sources of Effects

Discharge of all organic wastes lowers the DO in receiving waters. A shallow, swift mountain stream can assimilate large quantities of organic wastes without deleterious effects. This is because swift-moving streams have greater capacity for natural reaeration and for preventing deposition of organic materials at the stream bed. In a sluggish stream or reservoir, small amounts of BOD released may cause relatively large adverse effects. The solubility of oxygen in water decreases with increases in temperature and dissolved salts (in fresh water, solubility of oxygen at 0°C is 14.6 mg/L, and at 35°C, it is 7 mg/L). Biological activity is also increased at higher temperatures, and thus the rate of DO utilization from natural waters is significantly increased. Therefore, BOD wastes discharged into natural waters have more pronounced effects during summer months when the water is warm. Thus, water quality parameters, such as temperature, dissolved salts, depth and velocity of the stream, wind velocity, and natural reaeration, are all interdependent. Also, in nutrient-rich bodies of water, due to algae bloom, the DO level may reach supersaturation during sunny days. At night, however, the DO level drops considerably, due to lack of photosynthesis. High turbidity in water may also interfere with photosynthesis by reducing the depth of light penetration. Oil slicks may reduce the natural reaeration process, too. Therefore, nutrients, algae, sunny days, turbidity, and oil slicks are all interdependent parameters.

Variables to Be Measured; How Variables Are Measured

The unit of DO measurement is milligrams per liter. It can be measured by titration techniques using the azide modification method. Many commercially available DO meters can be used for DO measurement.

Evaluation and Interpretation of Data

The oxygen requirements for fish vary with species and age. Coldwater fish require higher oxygen concentration than do the coarse fish (carp, pike, eel). It may be stated that the 3- to 6-mg/L range is the critical level of DO for nearly all fish. Below 3 mg/L, further decrease in DO is important only insofar as the development of local anaerobic conditions is concerned; the major damage to fish and aquatic life will already have occurred. Above 6 mg/L, the major advantage of additional DO is as a reservoir or buffer to handle shock loads of high-oxygen-demanding waste loads. Table B.3 indicates five classes of water according to DO levels.

Geographical and Temporal Limitations

Typically, the most critical DO problems occur in summer when biological activity is high and saturated DO content is low.

Mitigation of Impact

The methods are the same as those given for BOD.

Secondary Effects

Secondary impacts are the same as those listed for BOD.

Dissolved Solids

Definition of the Attribute

High amounts of total dissolved solids (TDS) are objectionable because of physiological effects, mineral tastes, or economic effects. TDS is the aggregate of organic and inorganic compounds, such as carbonates, bicarbonates, chlorides, sulfates, phosphates, nitrates, and other salts of calcium, magnesium, sodium, potassium, and other substances. All salts in solution change the physical and chemical nature of the water and exert osmotic pressure; the magnitude of the change is, to a large extent, dependent upon the total salt concentration (salinity), measured as the sodium index.

Activities That Affect the Attribute

Major activities that may contribute to TDS include mining and quarrying, municipal and industrial waste disposal, brine disposal, lagooning, landfilling of solid wastes, and accidental spill of chemicals.

Sources of Effects

Major activities listed above may cause release of salts either directly or indirectly into the natural water system. Direct release includes discharging the waste laden with salts into the water system. Indirect release may be due to runoff from the affected land or seepage from filled areas. Landfill seepage or leaching may affect groundwater quality, and, if groundwater feeds the water courses, surface water may be affected as well.

As a result of salt discharge, many water quality parameters will be affected. DO will decrease as a result of high salinity. High quantities of salts give a mineral taste. Sulfates and chlorides are associated with corrosion damage. Sulfate in water has a laxative effect. Nitrate plus nitrite causes methemoglobinemia (blue-baby disease).

Variables to Be measured; How Variables Are Measured

Total dissolved solids are determined after evaporation of a sample of water and its subsequent drying at 103°C in an oven. This includes "nonfilterable residue." The results are expressed in milligrams per liter of TDS.

Evaluation and Interpretation of Data

For reasons of palatability and unfavorable physiological reaction, a limit of 500 mg/L TDS in potable water has been recommended. Highly mineralized waters are also unsuitable for many industrial applications. Irrigation crops are highly sensitive to salt concentrations; waters containing more than 2000 mg/L are of marginal value for irrigation use, and waters containing 3000 mg/L are unsuitable. The upper limits for some freshwater fish are as high as 5000 mg/L. In such cases, the sodium index is used to estimate the total salt concentration and its effects on osmotic pressure. Based upon TDS, the five impact classes are summarized in Table B.3.

Special Conditions

The amount of dissolved ionic matter in a sample may often be estimated by multiplying the specific conductance by an empirical factor. After the empirical factor is established, for a comparatively constant water quality, specific-conductance measurement will yield TDS. Specific-conductance measurement is relatively simple and is a measure of the water's capacity to convey an electric current at 25°C. Specific conductance is expressed as microohms per centimeter.

Mitigation of Impact

Wastes containing high TDS are difficult to treat. Recommended treatment methods include removal of liquid and disposal of residue by controlled landfilling to avoid any possible leaching of the fills. Deep well injection has been used for disposal of brine. All surface runoffs around mines or quarries should be collected and concentrated. The brine may be disposed of by deep well injection or other means acceptable to water quality control authorities.

Secondary Effects

Effects on irrigated cropland (reduced productivity and economic loss) constitute perhaps the most significant secondary impacts due to TDS. Other effects include those on health, where drinking waters are concerned, and those on economics and land use, where industrial and municipal consumption are to be considered.

Nutrients

Definition of the Attribute

Eutrophication is a term meaning enrichment of waters by nutrients through either human-induced or natural means. Present knowledge indicates that the fertilizing elements most responsible for eutrophication are phosphorus and nitrogen. Inorganic carbon (CO_2), iron, and certain trace elements are also important. Eutrophication results in an increase in algae and weed nuisances and an increase in larvae and adult insects. Dense algal growths (blooms) may form surface water scums and algae-littered beaches. Water may become foul smelling when algae cells die; oxygen is used in decomposition, and fish kills result. Filter-clogging problems at municipal water treatment plants and taste and odor in water supplies may all be due to the dense algal population and byproducts resulting from its subsequent decay.

Activities That Affect the Attribute

Sewage and sewage effluent contain a generous amount of the nutrients necessary for eutrophication. Treated or untreated sewage discharge will contribute to nutrients in receiving waters. Mining, tunneling, blasting, and quarrying into phosphate rocks may cause increased phosphorus from surface runoff. Dredging of waterways will release the storehouse of nutrients contained within the mud bottom; as a result, the water will become enriched during and soon after the dredging operation. Many other activities may enrich the natural waters. These include drainage from cultivated agricultural lands, surface irrigation return flows, logging and sawmilling, deposition of dead trees and leaves, and growth of natural organisms.

Sources of Effects

Nutrients released from many activities (described above) will cause aquatic plant problems, turbidity, taste, and odor; cause reservoir and other standing waters to collect nutrients and to store a portion of these within consolidated sediments (once nutrients are combined within the ecosystem of receiving waters, their removal by natural process is very slow); and induce excessive weed growth, which will eventually block waterways or turn lakes into swamps.

As a result of nutrients released into natural waters, many water quality parameters will be affected directly or indirectly. Some of these effects are turbidity, due to excessive algae growth. Then, when algae cells and other plants die, oxygen is used in decomposition and the DO level declines, causing fish kill; rapid decomposition of dense algal growths, giving rise to odors and hydrogen sulfide gas that create strong citizen disapproval; and serious water treatment problems, caused by color, taste, and odor.

Variables to Be Measured; How Variables Are Measured

Phosphorus, nitrogen, carbon, iron, and trace metals all act as nutrients. Growth of aquatic plants is governed by the law of minimum (i.e., any nutrient, out of a broad array of materials required for growth and development, governs the growth if it is present in a limiting concentration). In natural waters, phosphorus is present in limiting amounts and commonly governs the rate of normal plant growth.

Phosphorus occurs in natural waters and in wastewaters almost solely in the form of phosphates. These forms are commonly classified into orthophosphates, condensed phosphates (pyro-, meta-, and polyphosphates), and organically bound phosphates. These phosphates may occur in the soluble form, in particles of detritus, or in the bodies of aquatic organisms. Because the ratio of total phosphorus to that form of phosphorus readily available for plant growth is constantly changing and ranges from 2 to 17 times or greater, it is desirable to establish limits on the total phosphorus rather than the portion that may be available for immediate plant use.

Phosphate analysis embodies two general procedural steps: 1) conversion of the phosphorus form of interest to soluble orthophosphate, and 2) colorimetric determination of soluble orthophosphates. The result may be expressed as milligrams per liter phosphorus (mg/L P).

Evaluation and Interpretation of Data

Although the concentration of inorganic phosphorus that will produce problems varies with the nature of the aquatic environment and the levels of other nutrients, most relatively uncontaminated lake districts are known to have surface waters that contain 0.001 to 0.003 mg/L total phosphorus as P (they are nutrient deficient). Above 0.02 mg/L P, one gets into a region of potential algae bloom. Above 0.1 mg/L P, water is excessively enriched. Table B.3 categorizes five classes of waters, based upon total phosphorus contact.

Geographical and Temporal Limitations

Since algae growth is temperature-dependent, adverse effects due to eutrophication in northern climates are more pronounced in summers. In southern climates, the effects are felt over the entire year, with fall overturn in stratified reservoirs being the most critical time.

Mitigation of Impact

Once nutrients are combined within the ecosystem of the receiving waters, their removal is tedious and expensive. In a lake, reservoir, or pond, phosphorus is removed naturally only by overflow by insects that hatch and fly out of drainage basins, by harvesting a crop (such as fish), and by combination with consolidated bottom sediments.

The most desirable method to mitigate impact is to treat wastewater to a desired phosphorus level before discharge into the environment. Also, all major activities mentioned earlier should be performed under controlled conditions.

Secondary Effects

Various adverse secondary impacts occur with advanced stages of eutrophication, including a decline in recreational benefits, effects on land use, and the economic losses that normally accompany any deterioration in water quality.

Toxic Compounds

Definition of the Attribute

Wastes containing concentrations of heavy metals (mercury, copper, silver, lead, nickel, cobalt, arsenic, cadmium, chromium, etc.), either individually or in combination, may be toxic to aquatic organisms, and thus have a severe impact on the water community. Other toxic substances include pesticides, ammonia-ammonium compounds, cyanides, sulfides, fluorides, petrochemical wastes, and other organic and inorganic species. A severely toxic substance will eliminate aquatic biota until dilution, dissipation, or volatilization reduces concentration below the toxic threshold. Less generally, toxic materials will reduce the aquatic biota, except those species that are able to tolerate the observed concentration of the toxicant. Because toxic materials offer no increased nutrient supply, such as discussed for organic wastes, there is no increase seen in the population of those organisms that may tolerate a specific concentration.

Activities That Affect the Attribute

Many human activities may contribute to release of toxic compounds into the environment. These include waste discharged from maintenance and repair shops and from industrial operations. Wastes that are particularly likely to contain toxic compounds result from electroplating, galvanizing, metal finishing, and cooling tower blowdown. Other activities that may contribute to toxic chemicals are mining, accidental spills of chemicals, chemical warfare, and leaching of landfills containing toxic compounds.

Sources of Effects

Chemicals released into the environment may affect surface water or groundwater systems by direct discharge of wastes containing toxic compounds or from surface runoff that may come in contact with toxic material left as residue over the ground surface.

Variables to Be Measured; How Variables Are Measured

The spectrum of toxic materials is extremely large and highly diverse in terms of effects. Measurement may be expressed as μg/L of the specific compound under consideration. For a group of toxic compounds, it should be pointed out that possible synergistic or antagonistic interactions among mixed compounds may cause different effects from those associated with the respective toxic compounds considered separately.

Bioassay is an important tool in the investigation of these wastes, because results from such a study indicate the degree of hazard to aquatic life of particular discharges; interpretations and recommendations can be made from these studies concerning the level of discharge that can be tolerated by the receiving aquatic community.

Atypical basic bioassay might consist of a 96-hour exposure of an appropriate organism, in numbers adequate to assure statistical validity, to an array of concentrations of the substance, or mixture of substances, that will reveal: 1) the level of pollution that will cause irreversible damage to 50 percent of the test organisms, and 2) the maximum concentration causing no apparent effect on the test organisms in 96 hours.

Evaluation and Interpretation of Data

The bioassay may indicate the concentration at which toxic compounds will not cause an apparent effect upon the test organism. However, long-term effects of toxic compounds having more subtle changes, such as reduced growth, lowered fertility, altered physiology, and induced abnormal patterns, may have more disastrous effects on the continued existence of a species. Also, the biological magnification and storage of toxic residue of polluting substances and microorganisms may have another serious after-effect. For all these reasons, and as a practical matter, toxic compounds, if they can be detected in natural waters by modern water quality analysis methods, may render water undesirable for propagation of healthy aquatic life. The five classes of water, based upon toxic compounds, are given in Table B.3.

Special Conditions

Synergistic action may magnify toxic effects under special conditions (e.g., under an increased temperature or a low dissolved oxygen situation).

Mitigation of Impact

All wastes containing toxic chemicals should be monitored and controlled. Those released into sanitary sewers should be carefully regulated so that such release does not affect the treatment process. Also, after dilution, effluent concentration should not exceed the desired level. Runoffs from chemical-handling areas should also be considered, to the extent that pollution is expected. If necessary, suitable treatment may be given to all contaminated runoffs.

Secondary Effects

While toxic compounds have a primary effect on lower organisms in the aquatic environment, secondary effects may be felt all through the food chain, with human health as a final major consideration. Procedures to remove these compounds, once they have been released to the aquatic environment, may be nonexistent or, at best, extremely expensive. Failure to remove them or to prevent their initial entry may degrade the water quality, with ensuing effects on aesthetics, economics, and biophysical relationships.

Aquatic Life

Definition of the Attribute

Organisms in any community exist in a dynamic state of balance, in which the population of each species is constantly striving to increase. However, population is maintained at a fluctuating level determined by food supply, predators, chemical characteristics of the water, and physical variables. Since these factors vary greatly, several types of communities exist in balance. Any human-created pollution tends to upset the natural state of balance. This may cause abundance of a few types of organisms, while others may decline or completely disappear. Because of some variation in response among species to conditions of existence within the environment, and because of inherent difficulties in aquatic invertebrate taxonomy, ecological evaluation of the total organism community is the acceptable approach in water pollution–control investigation.

Activities That Affect the Attribute

All activities discussed earlier (with various water attributes) affect aquatic life to some degree. Change in an aquatic community depends upon the type and extent of pollution.

Sources of Effects

Discharge of organic wastes (sewage) tends to lower the natural DO and to eliminate DO–sensitive organisms. Thermal discharge affects the normal lifecycle of many organisms. Toxic wastes reduce the aquatic biota, except those species that are able to tolerate the observed concentration of the toxicant. In general, changes in any attributes, whether they are physical or chemical, influence the aquatic life.

Variables to Be Measured; How Variables Are Measured

For aquatic life interpretation, field observations are indispensable. However, many of the biological parameters cannot be evaluated directly in the field. The specific nature of a problem and the reasons for collecting samples will dictate those aquatic communities of organisms to be examined, and those, in turn, will establish sampling and analytical techniques. The following communities and types of organisms are considered: plankton, periphyton, macroinvertebrates, macrophytes, and fish. Sampling and identification techniques are based upon routine biological sampling and analysis methods. Readers are referred to the latest edition of *Standard Methods for Examination of Water and Wastewater*.

Evaluation and Interpretation of Data

Based upon the most common aquatic life in natural waters, five classes of water are given in Table B.3.

Mitigation of Impact

See all water quality attributes for mitigation of impact upon aquatic life.

Secondary Effects

Economic and recreational benefits may be affected as a result of adverse impacts on aquatic life. Loss of productivity reduces fishing harvest, and decline in recreational activity produces additional economic loss.

Fecal Coliforms

Definition of the Attribute

Water acts as a vehicle for the spread of disease. All sewage-contaminated waters must be presumed potentially dangerous. The presence of coliform organisms in water is regarded as evidence of fecal contamination, as their origin is in the intestinal tract of humans and other warm-blooded animals. They are also found in soil and water which has been subjected to pollution by dust, insects, birds, and small and large animals. Fecal coliforms, per se, are not as proximate a hazard to water supplies as they once were, but are still utilized as a surrogate for pathogens in general. However, the test continues to retain importance because of water-contact recreational usage of water, and of implications that viral diseases can be transmitted through fecal contamination of water supplies. Indirect routes, such as the contamination of foods with fecally contaminated irrigation water and accumulation of contaminants by oysters, clams, and mussels from fecally contaminated marine waters, continue to be areas of concern.

In the 1990s, the most common of all coliforms, *Escherichia coli* (*E. coli*), moved from being a benign component of the intestinal flora to being classified as a dangerous killer. This is the result of several outbreaks of an especially toxic strain named *E. coli* 0157:H7. Originally found in, and still most commonly associated with, undercooked hamburgers, it caused several deaths in the Pacific Northwest. Since that time, *E. coli* 0157:H7 has been found on fruits and vegetables, cheeses, hot dogs, poultry, and a wide variety of other foods. The common element in plant materials appears to be surface contamination with untreated water containing the organism, which now appears to be widespread in surface waters.

Activities That Affect the Attribute

The activities discussed in BOD and DO also apply to this attribute.

Sources of Effects

See BOD and DO attributes.

Variables to Be Measured; How Variables Are Measured

Two methods are used for determining the presence of coliform organisms: the multiple-tube fermentation technique and the membrane filter technique. The results of multiple-tube fermentation techniques are expressed as most probable number (MPN), based upon certain probability formulas. The results of membrane filter tests are obtained by actual count of coliform colonies developed over membrane filter. In both cases, the estimated coliform density is reported in terms of coliform per 100 mL. The equipment used is the type commonly needed in routine microbiological study.

Evaluation and Interpretation of Data

Present water quality criteria restrict the use of water, depending upon fecal coliform density. The desirable criterion for surface water supply is fecal coliform less than 20 per 100 mL, and for recreational use (including primary contact recreation), the recommended value is 200 per 100 mL. Based upon the coliform density, five classes of water are summarized in Table B.3.

Mitigation of Impact

See attributes BOD and DO.

Secondary Effects

Quantification of the presence of fecal coliforms in recreational waters results in a classification by permissible use. This classification restricts not only the use of the waters, but also the economic benefits which might be obtained from those waters. Effects on shellfish harvests are other economic impacts that may result from fecal contamination.

LAND

As with other resources, land is not available in unlimited quantities. Because of this, it is becoming increasingly recognized in this country, and in other countries with less of an endowment of land resources, that land use must be properly planned and controlled. Council on Environmental Quality regulations recognize this need for the rational management of land resources, and, because the price system does not allow rational allocation of land, the Council on Environmental Quality has provided for a specific consideration of the relationship of a changed pattern in land use to the existing pattern. Therefore, land is being treated in much the same manner as our other scarce natural resources, air and water.

To examine these factors requires comprehensive consideration of existing and projected land capabilities and land-use patterns. The most significant elements of the land-use question have been collapsed into three attributes:

- Erosion
- Natural hazards
- Land-use patterns

Erosion

Definition of the Attribute

Erosion is defined as the process through which soil particles are dislodged and transported to other locations by the actions of water and/or wind. The two most common forms attributable to water are sheet erosion, in which the upper surface of the soil is more or less evenly displaced, and gully or rill erosion, in which the downward-cutting action of the overland flow of water results in linear excavations deep into the soil horizon. While the latter type of erosion is often more spectacular to the eye, loss of uniform layers of topsoil through sheet erosion is the more serious of the two. Wind erosion is similar to sheet erosion in that very small soil particles containing plant nutrients and organic matter are the ones that are carried away, leaving coarse and less productive material.

Soils of almost all types are held in place by vegetative cover and its associated root system. Removal of this cover exposes the soil to the erosive forces of water and wind. Erosion is intensely destructive. First, the site itself may be denuded of its most productive topsoils and/or may be gullied to the extent that it becomes almost totally unproductive, often to the point of posing a physical barrier to other activities. Second, the streams and lakes which receive the attendant sediment loads may be affected. The landscape, after erosive forces have been at work, is barren and aesthetically unappealing.

Activities That Affect the Attribute

Activities that affect the extent and rate of erosion are those associated in any way with removal or re-establishment of vegetative cover. Some of these are land clearing for construction, road building, or other cut-and-fill operations; timber harvesting or vegetative suppression by herbicide application; controlled burning; reforestation or afforestation; strip mining; agricultural activities; off-road vehicular traffic; and large animal grazing.

Sources of Effects

Land clearing and mechanized off-road activities strip land of its vegetative cover, organic surface material, and root structures which formerly protected the soil, thereby opening it up to direct attack by wind and water. Timber harvesting, application of herbicides, and controlled burning can result in the removal of a sufficient quantity of organic surface material and vegetative cover to cause an increase in the intensity of rainfall and wind movement at the soil surface. Conversely, reforestation and afforestation can reintroduce a vegetative canopy and root structure that, over time, can reduce the intensity of these erosive forces and result in a buildup of organic surface material. Road building and other cut-and-fill activities lay bare previously vegetated soil, alter natural drainage patterns, change the gradient of slopes, and create somewhat unconsolidated fill areas upon which vegetative cover is often not immediately reestablished. The stripping away of vegetative shrub and ground cover in semiarid areas by overgrazing is one of the most widespread causes of wind erosion. If grazing rights are withdrawn, or native grazing animals are fenced out of and/or removed from overgrazed areas, seeding of native grasses can accelerate the return of vegetative cover and reduce erosion potential.

Variables to Be Measured

Major variables affecting erosion are soil composition or texture, degree of slope, uninterrupted length of slope, nature and extent of vegetative cover, and intensity and frequency of exposure to the eroding forces. The interaction of these variables is complex and difficult to measure directly. Magnitude of the impact is also directly dependent on the extent of the affected area.

Soil texture is determined by the percentage of its sand, silt, and clay components. Generally accepted textural classes in order of decreasing particle size (coarse to fine) are:

Sand	Sandy clay loam
Loamy sand	Clay loam
Sandy loam	Silty clay loam
Loam	Sandy clay
Silt loam	Silty clay
Silt	Clay

While such a statement is subject to contradiction on a specific site, finer-textured soils are usually more susceptible to water erosion. Sandy soils and granulated clays are those most easily eroded by wind.

Water erosion increases with the length and steepness of slope. A general rule is that if the length of slope is doubled, soil loss from erosion will increase by a factor of 1.5. The relationship between degree of slope (gradient) and erosion potential can be specified in general terms as follows:

10 percent $\geq$ highly erodible

10 percent $=$ moderately erodible

2 percent $\leq$ slightly erodible

The erosion hazard depends upon the intensity and frequency of rain and windstorms. While the amount of yearly rainfall is important, of greater significance is the force with which it strikes the ground, volume in a given time, and return frequency of intense storms. The impact of wind varies with velocity, direction, and soil moisture content.

The difference in types of vegetative cover and the extent of each also affect erosion potential. A mature forest with a heavy overstory (leaf or needle) cover, an understory of trees with less dense leaves, scattered ground vegetation, and a heavy layer of decaying organic matter will protect the soil from wind and water to a greater extent than will brush and sparse ground cover found in arid and semiarid areas. These are extremes—pasture and cultivated cropland fall somewhere between.

Before proceeding further, some informed judgment should be made as to whether these variables are operative to a degree and in sufficient combination to warrant the rather extensive calculations to be described next. If necessary, an agronomist or agricultural engineer from the local office of the Natural Resources Conservation Service (NRCS) could assist in making this initial assessment.

How Variables Are Measured

Most soil loss or soil erosion equations are based upon models that represent interrelationships among the variables just discussed. One such model developed for agricultural cropland (*Rainfall Erosion*, USDA Handbook 282), but subject to modification for other vegetative types is:

$$A = RKLSCP$$

where A = Computed soil loss per unit area (acre)
R = Rainfall factor
K = Soil erodibility factor
L = Slope length factor
S = Slope gradient factor
C = Crop management factor (or relative vegetation cover)
P = Erosion control practice factor

While the techniques of arriving at numbers to represent the various factors are adequately described in a handbook that should be available from the local NRCS office, it would be helpful to have the expert advice of a team of NRCS agronomists, hydrologists, and agricultural engineers in applying it to a specific site. Soil loss should be computed both with and without the project. This will provide a comparison for analysis.

The area affected should be outlined on a map overlay or geographic information system (GIS) at an appropriate scale. By using a planimeter (map overlay) or computer calculations, and with the assistance of an engineer, the number of acres affected can be determined. Total soil loss with and without the project can then be calculated by multiplying the soil loss per acre, as previously obtained from the model, by the number of acres involved.

Evaluation and Interpretation of Data

Overall magnitude of the impact can be represented by the percentage of change in total soil loss as calculated earlier. If a more sophisticated analysis appears to be warranted, this quantitative figure can be tempered by a further evaluation that takes into account change in soil fertility (productive capacity) and the impact of changes in sediment load in streams that drain the affected area. This kind of analysis could best be done by an interdisciplinary team of economists, agronomists, engineers, and ecologists.

Special Conditions

If the land were productive for agricultural crops or forest products, the economic and ecological impacts might be greater than if it were relatively infertile.

Geographical and Temporal Limitations

While there are few areas in the United States where the potential for at least moderate erosion does not exist, the most severe erosion has occurred in the Appalachian area of the Southeast, in the Great Plains, and in some desert and semiarid areas of the Southwest. The major temporal limitation on erosion involves the time of year when the soil is exposed and the length of time it remains exposed relative to the time of year that intense rain and windstorms are likely to occur.

Mitigation of Impact

It is much easier to prevent erosion before it begins than it is to arrest it or restore the land afterward. The environmental impact of soil erosion can best be mitigated by removing vegetative cover only from the specific site on which construction is to take place and by disturbing the vegetation in adjacent areas as little as possible. Construction, land management, or mining activities that result in the soil being laid bare could be scheduled in such a way that some type of vegetative cover appropriate to the site could be established prior to the onset of intense rain or windstorms. If grass is to be seeded, a mulch of straw will help to protect the soil from less extreme erosive forces until vegetative and root development begin. Natural drainage patterns can often be maintained by preparing sodded waterways or installing culverts. Steep slopes can be terraced, thereby effectively reducing the length of slope. Catch basins built near construction sites can reduce the quantity of eroded soil particles reaching free-flowing streams or lakes.

Secondary Effects

Secondary effects of erosion include increased sediment loads in streams that may clog reservoirs and fill large areas of bays and estuaries. These sediment loads also affect aquatic life through such mechanisms as the covering of fish eggs and spawning areas, coating of gills, and retarding light penetration, which, in turn, reduces the photosynthetic process necessary for aquatic plant production. As the aquatic environment is degraded, the results are losses in areas of aesthetic, recreational, and economic benefits. Other economic losses include adverse effects on land-use suitability, crop production reduction, and frequent filter replacement due to increased particulate materials in the air.

Other Comments

If the erosive effects resulting from an activity are not confined but spill over into adjacent private lands (sediment deposition), or if severely eroded land is visible from public highways, after-the-fact controversy over the project may develop. This is especially true if these considerations are not directly addressed in the environmental assessment/impact statement and if the mitigation possibilities are not discussed and evaluated.

Natural Hazards

Definition of the Attribute

Natural hazards are those occurrences brought about by the forces of nature that cause discomfort, injury, or death to humans; damage or destroy physical structures and other real or personal property; change the physical character of land, water, and air; and damage or destroy the plant and animal life of the affected area. The severity and frequency of occurrence of floods, earthslides, and wildfires may be influenced by various activities. Other natural hazards, such as earthquakes and hurricanes, may cause greater personal and physical damage than would be the case if human activities were located in areas other than those where these natural events occur with some frequency and severity.

Activities That Affect the Attribute

Some activities that often have an impact on the frequency and magnitude of natural hazards are construction, land management, land use, agriculture, and industrial development. These activities do not affect the natural processes that are the root causes of hazards—intense rain or windstorms, the geologic structure and soil and bedrock properties of an area, or lightning strikes from the thunderstorms. Rather, it is the destructive nature of the results of these occurrences that human activities influence.

Sources of Effects

The effects of construction activities on the destructive potential of natural hazards are quite diverse. Land clearing, which precedes most kinds of construction, lays bare the soil surface, a condition conducive to increased volumes of water runoff and increased sediment loads in streams—both of which tend to cause increases in flood heights and return frequencies, the two greatest determinants of flood damage. Paving large areas with asphalt and concrete—often done for parking lots and outdoor storage areas—reduces infiltration of water into the soil, thereby increasing runoff and the peak volume of water that streams are required to carry. The building of structures such as dams and levees, as well as stream channelization to reduce flood levels, may greatly modify the flow regimes of natural water courses, which, in turn, may result in the diversion of floodwaters to previously unflooded areas.

The probable incidence of earthslides may be increased by road construction activities if natural shear stresses in the Earth are increased, excessive pore pressure developed, or rock and soil strata exposed by road cuts. Failure may be induced by blasting, changes in slope, greater overburden, and the like. Earthslides can block streams and cause a backup of water, which, in turn, can result in upstream damage due to a gradual rise in water level and extensive downstream damage due to the rapid release of water when the slide is overtopped or eaten away. Earthslides also destroy vegetation, increase sediment loads in streams, and disrupt transportation routes. On the positive side, road construction in remote areas can reduce potential wildfire damage by permitting more rapid access by firefighting crews and equipment.

Land management includes activities such as timber harvest, reforestation and afforestation, herbicide application, and controlled burning. Timber harvest can create at least temporary increases in runoff volume and sediment loads as a result of the removal of some of the vegetation cover and the disturbance of the soil surface by tractors and other mechanized equipment. Rehabilitation of eroded areas by reforestation, afforestation, or seeding decreases runoff and sediment loads. Timber harvest on steep slopes can result in landslides that disturb the soil horizon to the extent that natural tree regeneration will not take place. When vegetation killed by herbicides and logging debris left after timber-harvest operations dries to the point where the plant material will ignite easily and burn with considerable intensity, lightning strikes are more likely to cause fires that are difficult to control and may do great damage. Conversely, controlled burning can reduce the incidence and destructive potential of wildfire by creating a low-temperature blaze that consumes the dry underbrush and organic matter on the forest floor without damaging mature timber. (This favorable impact of controlled burning should not overshadow the fact that it may adversely affect other environmental attributes, such as vegetative diversity, wildlife populations, and erosion.)

Land-use considerations that dictate where certain projects will be located often have a decided impact on natural hazards. Any physical structure (building, bridge pier, or temporary bridge) that occupies a portion of the floodway (the stream channel carrying the normal water flow) or is situated on the floodplain (that area covered by flood waters when a stream overflows its banks) will restrict the flow of water and decrease the volume which the floodplain can accommodate at a particular level, thereby increasing flood heights upstream and downstream. Permitting homes or other structures to be located in floodplains poses the possibility of increased physical damage to the structures and loss of life to their occupants. During a flood, portable or temporary structures can damage other structures by direct impact or lodge in the stream channel in such a way as to form a temporary dam, raising flood levels behind them. Siting housing areas on brush or forest land subject to wildfire can increase the damage potential to life and property. The same is essentially true of any structures placed near known fault lines in active earthquake zones or in coastal or inland river areas subject to frequent wind and water damage from hurricanes.

Variables to Be Measured

Each type of hazard has its own set of variables that influence frequency of occurrence and severity. For floods, changes in volume of the overland flow of water, changes in sediment deposits in stream channels, or alteration of the floodplain cause variation in flood height and resultant damage levels. Baseline data can sometimes be obtained from gauging stations that record the magnitude of the increased stream flow resulting from runoff associated with the storm. Changes in the infiltration rate of water cause changes in the volume of surface runoff from overland flow and in the amount of sediment carried into the stream. The resulting change in return frequencies of certain levels of flooding is the critical determinant of impact.

Earthslide-prone areas are those characterized by unstable slopes and land surfaces that—because of a history of actual occurrences, geology, bedrock structure, soil, and climate—present a significant hazard potential. The variables here are the extent to which soil and rock strata are exposed to wetting, drying, heating, and cooling processes; the slope gradient of the cut, which exposes the relevant stratum; and changes in internal Earth stresses caused by surface or subsurface loadings (e.g., blasting, heavy machinery operation, and installation of footings and foundations).

The variables associated with wildfire are changes in flammability of the organic matter on the ground (duff) and the areal extent of the activity. Changes in wind velocity near the ground, depth of the duff, and moisture content of the duff influence its capacity to support combustion and the intensity with which it will burn once ignited. The size of the activity, in terms of changes in the volume or area of standing timber, in the number and value of physical facilities, and in the number of people housed or working in areas susceptible to wildfire, influences the probable incidence of wildfire and the magnitude of the resultant damage.

How Variables Are Measured

Few, if any, of the variables associated with baseline data on natural hazards are subject to measurement by the layperson. It is even more difficult to project changes in the variables over time as a result of specific activities.

For floods, the assistance of an expert hydrologist is required to relate rainfall intensity (rate over time), infiltration capacity of the soil (the maximum rate at which soil in a given condition can absorb water), overland flow (rainfall excess that reaches stream channels as surface runoff) and its effect on channel depth, and the resulting increase in flow rate over time (hydrograph) which would yield a certain flood height and attendant damage level. The major variable—change in soil infiltration capacity—is influenced by such diverse and interrelated factors as interception of rain by trees and buildings, depth of surface detention of water and thickness of saturated soil layer, soil moisture content, compaction due to machines and animals, microstructure of the soil, vegetative cover at or near the surface, and temperature. The nearest district office of the Corps of Engineers or the USGS should be able to assist in obtaining baseline data and in projecting the effects of various activities on flood heights and return frequencies.

The relative tendency of an area to have earthslides is not subject to simple measurement; the forces that cause an earthslide and the extent of their interactions are extremely complex. To the expert geologist, the type of geologic structure common to the area, the type of bedrock, soil structure, height of water table, type of surface material, degree of natural slope, and past history indicate whether an area is prone to earthslides. Such general information can often be obtained from the USGS, from state geologists, or from local universities. If the area is prone to earthslides, an engineering analysis should be made to determine whether physical changes that result from the activity are likely to increase or decrease the probable incidence with which slides may occur. The services of a soil engineer and a civil engineer would be required for a thorough analysis.

Baseline data on the conditions and occurrence of wildfire should be available directly from the nearest office of the U.S. Forest Service or from the state forester's office. These records usually include or can be correlated with other data relating to the thickness of the duff, the relative humidity, number of days since the last rain, wind velocity, and other local factors, which in combination give the fire danger ratings and could assist in projecting the change the activity would have on the previously identified specific variables (i.e., wind velocity near the ground, depth of duff, and moisture content of the duff). Any change in the area (acres) susceptible to wildfire should also be measured. This can be done with before-and-after overlays of the area prepared from maps, aerial photographs, or site plans. Through using GIS or a planimeter, the size of the area for each can be determined. The assistance of an engineer may be required to make this calculation.

Evaluation and Interpretation of Data

For flood hazards, the magnitude of the impact of a change in infiltration capacity of the soil and the attendant change in rate of surface runoff on flood stage height and of return frequency need to be evaluated. A more sophisticated analysis could relate the change in flood height and return frequency to potential dollar losses or losses of human life, taking into account existing structures that might be affected, as well as any new ones to be located in the floodplain. This analysis could probably best be made by insurance underwriters associated with the National Flood Insurance Program or by the

Federal Housing Administration of the U.S. Department of Housing and Urban Development, who have maps of flood hazard areas.

Evaluation of changes in potential incidence of earthslides is less straightforward. The areas where earthslides are most likely to occur should be evident from the previously recommended engineering analysis. The impact of a slide in a particular area could be calculated in terms of the dollar value of physical damage to structures, loss of life, and the ecological damage to watercourses and vegetation. A team of engineers, geologists, and insurance underwriters could develop risk factors associated with changes in the potential incidence of earthslides.

Just as with other natural hazards, wildfire has two aspects to be separately evaluated—the change in potential incidence and the amount of damage that might result from an occurrence. Again, the considerations are complex and not amenable to one-dimensional evaluation and interpretation. The change in incidence is related to change in flammability and areal extent of the duff, to greater or lesser numbers of people in the area, to the nature of the proposed activity, and to measures taken to prevent or reduce wildfire damage. A team of foresters and fire insurance underwriters should be able to develop risk factors associated with the change in potential incidence and intensity of wildfire and then estimate property damage or the loss of life that might result, both with and without the project.

Special Conditions

If increases in flood heights and frequencies are likely to adversely affect floodplains where extensive industrial, commercial, or residential development already exists; if increased incidence of earthslides is likely to damage population areas and/or cause severe ecological damage; or if residential or prime-timber-producing areas are subjected to higher risks of damage from wildfire—particularly if any of the effects are felt outside the confines of the activity—then controversy over the projected magnitude of the impacts is almost certain to develop. In such instances, an interdisciplinary team of qualified professionals is needed to develop and substantiate these projections. Actions having such consequences may be regulated by state law.

Geographical and Temporal Limitations

Geographical limitations on natural hazards have to do with observed frequencies of occurrence (e.g., hurricanes are most likely to affect Gulf and Atlantic coastal areas, earthslides are unlikely to occur in areas of relatively flat terrain, and earthquakes occur more frequently and with greater severity along known geological fault lines). While floods and wildfire can occur almost anywhere, the frequency and severity of lightning storms in mountain regions of the Western states increase the incidence of wildfire in that geographical area. There are some general temporal limitations for natural hazards: Wildfire is most likely to occur in the summer and fall, when the moisture content of living vegetation and the duff is lowest; floods of greatest severity occur with certain predictability in the spring, but flash floods can take place at almost any time of the year; the hurricane season is considered to be summer and early fall, and earthslides of various types most often occur in the winter and spring. Temporal limitations do not seem to apply to earthquakes.

Mitigation of Impact

Primary mitigation techniques for hurricanes and earthquakes center around the avoidance of areas where these hazards occur with sufficient frequency and intensity to cause severe damage and the use of proofing techniques in the construction of physical facilities. Proofing techniques include the use of "floating" foundations and height restriction in earthquake zones and increased foundation height, wall strength, and roof support in areas periodically subject to hurricanes.

The frequency and/or severity of flooding can be held to a minimum by prohibiting any construction activity or land use that restricts the flow of water in natural channels or that reduces the floodplain area that retains overflow waters during times of flooding. Generally speaking, all forms of temporary structures should be banned from the floodplain, and all permanent structures should be raised to a height above the level which flood waters can be expected to reach, on average, once every 100 years (100-year flood). No temporary dwelling units—mobile homes and the like—should be permitted in the floodplain. Increases in surface runoff can be mitigated by disturbing the existing vegetation and natural contour of the land as little as possible. Installation of underground drainage structures helps to reduce sediment loads (overland flow is reduced), but not total runoff volume.

Earthslides can be mitigated by avoiding areas with a high probability of incidence or those where proposed activity will significantly increase their probability. Engineering plans can be drawn to reduce the area of exposed strata subject to earthslides, reduce the inclination of slope of Earth cuts on fills below what might otherwise be acceptable, provide physical support for exposed soil or rock faces, concentrate or distribute—as appropriate—the weight loadings of foundations to areas or strata better able to support that weight, use small charges for blasting, and restrict the movement of heavy machinery during the construction phase.

The effects of wildfire can be mitigated by clearing fire lanes in strategic locations and building restricted-access roads into areas having a high probability of wildfire incidence. Removal of live vegetative cover, which permits the drying forces of wind and sun to interact more directly with the duff, should, if possible, be avoided. In timber-harvest operations, the removal from the woods of as much of the total tree as is commercially possible to use will reduce the amount of vegetative logging debris left to contribute to depth and flammability of the duff. Restriction of the use of areas during periods of high fire danger is another type of mitigation technique. Also, buildings should be sited (on the prevailing downwind slope) and roads constructed (more than one access and egress point) to minimize physical damage and loss of life if a wildfire should occur.

Secondary Effects

Activities that increase the risk of occurrence of natural hazards also have secondary impacts on various social and economic factors. General feelings of security and well-being may be reduced by the increased threat of potential disaster. These psychological effects would be experienced most severely by individuals who believe their lives and property would be affected, should the disaster occur. Economic effects also could result in the forms of increased insurance premiums or changes in property values as hazard risks increase.

Other Comments

The impact of human activities in areas subject to hurricanes and earthquakes has not been treated in detail. The most appropriate measure of impact in such cases is the change in the number of people and in the dollar value of physical facilities exposed to these hazards as a result of the activity.

Land-Use Patterns

Definition of the Attribute

Land-use patterns are natural or imposed configurations resulting from spatial arrangement of the different uses of land at a particular time. Land-use patterns evolve as a result of: 1) changing economic considerations inherent in the concept of highest and best use of land, 2) imposing legal restrictions (zoning) on the uses of land, and 3) changing (zoning variances) existing legal restrictions.

The critical consideration is the extent to which any changes in land-use patterns resulting from an action are compatible with existing adjacent uses and are in conformity with approved or proposed land-use plans. Where a conflict or inconsistency exists (between a proposed action and the objectives and specific terms of an approved or proposed federal, state, or local land-use plan, policy, or control), the agency should describe the extent to which its analysis reconciled its proposed action with the plan, policy, or control, and the reasons why the agency has decided to proceed notwithstanding the absence of full reconciliation.

Activities That Affect the Attribute

Changes involving transportation systems (roads, highways, airports, etc.), water resources projects, industrial expansion, and changes in the working or resident populations are examples of activities likely to induce changes in the pattern of land use and create compatibility problems with adjacent uses. The building of new or the expansion of existing facilities through a program of land acquisition would be an activity likely to result in a conflict with approved or proposed federal, state, regional, or local land-use plans. If such a conflict exists, it is quite possible that a compatibility problem with adjacent uses will also emerge. Recreational opportunities and second home or resort area development are other areas where land-use conflicts are evolving.

Sources of Effects

Activities involving land acquisition will conform or conflict with approved or proposed federal, state, regional, and local land-use plans in relation to whether such plans exist at all, their detail, and the specific use of the acquired land. For example, if an agency purchased land for the construction of an office building in an area specifically designated for residential use by an approved zoning ordinance, there would be a direct conflict with a land-use plan. Conversely, if the land were purchased as a site for the construction of family housing units, there would be no apparent conflict.

In terms of changes in land-use compatibility patterns, increased or decreased noise levels could have a decided impact. If an industrial-type activity is established at a location that was previously administrative in nature, the attendant increase in rail and truck traffic, particularly if routed near or through residential areas adjoining the site, could result in increased noise levels that might be incompatible with the existing use. Even greater noise problems affecting land-use compatibility patterns arise when activities involve airfield expansion or construction or propose modification of flight patterns.

Military installation closings resulting in the working and resident populations being reduced almost to zero would usually have a decided impact on the land-use patterns of nearby private property. These changes might not be easily perceived at first. Residential and commercial areas would remain, but their intensity of use would probably be sharply curtailed. Portions of such areas might eventually revert to a lower use, the structures possibly razed, and the land permitted to return to open space or some nonintensive form of agriculture. The issue of compatibility with adjacent uses might arise if the use revision took place in a random and essentially uncontrolled fashion.

Large increases in a project-related labor force at a given location would almost certainly have repercussions on land-use patterns in the area. An example would be the introduction into nearby areas of residential structures that are basically unsuited for such development. Mobile home parks or high-density apartment complexes might be sited adjacent to the approach pattern of aircraft runways on what was previously agricultural land. This could come about if a variance to zoning ordinances was granted by some local governments in an attempt to encourage population growth in their political jurisdictions.

Activities that influence changes in land-use patterns certainly do not always do so adversely. There may be compatibility conflicts in the existing land-use pattern which would be ameliorated by other activities. An influx of people (with an appreciation of planning) into an area having no comprehensive zoning ordinances or land-use plans could result in the formulation and adoption of such ordinances or plans. Over time, this could result in more compatible land uses in the area surrounding the activity.

Variables to Be Measured

Compatibility of use between one parcel of land and adjacent properties involves variables such as type and intensity of use (residential, commercial, industrial, transportation, agricultural, mineral extraction, and recreational, and sub-breakdowns within each that reflect use intensity), population density, noise, transportation patterns, prevailing wind direction, buffer zones, and aesthetics. For example, a high level of residential/transportation land-use compatibility would be evident where a single-family home is set back 30 feet from a two-lane street having a traffic volume of 20 cars per hour which travel at an average speed of 25 miles per hour. Conversely, considerable incompatibility would exist if the same house is set back the same distance—with no intervening barriers—from a four-lane highway with a traffic volume of 2000 vehicles per hour, the majority of which travel at 55 or more miles per hour.

Conformity of a proposed new use of land with approved or existing land-use plans is determined by whether a plan exists for the area in question, and if so whether the proposed use conforms with the ones permitted in the plan. This is a very straightforward relationship unless attempts are made to correlate use/plan conflicts with variances under which precedents for change may have been set.

How Variables Are Measured

Because the constraints that influence compatibility vary widely with the types of land use involved and the spatial arrangement of one with another, variables (e.g., traffic flow; population density; noise levels; depth, width, and area of buffer zones; and constituents and quantity thereof in air, water, solid effluents) are subject to physical measurements by engineering and planning professionals. Even aesthetic qualities are subject to a somewhat objective measurement by landscape architects. With respect to compatibility of use, however, measurement alone does not indicate the magnitude of the impact. It is the relationship of these variables to one another in the context of their specific spatial arrangement that determines compatibility.

Measurement of variables reflecting conformity with a land-use plan is essentially a yes-no proposition. A plan with which the proposed use can be compared either exists or does not. If a plan exists, the proposed use either conforms or conflicts with its provisions. In practice, the assistance of a spatial planner/zoning expert would probably be required if the proposed use is complex or if the plan is couched in legal terminology. Land-use plans may be prepared at all levels of local government: by incorporated towns and municipalities, townships, and counties; by regional planning agencies (for agencies in specific areas, see the National Association of Regional Councils' directory); by state departments of planning, development, and natural resources (for specific state-by-state information, see *A Summary of State Land Use Controls*, Land Use Planning Reports, 1973); and by federal land management agencies, such as the Bureau of Land Management, the National Park Service, the Bureau of Reclamation, the Corps of Engineers, the Tennessee Valley Authority, and the Department of Energy.

Evaluation and Interpretation of Data

Discussion of the variables involved in land-use compatibility attempts to convey the idea that there is no simple way to relate these variables and arrive at a compatibility index. While planning standards exist, the way they are applied in practice varies considerably from one political entity to another, from one geographical area to another, and with the types of existing and proposed uses. The assistance of a city and regional planner with a background in the spatial arrangement of land uses would be essential in measuring and analyzing interactions among variables and, subsequently, in interpreting the results in terms of the relative compatibility of the uses.

For reasons of continuity, evaluation, and interpretation of whether a proposed use of certain parcels of land conforms or conflicts with existing or proposed land-use plans was included in the previous discussion on the measurement of variables.

Geographical and Temporal Limitations

There appear to be no geographical limitations directly influencing the compatibility of adjacent uses of land. On the other hand, geographical boundaries of political entities govern the areal extent of the particular land-use plans which the activity may affect.

Temporal considerations relate to the problem of projecting how land-use patterns are likely to evolve as a result of a proposed activity. The period of analysis usually used is the expected beneficial lifespan of the project.

Mitigation of Impact

Compatibility between adjacent land uses can best be assured by providing an open-space buffer zone between the proposed activity and nearby properties where any significant degree of incompatibility is likely to result. The width/depth/area of this buffer zone should not be excessive to avoid being construed as an inefficient use of land. As for mitigating the impact of changes in existing uses among adjacent off-post parcels of land likely to evolve as a result of the proposed activity, officials of affected local political entities and regional, state, and federal agencies should be apprised at an appropriate time of the projected impacts. They would then have the opportunity to change existing or enact new land-use plans.

Mitigation of conflicts between a proposed use of land and proposed existing land-use plans can best be accomplished during the planning stage. Obviously, it would be most desirable from an environmental standpoint to locate the activity where no conflict in use would exist. If this is not feasible, discussions could be held with representatives responsible for the plans, with a view toward resolving the conflict through the granting of a zoning variance or plan modification. Even if no satisfactory agreement can be reached, the fact that such discussions were initiated and conducted in good faith might have a positive impact on any future controversy or litigation.

Secondary Effects

Just as direct impacts on many geophysical and socioeconomic attributes induce effects on land use, direct effects on land use result in secondary effects on other biophysical and socioeconomic attributes. Transportation projects, for example, may concentrate air or ground traffic, with resultant increases in levels of air pollution and noise production. Population shifts result in changes in demand for utilities (water supply, sewage treatment, electricity, etc.), and affect wholesale and retail markets and community services (police, fire, schools, etc.). In essence, land-use designation can be related to all areas—air, water, land, ecology, sound, human, economic, and other resources.

Other Comments

On the surface, it would appear that proposed land-use plans, policies, or controls, as well as those which generally address land use without supportive legal instruments (ordinances, laws, administrative rules), would not be as binding—or taken into account to the same degree—as would those specifically and carefully drawn, officially enacted or promulgated, and having the support of legal precedent. However, the language of the previously quoted Council on Environmental Quality regulations is rather unequivocal. For an environmental impact assessment/statement, no differentiation is made between approved and proposed plans, policies, and controls. The charge is still to examine the conformance of the proposed action to the plan or policy.

ECOLOGY

The characteristics of the human environment are intimately related to the nonhuman ecology that surrounds it. Problems that affect lower-level elements in the ecological system may ultimately affect humans. For example, the accumulation of pesticides and heavy metals in lower levels of the ecological system may be harbingers of dangerous levels of these materials in humans.

In addition, despite progress that we have made in providing for our needs, the total ecological balance of the environment is crucial to the viability of our species. For this reason, species diversity and balance must be maintained. Convincing evidence exists that species diversity in an ecosystem is closely related to the stability of that system, with increasing species diversity indicating an increased ability of the ecosystem to resist disturbance and stress. Evaluation of impacts on a given ecological system should include an assessment of the effect of proposed alterations of the environment on species diversity, based on existing information or on special field studies.

The attributes that have been identified to describe the "ecology" resource are:

- Large animals
- Predatory birds
- Small game
- Fish, shellfish, and waterfowl
- Field crops
- Listed species
- Natural land vegetation
- Aquatic plants

Large Animals (Wild and Domestic)

Definition of the Attribute

Large animals are those, both wild and domestic, that weigh more than about 50 pounds when fully grown. Common wild animals falling into this category are deer, bears, elk, and moose. Domesticated animals of this size include horses, sheep, cattle, swine, and goats.

Activities That Affect the Attribute

Since most large animals (except for some which are quite rare, e.g., cougars, wolves) are browsers or grazers, activities having the greatest effect upon them are those which diminish the animals' vegetative food supply or otherwise make inhospitable to them all or portions of the area over which they range. Examples of such activities are construction of new facilities (roads, fences, buildings, etc.), military training exercises, and encroachment into wildlife habitat by vehicular traffic or recreation activities. In the Western states, encroachment on the unfenced open rangelands may have an equivalent effect on domestic livestock.

Sources of Effects

Vegetative and other forms of cover—for traveling, eating and watering, sleeping, breeding, and rearing of young—are required by all wild animals if they are to thrive in an area. Construction activities which result in the clearing of underbrush by burning or other physical means can reduce the available range over which large animals forage. Likewise, application of herbicides can reduce cover and food, unless utilized in programs specifically designed to increase cover and food. Acquisition of new land for various activities, if such land was previously used for the grazing of domestic livestock, can reduce the total area available for that purpose in a particular locality, resulting in human social and economic effects. Noise can cause large wild animals to leave or avoid a particular area. Fencing can restrict the movement of animals, either denying them access to food and water areas or keeping them penned within an area smaller than that required for their well-being.

Variable to Be Measured

The most direct variable is animal population. The type (species) and number of large animals should be determined. To arrive at the magnitude of the impact on the population, the change in the amount (acres) of land suitable for large animal habitat must be determined. A relative measure of the increased noise generated by extensive human intrusion into wild, remote areas formerly ventured into only by hunters or herders should be made. Intense and prolonged noise-generating activity can sufficiently change the habits of large animals to cause them to vacate an area, at least temporarily, until human activities are reduced or the animals become accustomed to them. Adjacent areas can be stressed by having to temporarily support greater populations.

How Variables Are Measured

A census of large animal populations can be made by direct observation. If small, the entire area can be censused. If large, counts can be taken on random plots and projected over the total area of suitable habitat. Good observational and outdoor skills are required for many direct counts. In some areas of fairly open terrain, skilled photo interpreters can take the census of large animals from aerial photographs. If direct observation is not practical or possible (lack of skilled people, large area, nature of the habitat or animal species), a local wildlife biologist affiliated with a federal or state wildlife agency should be consulted for his or her estimate of the population (numbers of domestic animals should be available from ranchers using the land). Wildlife specialists are professionally qualified to judge how noise and other nondestructive activities of humans and vehicles affect the use of an area by large animals.

The change in acreage of a particular habitat type can be obtained from before-and-after overlays prepared from aerial photographic prints, project plans, or maps. Through using GIS or a planimeter, the size of these areas can be determined with the assistance of an engineer or surveyor. While a simple proportional relationship can be made between the large animal population and acres of available habitat, it would be helpful to have a wildlife biologist review the calculations and determine the relative effect of the seasonal variation and other factors.

Evaluation and Interpretation of Data

The increase or decrease of the large domestic animal population of an area can be interpreted on the basis of the resulting change in annual income. A more subjective evaluation must be made for wild animals. The number lost or gained relative to the number originally in the area is the most critical element. If any of these wild animals prey on smaller animals, the effect of the increase or decrease in that population should be considered. Not to be overlooked are the aesthetic value of large wild animals and the economic dividends which accrue to an entire region if the animals are subject to hunting. Neither of these two values can be readily quantified, and any judgment of their significance must remain highly subjective. Activities that may adversely affect hunting access or success can be extremely controversial.

Special Conditions

If there is a long tradition of grazing rights for domestic livestock and these rights are to be withdrawn, the impact of the activity could become controversial—particularly if these rights had previously been exercised by Native American tribes. If any of the wild animals are considered to be endangered or threatened—regionally, nationally, or internationally—a reduction in their numbers as a result of some activity, particularly habitat alteration, would likely result in controversy and legal compliance problems. (The attribute discussion for listed species goes into greater detail on this subject.)

Geographical and Temporal Limitations

Concern about domestic animals and associated grazing rights is of significance primarily in the Western United States, where extensive rights to use federal lands for this purpose still exist. As already noted, the impact of a particular activity on wild animals may be short-term, occurring only during the construction or direct activity period, when people and equipment intrude most heavily on the animal's home range. Also, especially in alpine and high-plains areas, large animals have a summer and a winter range: a factor in determining their presence in, or absence from, an area. The impact of the reduction in summer range would likely not be as severe, for example, as would be a reduction in winter range.

Mitigation of Impact

The impact of activities on large animals can best be mitigated by intruding as little as possible on their habitat. If such animals use the area where the activity will take place, the activity should be concentrated to the maximum extent possible in those parts of the area they least often frequent. During the planning phase of an activity, an attempt should be made to avoid extending into the home range of large wild animals. If this is not feasible, the activity should be completed as quickly as possible at a time when the animals are not present, and regular and sustained use of the area over time should be minimized. If land acquisition is necessary and a choice is possible, a productive range used by large domestic and/or wild animals should be avoided.

Secondary Effects

Economic interests resulting from hunting-related business and aesthetic qualities supported by the presence of wild animal species may be affected as a result of impacts on large animals. Other secondary impacts may occur if natural predator-prey balances are upset by the activity. Undesirable effects may also result if some aspect of a project, such as extensive irrigated landscaping, *attracts* large populations of the animals.

Other Comments

If the activity impinges upon the range of large wild animals that have previously been hunted in the particular area and if the activity will result in either closing that area to hunting or a reduction in the number of such animals available for annual harvest, fish and game clubs are likely to oppose the activity.

Predatory Birds

Definition of the Attribute

Birds of prey are flesh eaters and obtain their food primarily by hunting, killing, and eating small animals, other birds, and fish. Common birds in this group (orders *Falconiformes* and *Strigiformes*) are hawks, owls, and vultures.

Less common are eagles, ospreys, and some of the falcons. The California condor is quite rare.

Activities That Affect the Attribute

Since birds of prey nest primarily in trees—sometimes in areas remote from human habitation—cutting of mature timber stands or the selected removal of individual overmature or noncommercial trees could result in a disproportionate reduction in their numbers. Burning of brush or grasslands, applications of herbicides and pesticides, and the use of poisoned bait in animal-control programs are other activities that could directly affect the survival of predatory birds. Activities resulting in intrusions by persons into or near nesting areas could affect these birds, particularly eagles, ospreys, condors, and some types of falcons that are less tolerant of humans. Historically, widespread use of chlorinated hydrocarbon pesticides caused populations of many of these species to become endangered. This has become less critical following the ban on most uses for these materials.

Sources of Effects

The removal of nesting trees as a part of any general land-clearing program preceding construction activities or the selected removal of such trees in a forest management "sanitation" cutting could destroy unhatched eggs or cause the death of birds too young to survive outside the nest. If suitable nesting habitat is not available elsewhere in the vicinity, adult birds may disappear from an entire area. Burning of brush and grasslands destroys the habitat and large numbers of the prey species (small animals) on which predatory birds depend for food. Similarly, application of defoliants could reduce the food and cover available for small animals and birds, with a consequent reduction in their numbers. The reproductive capacity of these and many other birds may be reduced if sufficient quantities of dichlorodiphenyltrichloroethane (DDT) and other chlorinated hydrocarbon insecticides are concentrated in the food. For example, eggshells can be weakened to the point where they break before the young are ready to emerge. Direct killing of predatory birds can result from their eating of poisoned bait (portions of animal carcasses) intended for coyotes, cougars, and other flesh-eating animal predators. Extensive outdoor activities resulting in the visibility of humans and the noise of vehicles and heavy equipment use, if conducted intensively over an extended period of time or at frequent intervals, could cause birds to desert their nests. If the activity is sustained over a long enough period of time, adult birds might leave the area permanently.

Variables to Be Measured

The number and types of birds of prey that nest and/or capture their food within the affected area should be determined. The change in the amount of available habitat (nesting and/or feeding) must be ascertained to estimate the numbers of birds the existing habitat will support once the activity is completed or the project becomes operational.

How Variables Are Measured

While a direct census of common birds of prey is possible in areas of limited size, the observational and general outdoor skills and the time required make it most impractical to conduct one. A usable population figure could be best obtained from a local wildlife biologist affiliated with a federal or state wildlife agency. A biologist of the Natural Heritage Program, Audubon Society, or similar private wildlife conservation organization may also be able to provide accurate counts of the less common species and the locations of their nesting and feeding areas. The change in acreage of nesting and feeding habitats can be obtained from before-and-after overlays prepared from aerial photographic prints, mosaics, or topographic maps. Through using GIS or a planimeter, the size of these areas can be determined with the assistance of an engineer or surveyor. For the more common species of hawks and owls, the nesting and feeding habitats can be combined, and a direct proportion established between the bird population and the number of acres of available habitat.

The relationship between available habitat and the generally larger, less numerous predatory birds is less direct and more subjective. If such species as the bald eagle, golden eagle, osprey, peregrine falcon, or California condor are present in an area, it will be necessary to solicit the opinion of expert wildlife biologists in determining what portion of the existing population would remain after the activity was completed. If the species are threatened or endangered, consultation with the U.S. Fish and Wildlife Service (FWS) is mandatory.

Evaluation and Interpretation of Data

The change in numbers of common birds of prey, as related to a particular activity and location, is an overall indicator of the change in habitat quality for other birds and animals within the area. Any substantial reduction in the numbers and types of hawks and owls would be generally indicative of a widespread adverse ecological impact. As with the large wild animal attribute, any reduction of the less common species of avian predators could be expected to bring forth objections from private conservation organizations, as well as from federal and state agencies charged with their management and protection.

Special Conditions

If any species of the predatory birds in the area is considered to be threatened or endangered—regionally, nationally, or internationally—any effects on their habitat resulting from the activity would be controversial and subject to FWS review. (The attribute discussion covering listed species goes into greater detail on this subject.)

Geographical and Temporal Limitations

Most of the large, less common birds of prey have very restricted geographical ranges. Maps showing these ranges are contained in most field guides to bird identification. A review of such range maps would reveal whether or not these species are likely to be found in the activity area. Special attention should be given to any short-term activities that might disturb the birds during their nesting season. The regional office of the FWS is the definitive authority on these matters.

Mitigation of Impact

The potential detrimental impact of human activities on the avian predator population can best be mitigated by locating the activity at places not considered a part of the habitat essential for the survival of these birds. This is best accomplished during the site-selection planning stage of a project, rather than after a specific site has been chosen. Unless operational considerations are absolutely overriding, the habitat of the large, uncommon species should not be disturbed at all. Regular or sustained intrusions of workers or equipment into nesting areas should be avoided to the maximum possible extent, especially while eggs are being incubated by the adults and until the young have left the nest. No known nests should be destroyed by the sanitation cuttings of individual noncommercial trees.

Secondary Effects

Secondary impacts from an increase or decrease in predatory birds may be observed in the populations of animals upon which these birds prey. These animals may, in turn, have economic benefit through hunting-related business, or they may play significant roles in other ecologic relationships.

Other Comments

If the existing habitat of the bald eagle, golden eagle, osprey, peregrine falcon, California condor, or other threatened or endangered species is affected by an activity, the resultant controversy is likely to be intense, prolonged, and acrimonious.

Small Game

Definition of the Attribute

Small game include upland birds and animals which, as adults, weigh less than about 30 pounds—many are commonly hunted for sport. Some small game species falling into this category are rabbit, squirrel, raccoon, quail, grouse, and pheasant.

Activities That Affect the Attribute

Since most small game animals and upland birds are relatively tolerant of humans, the activities most damaging to them are those that physically destroy their habitat (area in which all welfare factors such as food, cover, water, and space required for their survival and propagation are present in sufficient quantity and diversity). Land-clearing activities (e.g., for buildings, road construction) often significantly and adversely affect small game. Conversely, such game can be expected to return to formerly built-up areas, which, when abandoned, revert to native vegetation. Distribution of poisoned baits used in rodent and predator control and use of herbicidal defoliants can also reduce small game populations, as can the use of certain pesticides.

Sources of Effects

The removal of native vegetation from, or the rearrangement of topography and surface features by the grading of, an area denies small game the kinds of habitats they require. Without the food and cover provided by vegetation and irregular surface features, populations of small game diminish rapidly. Conversely, they will often quickly return to abandoned areas given over to native vegetation. If poisoned bait is used, only a few small game animals and birds are likely to be affected, except in winter, when food is scarce and populations are at their annual minimum. Herbicides temporarily destroy small game habitat, and repeated applications can cause the permanent abandonment of an area. Persistent chemicals are accumulated in body tissues through ingestion of residues with food and water.

Variables to Be Measured

The small game population of the area to be affected by the activity must be censused. Once this is accomplished, the number of acres of existing habitat must be determined, as well as the amount by which it will increase or decrease over time as a result of the activity. The relationship between these variables and the attribute is fairly straightforward; the carrying capacity (wildlife population an area can support indefinitely without habitat degradation) is increased or decreased in direct proportion to the amount of available habitat remaining. While the quality of small game habitat existing before, and available after, the completion of an activity is an important variable, it is very difficult to quantify and will not be specifically discussed. It will, however, enter into subjective evaluations and judgments.

How Variables Are Measured

While an accurate census of small game is difficult to make, usable estimates of the number of different species per acre of habitat can often be obtained from local wildlife biologists affiliated with federal or state wildlife agencies.

The change in acreage of small game habitat can be obtained from before-and-after habitat overlays prepared from aerial photographic prints, mosaics, or topographic maps. Through using GIS or a planimeter, the size of these areas can be determined with the assistance of an engineer or surveyor. A direct proportion can then be established between the small game population and the number of acres of suitable habitat.

Evaluation and Interpretation of Data

The relative importance of a change in the small game population of an area is a very subjective judgment. If habitat is to be destroyed, significance should be attached to the relative amount and quality available in adjacent areas, as well as to the relative amount and quality of total habitat under control that will remain after the activity is completed.

Special Conditions

If the activity will cause a significant reduction in the available small game habitat in an area subject to heavy hunting, the impact will likely be controversial to sports enthusiasts and, to a lesser extent, economic interests in the area. This could happen if a prime small game–hunting area is fenced and placed off limits to the general public, or if its quality is to be heavily degraded.

Geographical and Temporal Limitations

While it is unlikely that any small game species would fall into the endangered or threatened category nationally, certain ones, such as grouse, woodcock, and turkey, might be rare in some states or local areas. Many outdoor activities during nesting season often destroy eggs, the result of which may be a significant reduction of the game-bird population for 1 year or longer.

Mitigation of Impact

Activities affecting small game can best be mitigated by disturbing the vegetative cover and altering the physical contour of the land as little as possible. Selecting areas of poorer habitat quality and preserving prime areas reduces the severity of the activities' impact on the small game population. Opening of large areas to the general public during certain periods of the small game–hunting season (opening day and holidays, when hunting pressure is particularly heavy) also tends to ameliorate the withdrawal of areas formerly freely available to public hunting.

Secondary Effects

Economic interests resulting from hunting-related business and aesthetic qualities supported by the presence of wildlife may be affected as a result of impacts on small game. Other secondary impacts may occur if natural ecological predator-prey balances are upset by the activity. Most changes in small animal populations are the result of, not the cause of, secondary effects.

Fish, Shellfish, and Waterfowl

Definition of the Attribute

Fish are coldblooded, water-dwelling animals that obtain oxygen through a gill system. They inhabit saltwater and freshwater bodies and streams and vary widely in size. Common species are minnows, sunfish, trout, bass, pike, salmon, and tuna.

Shellfish are aquatic animals that have an exoskeletal shell rather than an internal vertebrate structure of backbone and ribs. Common freshwater and saltwater species are mussels, crayfish, clams, oysters, shrimp, crabs, and lobsters.

Waterfowl are birds which frequent and often swim in water, nest and raise their young near water, and derive at least part of their food from aquatic plants, animals, and insects. Ducks and geese are the most familiar waterfowl. Because of similar habitat requirements, the generally protected swans, herons, cranes, pelicans, and gulls are also included here. The whooping crane is a frequently cited example of an endangered species that falls into the waterfowl category.

Activities That Affect the Attribute

Since fish, shellfish, and waterfowl depend directly upon good-quality water for all or some facets of their existence, activities that affect water quality and water level have the greatest impact upon their well-being. Examples of particularly damaging activities are dredging, stream channelization, construction that exposes mineral soil and subsoil subject to erosion, disposal of untreated or insufficiently treated sewage in water courses, permitting toxic materials to drain into water courses without collection and treatment, disposal of industrial cooling water in the ocean or in streams and lakes, application of pesticides (the residue of which may drain into water courses), draining of swamps or potholes, building of water-level control structures such as dams or dikes, and disposal of hazardous wastes at sea.

Sources of Effects

Dredging can temporarily displace the bottom organisms on which these categories of wildlife feed and can destroy spawning grounds. Stream channelization results in the removal of native vegetation that supports the insects eaten by fish. In addition, alteration of flow and substrate characteristics resulting from stream channelization can be as harmful as loss of vegetation. Certain species of fish are affected by even small amounts of solid material suspended in the water, a condition resulting from dredging or soil erosion. Some species of fish and shellfish are affected by siltation, which can cut off their oxygen supply and reduce the availability of food. A special case should be pointed out with respect to release of trapped pollutants when bottom sediments are disturbed, as through dredging. Heavy metals, such as mercury, and persistent pesticides, such as DDT and its derivatives—even though their use and disposal has been prohibited for decades—may be reintroduced into the food chain. Analysis of the bottom sediments prior to removal is now routine.

Discharge of insufficiently treated sewage may introduce disease-causing bacteria and viruses and reduce the oxygen content of the water—the life-support system upon which fish and shellfish are totally dependent. Insufficiently treated sewage also introduces nutrients which accelerate plant growth and decay in the water, often affecting the quantity of available fish habitat by further reducing the oxygen supply. Toxic materials, such as oils spilled or draining into water courses, cause the feathers of waterfowl to no longer shed water, bringing about death from exposure. Toxic materials, such as mercury, can eventually be so concentrated in the food chain that fish are no longer safe for human consumption. Other toxic materials can cause the outright death of fish by damaging their gills and preventing them from extracting oxygen from water.

The acidity level of water, if too high (pH 5 or less) or too low (pH 11 or greater), can cause similar gill damage. Increases in water temperature often cause sport fish to abandon the area to less desirable species of so-called rough fish such as carp. Rapid fluctuations in water temperature can kill fish outright. Pesticide residues draining into water courses and concentrating through the food chain may eventually become present in sufficient quantities in fish to cause their reproductive capacity and the survivability of young to be impaired. Pesticides can become even more concentrated in the tissues of fish-eating birds and animals.

Draining of swamps or potholes is very detrimental to waterfowl, as it is in these bodies of water that reproduction, nesting, and the rearing of young take place. The artificial raising and lowering of water levels is often beneficial to wildlife habitat, if done at times consistent with needs for food and nesting cover. However, since changing of water levels is most often a flood-control requirement, fish and waterfowl habitat can be drastically affected by changes not in consonance with their needs. Depending on the lethality of the material, hazardous waste disposed of at sea could cause the destruction of all aquatic life in the immediate area and other areas where the waste is transported by ocean currents.

Variables to Be Measured

The detailed variables to be measured for fish are the same as those identified in the attribute descriptions involved with surface water quality. Some of these important variables are dissolved oxygen (DO) content, coliform bacteria levels, acidity levels (pH), heavy metal concentrations, and pesticide concentrations detrimental to fish life.

While many substances (petroleum products, hydrogen sulfide, copper, and other metals) can taint shellfish and make them unpalatable for reasons of odor, taste, or color, the pathogenic bacteria and viruses they take up from the surrounding water may render them unfit for human consumption. Measurements of coliform bacteria present in the water provide a standard for determining when oysters, clams, and mussels can be safely eaten.

The main variable to be measured for waterfowl is change in available habitat. Quantity of suitable nesting habitat—which equates roughly to the length of shoreline—is a heavy determinant of waterfowl population on a year-by-year basis, but it is difficult to relate the two exactly. Winter habitat is also important but more difficult to quantify and to relate to increases or decreases in waterfowl.

How Variables Are Measured

As indicated, measurements of water quality variables are discussed under surface water quality. Some acceptable general standards for maintaining a healthy aquatic fish habitat are that dissolved oxygen content should not fall below 5 mg/L and that pH level should be maintained in the 6 to 9 range. The latest EPA or state water quality standards, which specify limits for pollutants within various water use categories, including aquatic life, should be followed.

While the standards for fish also apply generally to shellfish, coliform bacteria count is the important variable to be measured. Criteria for water from which shellfish are harvested are contained in the U.S. Public Health Service Manual, *Sanitation of Shellfish Growing Areas*. The general standard for coliform bacteria is that the median most probable number (MPN) must not exceed 70 per 100 mL.

If the length of existing shoreline or its character is altered so as to render it unsuitable for waterfowl nesting, the amount of change should be determined. Before-and-after overlays of suitable wildlife nesting habitat along shorelines should be prepared from aerial photographs, project plans, or maps. Through using GIS or a map measurer, shoreline length can be determined. The amount of change between present and future habitat can then be calculated. Additionally, the change in number of individual bodies of water between the two overlays should be noted. Once these data are obtained, they are still not directly convertible to change in the number of pairs of nesting waterfowl the habitat can support. This is a subjective judgment that only an expert wildlife biologist (e.g., from the FWS) can make.

Evaluation and Interpretation of Data

Although it is difficult to directly relate small alterations in water quality to changes in fish and shellfish populations, changes in fecundity, population counts, and growth rates are often sensitive indicators of such alterations. Therefore, an attempt should be made to assess population changes that might result from proposed alteration of the environment. If water quality is degraded or improved to the point where commercial fishing activities are affected, the change in annual revenues derived from this source can be determined. If the change in water quality affects species associated with sport fishing, the number of miles of streams affected would provide some measure of the significance of the impact. If a prime sport-fishing area is involved, economic gains or losses to businesses deriving a part of their income from those who fish might be an important consideration. Estimates of the effects of such changes might be obtained from federal or state wildlife agencies.

Changes in quantity of nesting habitat would definitely affect the number of waterfowl available for annual harvest. However, the effect is felt more in areas where waterfowl are hunted than where they nest. An expert from the

FWS could provide insight into the extent of the resulting environmental (ecological and economic) impacts.

Special Conditions

If activities will cause a significant reduction in the length of streams or areas of coastal waters suitable for sport fishing or in the amount of waterfowl nesting habitat, the impact will likely be controversial to anglers. This could happen if even small stretches of renowned trout streams were to be affected or if prime fishing waters were placed off limits to the general public. Commercial interests would most likely oppose any intrusion into prime fish and shellfish areas or any reduction in the annual catch/harvest. If any waterfowl considered to be threatened or endangered—regionally, nationally, or internationally—use the activity area for nesting, migration stopover, or feeding, significant controversy would probably result. (The attribute discussion covering listed species goes into greater detail on this subject.)

Geographical and Temporal Limitations

The only geographical limitations on fish and shellfish relate to particular types found in the activity area and whether coastal estuaries or open sea areas are involved. Temporal considerations are those involved with conducting the activity during spawning, migration, or harvest seasons.

The critical region of migratory waterfowl nesting habitat is generally considered to be in the northern tier of states, Canada, and Alaska. This would, however, not be true of nonmigratory waterfowl associated with estuaries and seacoasts. Activity that would disturb waterfowl during the nesting season and while the young are being reared would be most damaging.

Mitigation of Impact

Impacts upon fish and shellfish populations can be mitigated by restricting the input of polluting substances into fresh water bodies, estuaries, and the open sea. This can best be accomplished by ensuring that wastewater treatment facilities of suitable capacity and design are constructed to be in operation by the time it is anticipated that waste products from the proposed project will be generated. If soil erosion is a problem, construction activities should be scheduled at times of the year when intense rainfall is least likely to occur. Protective measures such as catchment and retention basins and silt fences may be effective.

Impacts on waterfowl from an activity can best be mitigated by disturbing the land-water interface in the area as little as possible. Vegetation along water courses should not be cleared indiscriminately. Neither should potholes or swamps be drained unless absolutely necessary for successful completion of the activity. Additionally, when a part of the activity involves water-level control, changes in such levels should be programmed—to the extent it is possible to do so—in a way that will only minimally disturb nesting and feeding habitat. These considerations for the natural environment will help to ensure that waterfowl habitat available for nesting and feeding will not be appreciably diminished in either quantity or quality. If habitat is permanently lost, the FWS may require compensatory development of new waterfowl habitat.

Secondary Effects

Economic interests resulting from business related to hunting and commercial and sport-fishing activities would be affected by impacts to fish, shellfish, and waterfowl. Other secondary impacts may occur if natural ecological relationships are upset by the action.

Other Comments

Water quality and fish and shellfish habitat go hand in hand. Any substantial degradation of the former will have a decided impact on the fish and shellfish populations relative to quality and number. All aquatic oxygen-using (aerobic) organisms will be affected to some degree by decreases in water quality. The effect of an activity on fish and shellfish is a general indicator of the impact on the entire water environment.

Field Crops

Definition of the Attribute

Field crops are those commercially cultivated for the primary purpose of providing food and fiber for people and food for domestic livestock. Common field crops include corn, wheat, cotton, soybeans, and truck produce (tomatoes, melons, and table vegetables).

Activities That Affect the Attribute

Since almost all land highly suitable for field crops is in private ownership, acquisition of that land—for whatever project purpose—would take it out of agricultural production. Acquisition of prime agricultural lands for non-agricultural purposes is likely to have the greatest impact on field crops.

Reservoir construction and operation, along with various runoff-control projects, may affect the flooding regime of large areas of field crops. Application of herbicides on land adjacent to an agricultural area planted in field crops would have a more localized impact.

Sources of Effects

Diversity, both human and natural, is an important and valuable characteristic of ecosystems. If the area previously given over to field crops is to be built upon (the most likely reason for acquiring the relatively flat land that field crops usually occupy) or is to be used extensively for nonagricultural activities, the vegetative diversity will be reduced. Wildlife could also be affected, as many game and nongame animals and birds obtain some food and cover from field crops. If the acquired land is later allowed, through successive vegetative stages, to revert to the natural climax type of area, the impact might be ecologically beneficial.

Reservoirs and impoundments may raise groundwater levels, flooding root systems and severely damaging crops. Other flow diversions may decrease probability of flood damage.

Herbicides applied by aerial spraying might carry onto adjacent agricultural land, killing crops with which they come in contact. While the area might be relatively small, the resulting damage could be highly controversial.

Variables to Be Measured

The main variables to be measured are the number of acres of land now given over to field crops that would be taken out of production, as well as the percentage of land which would be permitted to revert to natural vegetation. Since field crops and natural vegetation are both ecologically important, an assumption can be made that if one type is not unduly created at the expense of the other, each is of equal significance. In practice, row crops are not as valuable per acre as natural vegetation for purposes of wildlife habitat. The measure of ecological impact would then be determined by the loss of productive vegetative cover.

How Variables Are Measured

Specific acreages of field cropland to be taken out of production by a land acquisition program could be measured directly, but it would be easier to obtain figures from local offices of the Farm Services Agency (FSA) of the U.S. Department of Agriculture. Land previously used for crops but permitted to revert to natural vegetation should be depicted on an overlay prepared to scale from a project plan, map, or aerial photograph. Through using GIS or a planimeter, the size (acreage) of that area can be determined with the assistance of an engineer or surveyor. The percentage of cropland reverting to natural vegetation could then be derived.

Only a general estimate is possible when determining field crop acreages that might be damaged by herbicidal spraying. Some of the variables involved would be the kind of application system used, wind direction and velocity, and state of crop development. However, if these variables are reduced to an assumption that 500 feet is the maximum distance into the field that the herbicide could produce crop damage, the other variable involved would be the linear measure of cropland directly adjoining the area where the herbicide is to be applied. Area affected and potential economic cost could then be calculated. The FSA should be able to provide acreage yields and selling prices of various field crops that might be affected. Herbicide programs are always controversial, and are probably best avoided.

Evaluation and Interpretation of Data

The magnitude of the impact of the change in land use that results from cropland acquisition is related to the percentage of that land which will continue to support natural vegetation. The greater the percentage of field cropland that is built upon or otherwise taken out of vegetation production, the greater the impact. For crops damaged by application of herbicides, a measure of impact could be made by comparing the dollar loss of the destroyed crops to the annual value of that crop in the country or area concerned. Again, the greater the percentage of dollar loss is of the total crop value, the greater the impact.

Special Conditions

If the cropland is especially productive relative to other cropland in the general area, or if the crop grown upon that land is of very high value, the impact may be greater than what would otherwise be anticipated.

Geographical and Temporal Limitations

Because of climate and soil or other requirements, some field crops—particularly specialty crops (avocados are a good example)—can be grown only in a very limited geographical area. If the cropland to be acquired is in such an area, a significant reduction in the local or even national output of that crop might result. On the other hand, there are vast areas in the Western United

States where conditions are not suitable for the cultivation of field crops. Land acquisition activity in those areas would not affect this attribute.

Herbicidal damage to field crops is greatest when the plant is growing fastest (spring), before the vegetative product (corn ears, grain kernels, bean pods) has matured. However, this is generally the time when herbicides will be used, because they have the greatest suppressive effect on the vegetation at which they are directed. This is most severe when croplands are intermixed with forest or rangeland where herbicide programs are most commonly proposed. This is a form of land-use conflict.

Mitigation of Impact

The detrimental impact of acquiring productive field cropland can best be mitigated by locating the activity in an area where very little land is given over to field crop production or where the farming enterprise is of marginal economic value. Some additional mitigation in the form of tradeoffs is possible if a large portion of the cropland is allowed to revert to natural vegetation. This would be possible in buffer areas acquired to shield private lands from the activities of a major development project.

Mitigation of the impact of herbicidal applications could take the form of cutting vegetation and applying the herbicide directly to the stumps in those areas where field crops are directly adjacent to the activity. Further mitigation of impact is possible if the stump application of herbicides is done at a time when the adjacent field crops are vegetatively dormant. If spraying is a preferred method of vegetative suppression, it should be done at times when wind velocity is low and wind direction is such that the possibility of the herbicide carrying into the field crop area is minimal. This may be regulated by state law or local regulation.

Secondary Effects

Loss of field crop production could have significant effects on local or regional economic stability, particularly if the loss is of long-lasting or permanent duration. Other effects on land prices and farm product availability could result. Such effects are also highly controversial.

Other Comments

If significant economic loss will result from the acquisition of cropland and its removal from agricultural production, farmers' organizations will be likely to actively oppose the project.

Listed Species

Definition of the Attribute

Federally listed species (including those categorized as threatened and endangered) include all forms of plant and animal life whose rates of reproduction have declined to the point where their populations are so small they are in danger of disappearing or may soon decrease to this level. Listed species are classified as such on both a regional and a national basis. A species classified as threatened within a state may occur only in limited numbers at very few locations within that state but be relatively common in other states. National endangered species are those found only in very small numbers or near extinction throughout the United States. Lists of threatened and endangered animal and plant species are published periodically by the FWS, U.S. Department of the Interior* (see 50 CFR 17 Subpart B). Examples of more commonly known listed species are the timber wolf, grizzly bear, southern bald eagle, California condor, and whooping crane. Less commonly known listed species include the black-footed ferret, key deer (Florida), Devil's Hole pupfish, Florida kite, Nene goose, and Delmarva fox squirrel. While animal species are the ones most often in the public eye, there are many species of plants that qualify for listing, but few are well known to the general public, and all are of very restricted distribution. See also section 13.4.

Activities That Affect the Attribute

These activities are basically the same, depending on the animal or plant species involved, as those mentioned under the large animals, predatory birds, and natural land vegetation attributes. Refer to those sections if a listed species' habitat is located within the geographic area that a specific action will affect. Threatened and endangered species are also discussed in the National Environmental Policy Act (NEPA) context in Chapter 13 of this book.

Sources of Effects

The source of the effects of various activities on listed species of animals and plants is essentially the same as those listed for large animals, predatory birds, and natural land vegetation. Refer to those attributes if the habitat of a listed species is located within an area where the effects of a particular action will be felt. Consultation with the FWS will be required.

* The "list" maintained by the Secretary of the Interior is literally a list of those species determined to be threatened or endangered, thus the origin of the name, *listed species*.

Variables to Be Measured; How Variables Are Measured

The variables to be measured and the method of doing so are highly dependent upon the particular species of plant or animal affected. While the information contained in similar parts of the attribute discussion for large animals, predatory birds, and national land vegetation could serve as a general guide in the case of listed species, the assistance of an ecological team of wildlife biologists, zoologists, botanists, and plant physiologists in accumulating relevant data would be almost a necessity.

Evaluation and Interpretation of Data

This function can be adequately carried out only by a group of professional ecologists familiar with the myriad details associated with the listed species itself, its place in the ecosystem, and the nature of the particular habitat that is to be affected. Logically, this team of ecologists should be the same group responsible for collection of the basic data on which the evaluation is to be based. However, an additional critical review of their conclusions by an eminent ecologist might help to ensure public acceptability of those findings. The various state natural heritage programs will also be interested parties.

Special Conditions

Any potential effect to either a listed species or any special interest species is extremely sensitive, and likely to be controversial. This controversy may be the basis of public opposition or legal challenges or both. Federally listed species are specifically protected by the Endangered Species Act (ESA), and strong objections are also certain to be raised by the FWS. The project may trigger controversy even if the proposal is not directed toward the listed species. Secondary consequences, if predictable, are adequate to trigger the provisions of the ESA. This is clearly an area where extreme care must be taken every time a listed species is affected in any manner by a proposed action. Many states have protective legislation as well, which will cover species of local importance. Compliance with these regulations must also be considered mandatory, or the proponent will suffer the cost of acrimonious public relations in addition to legal penalties.

Geographical and Temporal Limitations

Clearly, species never found within the sphere of effects of the proposed action cannot be involved. Many nonresident species may, at some time of the year, however, utilize other lands and waters for migration, breeding, or feeding. A brief action during the period when a listed species is not present may be permissible, although coordination with the FWS is mandatory even in this case. Planners should consult with knowledgeable wildlife professionals for every proposed project, period. The state natural heritage programs maintain records of presence of listed species, as do state wildlife and natural resources agencies and the FWS. All will provide basic information readily at no cost.

Mitigation of Impact

The primary way to mitigate the impact of activities on listed species is to avoid any disruption—physical or biological—of their habitats that might result in a decrease in their populations. While it would appear to be less damaging to disturb the habitat of a species classified as threatened by a state than of one that is federally listed or as threatened rather than endangered, these tradeoffs are usually not feasible. It is best to avoid disturbing the known habitat of any listed species. The rulings (opinions) of the FWS will state what accommodations are required to meet legal requirements.

Secondary Effects

As indicated earlier (in special conditions), many secondary effects occur along with the impacts on threatened species. In addition to their human and aesthetic interest value, some of these species may be of significant importance to the dynamic aspect of the ecosystems in which they are found. Their use as indicators of overall environmental quality should not go unnoticed.

Other Comments

If any activity has the potential of adversely affecting the populations of any listed species, naturalist and wildlife groups are almost certain to vigorously oppose it in public hearings and/or in court. The opinion of the FWS must, by law, be sought prior to taking any action.

If any question exists as to the presence of a listed species—either intermittently or year round—in the area of a project, FWS wildlife biologists or botanists should be called upon to verify that presence and to give a preliminary assessment of the impact of the activity on the population of this species.

Natural Land Vegetation

Definition of the Attribute

Natural land vegetation is that which uses soil (as opposed to water) as its growth medium and which is not the subject of extensive cultural practices by humans. Included in this category are a number of diverse groups of plants, including trees, shrubs, grasses, herbs, ferns, and lichens.

Activities That Affect the Attribute

Any activities that affect the land surface will affect the vegetation that grows upon it. Timber-harvest operations, land-clearing activities prior to construction, burning, application of herbicides, off-road vehicular traffic, and the application of artificial paving materials are some activities that can cause adverse impacts on natural vegetation. Abandonment of a project site can result in natural vegetation becoming reestablished through a series of successional stages.

Sources of Effects

Timber-removal operations employing inappropriate forest management methods can reduce the possibility of reestablishing fully stocked stands of the same species. Without the protection of the forest canopy, shrubs and other plants left after timber removal may weaken and become prime targets for disease and insects. Land-clearing activities can cause the outright destruction of natural vegetation, and resulting soil erosion can inhibit its reestablishment. Improper use of herbicides can result in the destruction of nontarget species of natural vegetation and can disrupt the overall stability of the ecosystem. Mechanized military field training destroys lower vegetative forms outright, and the resultant soil compaction and erosion—each in its own way—can inhibit their re-establishment. Paving can deny native vegetation to large areas for extended time periods. As previously indicated, a reduction in the magnitude of activity at a particular installation or its closing can encourage the re-establishment of native vegetation.

Variables to Be Measured

The variables to be measured are the number of acres of native vegetation existing before and after the activity, as well as any significant vegetative changes that may develop. A reduction in an area given over to native vegetation can result in increased soil erosion, a decrease in soil fertility, and a decrease in quality and quantity of wildlife habitat. It can also accelerate the invasion of weeds and other undesirable pest species. Reintroduction of native vegetation can—over time—have the opposite effect. Successional change in vegetative type is slow, however, and the least desirable plant types are the first to become reestablished on a site after a major clearing activity.

How Variables Are Measured

The change in acreage of natural vegetation can be obtained from before-and-after overlays of vegetative types. The before overlay can best be prepared from recent aerial photographs. A photo interpreter can assist in differentiating and plotting the major vegetative types. In this way, the total area of vegetation cover can be ascertained along with the subareas in each of the major types. The after-activity overlay should be prepared at the same scale, using the project plan to outline areas of existing natural vegetation that will be affected. The remaining total acreage in native vegetation by major type should then be determined. These calculations of acreage can best be done through using GIS or a planimeter, information from a remote-sensing system. The percentage of original native vegetation remaining—the total and by major type—is then derived.

Evaluation and Interpretation of Data

The magnitude of the impact of the activity on natural vegetation can be determined from the percentages previously given. However, the specific changes and types of vegetation that would result from the activity can be projected only by a botanist or forester intimately familiar with the local area. Even more difficult to interpret objectively are the aesthetic considerations involved.

Special Conditions

Destruction of natural vegetation in the particularly fragile ecosystems that exist under extremely adverse environmental conditions—such as tundra and desert—can have greater impact than in an area with a more moderate climate. They may also require many more years to recover—40 to 50 years or longer.

Geographical and Temporal Limitations

The only geographical limitations of impacts on this attribute occur in those rare areas of desert and bare rock where no native vegetation exists. Much greater damage may occur when the soils are wet, or when annual vegetation has not become established. Fire, including prescribed burning, may be too destructive when conditions are dry.

Mitigation of Impact

The best way to mitigate the impact of activities on natural vegetation is to design the project so as to restrict the area affected. Examples of other mitigation possibilities are to restrict land-clearing activities to the absolute minimum, apply ecologically sound management practices in timber harvest and timber stand improvement, confine vehicular activities to designated areas and restrict expanding them into new areas, apply vegetation suppression techniques of controlled burning and herbicide application only when other methods are not feasible, and use crushed stone rather than asphalt or concrete for surfacing parking areas.

Secondary Effects

In addition to economic gains from timber harvesting, natural land vegetation provides habitat for wildlife species; recreational areas for hunting, camping, and other pursuits; and countless other resources of both aesthetic and material nature, including reduction of erosion and runoff from storms.

Other Comments

If activities result in the destruction of unique areas of natural vegetation, opposition can be anticipated from local and national naturalist organizations. These natural areas are usually well known locally and are often cataloged at the state level by departments of natural resources or natural heritage programs. Any activity that would alter these unique and rare areas of natural vegetation should be avoided to the same extent as one involving the habitat of a threatened species of wildlife.

Aquatic Plants

Definition of the Attribute

Aquatic plants are those whose growth medium is primarily water, though they may be rooted in bottom sediments. They include free-floating plants such as phytoplankton, all surface and submerged rooted plants, and swamp and marsh vegetation whose roots are periodically or permanently submerged in water. Aquatic plants are essential elements in the food web.

Activities That Affect the Attribute

Activities that cause changes in water level or water quality parameters have the greatest impact on aquatic plants. Examples of particularly damaging activities are dredging, stream channelization, construction that exposes mineral soil and subsoil subject to erosion, disposal of untreated or insufficiently treated sewage in water courses, disposal of cooling waters in oceans and in streams or lakes, draining swamps and marshes, and building of water-level-control structures such as dams or dikes.

Sources of Effects

Dredging can temporarily—and sometimes for long periods—displace rooted and bottom-dwelling aquatic plants. Stream channelization intentionally removes all stream-side vegetation. Erosion can cause increased sediment loads sufficient to restrict the sunlight on which aquatic plants depend for photosynthesis. The discharge of insufficiently treated sewage into the water courses induces excessive aquatic plant growth. Increases in temperature also tend to accelerate aquatic plant growth, particularly algae. The draining of swamps and marshes reduces the area in which aquatic plants can survive. Changes in water level can cause the destruction of aquatic plants, either by exposing their roots to the drying influence of sunlight and air or by flooding to levels that deny air to bank- or marsh-dwelling species for long periods of time.

Variables to Be Measured

The essential variable is the change in amount of water area suitable for the growth of aquatic plants. There are two elements to this variable: changes in water surface areas and changes in those elements of water quality that accelerate or restrict plant growth. Any changes in the kind of vegetation and its productivity can influence all other organisms that depend upon it for food.

How Variables Are Measured

The only direct measurement that can be readily made is the quantity of total aquatic plant habitat available before and after the activity. This can be done by an expert photo interpreter, who should prepare before-and-after overlays from large-scale aerial photography. Through using GIS or a planimeter, the acreage can be calculated and the change in total available aquatic habitat derived. Infrared photography or remote sensing are especially useful.

The quality of the water habitat existing before and after the project can be ascertained only by intensively examining the aquatic plant life, measuring the various water quality parameters affecting plant growth, projecting changes in water quality that will result from the activity, and projecting the changes in aquatic plant habitat that will follow. This is a complex procedure that can best be accomplished with the assistance of an interdisciplinary team of biologists, botanists, zoologists, ecologists, and engineers, and should be a part of the water quality studies.

Evaluation and Interpretation of Data

Since it is not usually possible to measure directly the change in the quality and quantity of aquatic plant life, only a very imprecise measure of impact can be obtained from the change in water area. Generally, if the percentage change in aquatic plant habitat exhibits a value greater than 20, an attempt should be made to measure the qualitative change as well. Further, if changes in the water quality parameters measured or projected under surface water attributes indicate increased nitrogen and phosphorus concentrations, increased water temperature, decreased water flow, or high sediment loads, the advice of ecological experts should be sought relative to the extent of the impact on aquatic life.

Special Conditions

If the change in quantity, quality, or type of aquatic vegetation will result in waters being rendered unfit for swimming or will cause a reduction in the game fish or commercial fish populations, greater controversy over the project is likely to result, since the impact will be more directly felt by the general public. Dredging and filling of wetlands and water areas is regulated by federal law and by many states as well. Permits are required before actions may take place.

Geographical and Temporal Limitations

The only geographical limitations on aquatic vegetation are the particular types native to certain areas. Temporal considerations do not appear to be significant, except in that explosive growth of algae and floating plants (blooms) is most common during warm weather.

Mitigation of Impact

Impacts on aquatic plant life can best be mitigated by minimizing the input of nutrients, erosion products, and heat into water bodies. This can be accomplished by assuring that wastewater treatment facilities of appropriate size are constructed to be in operation by the time the increased amount of nutrients is scheduled to be generated. In addition to catchment, catch basins can be constructed to permit the settling out of suspended solids prior to the runoff water reaching natural water bodies. (The attribute discussion covering erosion goes into greater detail on this subject.) Additionally, construction activities can be scheduled at times of the year when intensive rainfall is least likely to occur. Cooling water can be processed or stored in artificial ponds until the difference in temperature between it and the receiving water is more nearly equal.

Swamps and marshes should not be proposed to be drained unless such action is absolutely necessary for the successful completion of the activity. Artificial changes in water level should be minimized and programmed during the fall and winter, when the plants are dormant. If herbicides are used to suppress excessive aquatic plant growth, they should be applied selectively and in amounts that will reduce the undesirable species but not kill all aquatic plants. Herbicide use is controlled by federal and state law.

Secondary Effects

Since aquatic plants are essential elements in the food web, adverse impacts to these elements will also be reflected in impacts to higher order consumers (fish, animals, and humans). Excessive growth of aquatic plants, on the other hand, can choke waterways and recreational areas, with resultant induced reduction of economic, social, and aesthetic benefits. Algal blooms may affect the taste and odor of public water supplies.

Other Comments

Water quality and quantity are directly related to the suitability of water bodies for desirable aquatic plant growth. Introduction of pollutants will reduce plant productivity and plant species diversity and result in an aquatic plant community composed predominantly of pollution-tolerant forms. This will, in turn, have a decided impact on the fish populations that inhabit the waters. Changes in the food web can have impacts throughout the ecosystem, but these are often not completely understood. Some contaminants may accumulate in aquatic plants and be further taken up by birds, other animals, and humans.

SOUND

The level of sound (noise) is an important indicator of the quality of the environment. Ramifications of various sound levels and types may be reflected in health (mental and physical) and/or in aesthetic appreciation of an area. Because of the important consequences of a too noisy environment, sound is examined separately rather than under various other resource categories.

The sound (noise) in an environment is indicated by many attributes, but some important ones are:

- Physiological effects
- Psychological effects
- Communication effects
- Performance effects
- Social behavior effects

Physiological Effects

Definition of the Attribute

Noise can affect the physiology of the human body in three important ways:

- Internal bodily systems
- Hearing threshold
- Sleep pattern

Internal bodily systems are defined as those physiological systems essential for life support—cardiovascular (heart, lungs, vessels), gastrointestinal (stomach, intestines), neural (nerves), musculoskeletal (muscles, bones), and endocrine (glands). Noise stimulation of nerve fibers in the ear may indirectly harmfully affect these systems. High-intensity noise (e.g., artillery fire, jet aircraft takeoff) constricts the blood vessels, increases pulse and respiration rates, increases tension and fatigue, and can cause dizziness and loss of balance. However, these effects are generally temporary and, to some extent, adaptation does occur. The process of adaptation is in itself indicative of an alteration in body functions and is therefore undesirable. High noise levels can also reduce precision of coordinated movements, lengthen reaction time, and increase response time, all of which can result in human error (Miller, 1971).

Hearing threshold is defined as the lowest sound level or loudness of a noise that can be heard. The lower the sound level that can be heard, the lower the hearing threshold. If the sound level necessary for a noise to be heard (or the hearing threshold) is higher than normal for a person, then hearing loss or partial deafness is indicated. Noise can cause temporary or permanent hearing loss (i.e., an increase in the hearing threshold) and can cause ringing in the ears (tinnitus). Hearing loss can be temporary, in that the ear recovers relatively soon after the termination of the noise. Over time, the recovery may be incomplete, and a permanent loss results. Hearing loss of any degree is serious because accidents can occur if warning signals, commands, or other important noises cannot be heard or understood. In addition, hearing loss is undesirable from social, economic, psychological, and physiological points of view.

Sleep pattern is defined as a natural, regularly recurring condition of rest, and is essential for normal body and mental maintenance and recuperation from illness. Noise can affect the depth, continuity, duration, and recuperative value of sleep. The disruption or lack of sleep results in irritability, often irrational behavior, and the desire for sleep. Even a shift in the depth of sleep can result in fatigue. Also, while suffering or recovering from illness, rest and sleep are essential to health and recovery. Thus, it is important for noise to be kept at a minimum, or at least constant, during night hours.

Activities That Affect the Attribute

Most human activities cause some level of noise, but the most serious impacts result from the following.

Construction

Construction projects create noise through the use of vehicles, construction equipment, and power tools. The noise affects the operators, personnel, and communities near the site, and the people near transportation routes to the site.

Work Activities

The operation of most types of aircraft and surface vehicles, machinery, and power-generating equipment will generate noise. Maintenance and repair produce noise through the use of all types of tools and when a number of noise sources are operating at the same time in the same general area (e.g., a vehicle repair shop).

Military Training

Training courses and exercises that use any type of vehicle, weapon, power tools, appliances, and machinery create noise for operators and military and civilian personnel, and, in large-scale exercises, can affect nearby civilian communities. High-performance aircraft and heavy weapons use are the most intrusive.

Industrial Plants

The machinery and tools contained in these plants are a significant source of noise to the personnel and, if noise levels are sufficiently high, can affect the nearby community.

Sources of Effects

The sources of noise that affect this attribute include the following.

Military Equipment

Missiles and artillery of all types, including small arms, have extremely high noise levels and can severely affect the hearing threshold of their operators in addition to disrupting civilian activities.

Vehicles

Vehicles in the air, on the ground, or on water are important noise sources that affect the operator, other personnel, and the community. Examples include the following:

- Aircraft on and around commercial airports and military air bases significantly affect the community, particularly sonic booms or night operation, which can affect sleep patterns.
- Large vehicles such as trucks, buses, and armored vehicles can affect the hearing threshold of the operators and passengers.
- Most vehicles, when operated at night, can affect sleep patterns.

Construction Equipment

These types of equipment, which include vehicles and power tools, have high noise levels that can affect hearing thresholds of operators and site personnel. Pile drivers are notorious offenders.

Machinery

Machinery in industrial plants, where noise levels are high and continuous, can significantly affect operators' hearing thresholds.

Variables to Be Measured

The important variables of noise that affect this attribute are its loudness, duration, and frequency content. As the loudness and/or duration increase, the effects of noise on the body increase. The internal bodily systems are increasingly under stress, the hearing threshold increases to the point where permanent damage (called noise-induced hearing loss) can occur, and sleep becomes increasingly impossible. Noises that contain high frequencies or contain or are pure tones are more damaging and disturbing than those that do not.

Finally, the impulsivity of a noise is important. An impulsive noise is highly intense and short in duration (generally less than 1 second), for example, artillery or small arms fire. Recommended noise measures and their explanation are provided in Table B.5.

Table B.5 Noise Measurement for Environmental Assessment

Type of environment	Type of criteria	Recommended measures
General audible noise	Hearing loss potential	A-weighted L_{dn}*
	Health and welfare effects on people	A-weighted L_{dn}
	Environmental degradation/effects on structures and animals	A-weighted L_{dn}
High-amplitude impulsive noise blasts, artillery, helicopters, pile drivers	Structural damage	Peak pressure/peak acceleration
	Annoyance	C-weighted L_{dn}

*L_{dn} = Day/night average sound levels; a measure of the noise environment over a 24-h day with a 10-dB penalty applied to nighttime (10:00 p.m. to 7:00 a.m.) activities (Goff & Novak, 1977).

How Variables Are Measured

The loudness of noise is measured in terms of decibels (dB). Decibels are measured by using a sound-level meter. Normally, loudness is measured with a sound-level meter incorporating an "A"-weighted electronic network. The resulting measure is called dBA or dB(A). Most of the evaluation criteria are given in dB(A) units. The intensity of an impulsive noise may be difficult to read visually from a sound-level meter alone, due to the very short duration of the noise. To determine the intensity of an impulsive noise, special equipment, such as a true integrating noise monitor, is needed and C weighting is used. Some of the pioneering work on compulsive noise has been done at the U.S. Army Construction Engineering Research Laboratories, including developing a true integrating noise monitor for measuring impulsive noise levels and community response to high-amplitude impulse noise (Schomer, 1977, 1985, 1986, 1991).

The frequency content of noise is more difficult to measure, and complex equipment is required. Subjectively, however, high-frequency content and pure tones are recognizable (assuming the observer's hearing is normal). For example, noises with high frequencies have a whine (jet aircraft), screech (certain machinery), clank or clink, squeal, squeak, whistle, ping, or simply a tone. Noises with these characteristics are more annoying and disturbing to people and, at high loudness levels, more damaging. In general, subjective evaluations are not acceptable except to support or verify objective measurements.

Measurement of the physiological attribute for existing situations should be taken at the expected position of the human body with respect to the noise source(s). The sound-level meter should be placed where the body or people are or will be located. When the noise source is active, several readings should be taken and averaged (see discussion in geographical and temporal limitations section).

In those situations where the noise source is in the future and thus cannot be measured directly, which is often the case for environmental assessment, analytical models need to be used for estimating noise levels (*CHABA Guidelines*, 1977; Goff & Novak, 1977; Gordon, 1971).

Finally, to measure hearing loss or hearing thresholds of an individual, an audiometer should be used by a trained person certified as an audiometric technician under the supervision of a physician or an audiologist. It is important to measure an individual's hearing before he or she is subjected to noise sources so that a baseline audiogram can be prepared. This audiogram can then be used for future reference and comparisons with later tests.

Evaluation and Interpretation of Data

The following criteria can be used to determine if the noise source will affect the body in any manner. The intensity and duration of the noise at the body should not exceed the values given in Table B.6.

Special Conditions

The most serious noise impacts on this attribute are:

- Partial hearing loss caused by artillery or small arms fire
- Partial hearing loss to equipment operators caused by construction equipment or vehicles
- Sleep loss

Noise-induced hearing loss due to artillery, small arms fire, or combat vehicles is not uncommon in the military. Military personnel exposed to these noise sources should have their hearing checked periodically and wear protective equipment at all times.

Noise sources of any type should not be located near schools, hospitals, or homes for the aged. Night operations should be isolated from these places and from any areas where people are sleeping.

Table B.6 Noise Exposure Intensity and Duration Levels

	Intensity	**Duration**
Internal bodily system	85 dB(A)*	Any
Hearing threshold (continuous sound, if sound of intermittent summation is required; use meters especially designed for this purpose or contact audio engineers or sound specialists)	80 dB(A)†	16 h
	85 dB(A)	8 h
	90 dB(A)	4 h
	95 dB(A)	2 h
	100 dB(A)	1 h
	105 dB(A)	30 min
	110 dB(A)	15 min
	115 dB(A)	7.5 min
	>115 dB(A)	Never
Hearing threshold‡ (Impulsive sound)	140 dB (at ear)†	100 μsec
Sleep pattern		
Causes awakening	55–60 dB(A)	Any
Causes shift in sleep	35–45 dB(A)	Any

*These dB(A) levels may be changed to reflect different distances between the noise source and measurements by applying the rule of subtracting or adding 6 dB(A) per doubling or halving of distance. For example, if the estimate is given as 90 dB(A) measured at 50 feet and the actual distance between the noise source and the personnel is 100 feet, the dB(A) can be estimated to be 84 dB(A). Noise sources that are "line" sources, such as trains and heavy streams of traffic, reduce in noise level 3 dB(A) per doubling of distance.
†American Conference of Government Industrial Hygienists (ACGIH), 1973.
‡Operators of artillery and small arms can be expected to receive higher intensity levels.

Geographical and Temporal Limitations

Any activities and noise sources should be geographically located so as to minimize their impact on communities and populations. Isolation of the activity can be accomplished by geographical distance and/or placement with natural barriers (vegetation, hills, or mountains).

Noise sources affect people differently during the day. During the day people expect noise levels to be higher, but during the evenings when outdoor events, family activities, rest, television watching, and other quieter activities take place, noise levels are expected to be much less. At night, of course, noise sources are not expected to be active. Similarly, during weekends, noise sources should not be active. The use of the 10-dB night penalty reflects this expectation.

Variables should be measured or projected at various geographical distances and directions from the source until criterion values are reached to determine the extent of the noise. In addition, it is important to measure noise from transportation routes and flight patterns through communities and the airfield. Also, the variables should be measured at various times during the day, evening, and night to determine the worst and best noise conditions.

Mitigation of Impact

The optimal method of reducing sound level is to reduce the noise being produced by the source. Since this method can be difficult or expensive to use on existing noise sources, the techniques of isolation and insulation are often used. If these techniques fail to reduce noise levels sufficiently, then the use of ear protective devices is recommended.

To reduce noise levels at the source requires engineering solutions. These methods may include damping, absorption, dissipation, and deflection. Common techniques involve constructing sound enclosures, applying mufflers, mounting noise sources on isolators, and/or using materials with damping properties. Redesigning the mechanical operation of noise sources may be necessary. Performance specifications for noise represent a way to ensure that the procured item is controlled.

When an individual is exposed to steady noise levels above 85 dB(A), in spite of the efforts made to reduce noise level at the source, hearing conservation measures should be initiated.

The federal government has promulgated three regulations that relate to controlling noise at the source. These noise regulations have been issued by the General Services Administration, the Environmental Protection Agency, and the Department of Labor.

General Services Administration

The General Services Administration issued construction-noise specifications effective July 1, 1972, for earth-moving, materials-handling, stationary, and impact equipment (see Table B.7). They require that all on-site equipment used by personnel under contract with the General Services Administration have A-weighted sound level requirements (dB[A]) measured 50 feet from the equipment. For example, a tractor, regardless of type, must not exceed 80 dB(A) while in operation on the site at a distance of 50 feet. Noise violations result in a cancellation of the contract. Construction equipment that exceeds these levels would require some type of engineering noise control, and "quiet" equipment has been made available for many purposes.

Table B.7 General Services Administration Construction-Noise Specifications

Equipment	Effective dates: July 1, 1972	Effective dates: January 1, 1975
Earth-moving		
Front loader	79	75
Backhoes	85	75
Dozers	80	75
Tractors	80	75
Scrapers	88	80
Graders	85	75
Trucks	91	75
Pavers	89	80
Materials-handling		
Concrete mixers	85	75
Concrete pumps	82	75
Cranes	83	75
Derricks	88	75
Stationary		
Pumps	76	75
Generators	78	75
Compressors	81	75
Impact		
Pile drivers	101	95
Jackhammers	88	75
Rock drills	98	80
Pneumatic tools	86	80
Other		
Saws	78	75
Vibrators	76	75

Note: Equipment to be employed on the site shall not produce a noise level exceeding the following limits of dB(A) at a distance of 50 feet from the equipment under test in conformity with the Standards and Recommended Practices established by the Society of Automotive Engineers, Inc., including SAE Standard J 952 and SAE Recommended Practice J 184.

Environmental Protection Agency

Under provisions of the Noise Control Act of 1972, the EPA is required to promulgate noise-emission standards for four new product categories:

- Construction equipment
- Transportation equipment
- Motor or engine
- Electrical or electronic equipment

In addition, all railroad and motor carriers engaged in interstate commerce will be subject to noise-emission requirements. Furthermore, any product adversely affecting the public health or welfare must be labeled with the specific sound level (see Noise Control Act, Chapter 2).

Department of Labor

Noise exposure criteria have been established by the Department of Labor under provision of the Occupational Safety and Health Act. To meet the provisions of this act, a hearing conservation program must be initiated for protecting noise-exposed personnel; emphasis should be placed on engineering noise control. Hearing protective devices must be issued to the workers, but only as an interim measure while engineering solutions are being planned. In practice, the "interim" has lasted more than 20 years in many industries.

Other mitigation methods include isolation and insulation. The noise source and personnel or structures can be isolated from one another by distance. (The intensity of noise decreases at an approximate rate of 6 dB per doubling of distance.) Another method is to build barriers between the noise source and personnel. Increasing insulation in structures can also reduce inside noise levels.

Ear protective devices can be used to shield and protect individuals from noise. Occupational health programs have emphasized the proper fitting and issuing of hearing protective devices (i.e., earplugs or earmuffs) to noise-exposed personnel as an essential element of a hearing conservation program.

Secondary Effects

Exposure to high noise levels appears to have potentially detrimental effects on worker performance and accident rates and absenteeism in industry. In addition, this exposure can cause general stress. Continued noise production can lead to land-use changes, with associated socioeconomic and biophysical ramifications.

Psychological Effects

Definition of the Attribute

Noise can affect an individual's mental stability and psychological response (annoyance, anxiety, fear, etc.). Mental stability refers to the individual's ability to function mentally or act in a normal manner. The mental well-being of an individual is essential for personal maintenance and efficiency. It is generally agreed that noise does not cause mental illness but may aggravate existing mental or behavioral problems. Noise predominately causes psychological responses such as anger, irritability, increased nervousness, and, most of all, annoyance. It is the annoyance reaction that can cause individual and community outcry and lawsuits against noise sources such as airports, aircraft, and highway transportation.

Activities That Affect the Attribute

Many activities can cause annoying and unacceptable noise. The most serious are discussed here.

Construction

Construction projects create noise through the use of vehicles, construction equipment, and power tools. The noise affects operators, personnel, and communities near the site, and those people near transportation routes to the site.

Work Activities

The operation of most types of air/surface vehicles, machinery, and power-generating equipment generates noise. Maintenance and repair produce noise through the use of all types of tools and when a number of noise sources are operating at the same time in the same general areas (e.g., a vehicle repair shop).

Military Training

Training courses and exercises that use any type of vehicle, weapon, power tools, appliances, or machinery create noise for operators and military and civilian personnel. In large-scale exercises, the noise might affect nearby civilian communities.

Industrial Plants

The machinery and tools contained in these plants are a significant source of noise to the personnel, and, if noise levels are sufficiently high, can affect nearby communities.

Sources of Effects

The sources of noise that affect this attribute include the following.

Military Equipment

Missiles and artillery, including small arms, have extremely high noise levels that can disturb and annoy personnel and nearby communities.

Vehicles

Vehicles in the air, on the ground, or on water are significant sources of noise that annoy and disturb operators, personnel, and nearby communities. In particular, aircraft around airports and military bases can disturb and annoy base personnel and nearby communities. Some individuals living directly beneath flight paths experience anxiety and fear from the aircraft noise. Additionally, they may find they must stop their work and mental processes due to passing aircraft, which, in turn, produces annoyance reactions.

Construction Equipment

Construction equipment, which includes vehicles and power tools, has high noise levels that annoy operators, workers, and nearby community citizens.

Variables to Be Measured

The important variables of noise that affect this attribute are loudness, duration, and frequency content. As loudness and duration increase, psychological stress, annoyance, anger, and irritability also increase. In terms of frequency content, people are generally more annoyed by high frequencies and pure tones. The frequency content of a noise source also gives the sound an identity. Certain noises are annoying, disturbing, or fear-producing (to some people) because of their identity (e.g., sirens, jackhammers, horns, motorcycles, aircraft, buzzers, trucks, backfires, gunshots, and air compressors).

Noises that have very high levels but very short durations (called impulsive noises), such as gunshots, vehicle backfires, and sonic booms, startle people. These individuals not only are annoyed, but express feelings of fear and anxiety, and their activities (particularly sleep) are severely interrupted.

How Variables Are Measured

The measurement of loudness, duration, frequency content, and impulsivity is discussed under physiological effects.

Evaluation and Interpretation of Data

It is difficult to establish a single set of criteria, due to the variety of acoustical and social factors. In addition to the intensity or loudness and duration of noise, other acoustical considerations involve pattern, occurrence, and the noise source itself. Social variables, such as demographic characteristics, personality type, and predisposition to nervousness, must be considered.

While the spectral content and temporal patterns of noise pressure levels are important, as general criteria, ambient noise levels exceeding 55 dB(A) during the day or 45 dB(A) during the night will disturb and annoy some people. Figure B.6 describes the community reaction to intrusive noise as a function of normalized day/night sound equivalent level. Table B.8 provides a summary of human response to selected (55, 65, and 75 dB) day/night sound equivalent levels.

Special Conditions

While environmental noise alone probably does not produce mental illness, the continual bombardment of noise on an already depressed or ill person cannot be helpful. Certainly it interferes with sleep, producing irritability and other tensions. Comparative studies of persons living adjacent to London's Heathrow Airport with others living in a quieter environment

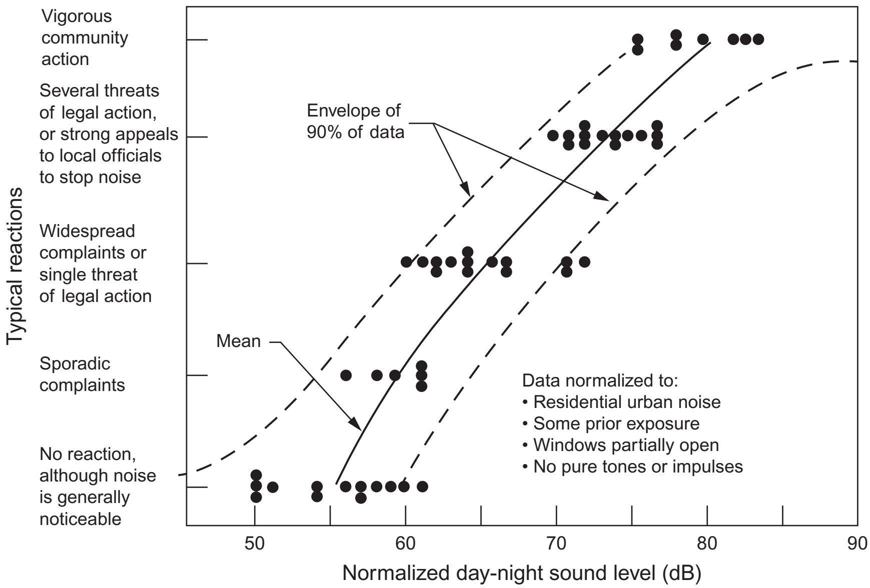

Figure B.6 ***Community reaction to many types of intrusive noise as a function of normalized daylight sound equivalent level.*** Source: *Community Noise, NTID 300.3 U.S. EPA, 1971.*

Table B.8 Summary of Human Response to Selected Sound Levels

Type of effect	**Magnitude of effect** $L_{dn} = 55$ **dB**	$L_{dn} = 65$ **dB**	$L_{dn} = 75$ **dB**
Speech—indoors	100 percent sentence intelligibility (average) with a 5-dB margin of safety	99 percent sentence intelligibility (average) with a 4-dB margin of safety	Sentence intelligibility (average) less than 99 percent
Speech—outdoors	100 percent sentence intelligibility (average) at 0.35 m	100 percent sentence intelligibility (average) at 0.1 m	100 percent sentence intelligibility not possible at any distance
	99 percent sentence intelligibility (average) at 1.0 m	99 percent sentence intelligibility (average) at 0.35 m	99 percent sentence intelligibility (average) at 0.1 m
	95 percent sentence intelligibility (average) at 3.5 m	95 percent sentence intelligibility (average) at 1.2 m	95 percent sentence intelligibility (average) at 0.35 m
Average community reaction	None; 7 dB below level of significant "complaints and threats of legal action" and at least 16 dB below "vigorous action" (attitudes and other nonacoustical factors may modify this effect)	Significant; 3 dB above level of significant "complaints and threats of legal action" but at least 7 dB below "vigorous action" (attitudes and other nonacoustical factors may modify this effect)	Very severe; 13 dB above level of significant "complaints and threats of legal action" and at least 3 dB above "vigorous action" (attitudes and other nonacoustical factors may modify this effect)
High annoyance	5 percent, depending on attitude and other nonacoustical factors	15 percent, depending on attitude and other nonacoustical factors	37 percent, depending on attitude and other nonacoustical factors
Attitudes toward community	Noise essentially the least important of various factors	Noise is one of the most important adverse aspects of the community	Noise is likely to be the most important of all adverse aspects of the community

Source: From *Guidelines for Preparing Environmental Impact Statements on Noise*. Report of CHABA Working Group Number 69 (Committees on Hearing and Bioacoustics, February 1977).

revealed that among those living in the noise environment there was a significantly higher rate of admission to mental hospitals (EPA, 1972).

Another medical discovery was the effect of noise on unborn babies. It was once thought that unborn babies were insulated from the noise stress of the outside world, but now physicians believe that external noises can trigger changes in fetuses (EPA, 1972).

Study of steelworkers indicated that those working in a noisy environment are more aggressive, distrustful, and irritable than workers in a quieter environment (EPA, 1972). These studies show that it is very important to keep noise levels as low as possible in communities near hospitals, mental institutions, homes for the aged, and any place where people may be particularly annoyed or placed under stress by noise.

Geographical and Temporal Limitations

See discussion under physiological effects.

Mitigation of Impact

Mitigation procedures relevant to the attribute are discussed under physiological effects.

Secondary Effects

Continued noise production can lead to land-use changes, with the associated socioeconomic and biophysical ramifications.

Communication Effects

Definition of the Attribute

Noise can affect face-to-face and telephonic communication, and, during extremely high levels of intensity, visual impairment has been reported.

Aural face-to-face communication, or the ability to give and receive information, signals, messages, or commands, without instrumentation, is an essential activity. The temporary interference with or interruption of communication during phases of human activity can be annoying, and occasionally hazardous, to personal well-being. Interference occurs when background or ambient noise levels of the environment are of sufficient intensity to mask speech, making it inaudible or unintelligible. Noise that interferes with communication can be dangerous, particularly when a message intended to alert a person to danger is masked or when a command is not heard or understood. More commonly, however, noise is annoying because it disrupts the communication process.

Telephonic communication, or the ability to give and receive information through telephones, headsets, receivers, and other devices is also an important activity. Noise affects this type of communication in the same way as face-to-face communication (i.e., it causes annoyance and disruption). However, due to the insulation effect of the telephone or headsets and control over the volume of the incoming or outgoing signals, higher levels of loudness or intensity can be tolerated.

Activities That Affect the Attribute

Many activities generate noise sufficient to interfere with aural communication.

Construction

Construction projects create noise through the use of vehicles, construction equipment, and power tools. Noise levels are high enough to affect all types of communication, particularly for the operator and personnel in the general construction area.

Work Activities

The operation of most types of vehicles, machinery, and power-generating equipment will create noise at levels that interfere with communication of operators, personnel in the area, and communities. Communication in and near operating maintenance and repair shops can also be affected by the noise generated by tools and vehicles.

Military Training

Training exercises that use air, land, and water vehicles; weapons; and machinery create noise levels sufficient to interfere with communication between military personnel.

Industrial Plant Activities

Machinery and power tools contained in industrial plants are a significant source of noise affecting communication within the plant.

Sources of Effects

The sources of noise that affect this attribute include the following.

Vehicles

Vehicles in the air, on the ground, or on water are important noise sources that affect the communication of operators and the community. Examples include the following:

- Aircraft on and around airports and military air bases significantly affect communication, particularly in airport operations and in community areas directly beneath flight paths.
- Large vehicles generate very high noise levels and can affect communication between the operators and other personnel in operating areas.
- Other vehicles, particularly when operating in groups, affect communication near highways and other routes.

Construction Equipment

This equipment also has high noise levels and affects the intelligibility of communication at the construction site. Transportation or routes to the site may also generate noise levels that interfere with communication near the routes.

Military Equipment

Weapons of all types (including small arms) have extremely high noise levels and can interrupt face-to-face communication. During large-scale activities, even telephonic communication can become difficult. Weapons achieve noise levels that may be sufficient to momentarily distort vision.

Machinery

Machinery located in industrial plants where many machines are operating continuously can severely affect the attitudes and irritability of workers within the plant.

Variables to Be Measured

The important variables of noise that affect face-to-face communication are loudness of the ambient noise level and the distance between the speaker and the listener. As the loudness increases, masking of the speech increases and speech intelligibility and discriminability decrease. Also, as the distance between speaker and listener increases, the speech becomes more difficult to hear and to understand, and annoyance and frustration rise. In telephonic communication, the noise variable of concern is the loudness of the background noise level.

As these variables increase, the speaker raises his or her voice to overcome the masking. Of course, the voice reaches a point where it strains and cannot overcome masking, and communication becomes impossible. In addition, the strain of shouting—and of trying to hear—is fatiguing and frustrating in any situation, and may lead to inefficiency.

How Variables Are Measured

The variable loudness can be measured or projected in dB(A) units, as specified in the physiological effects section. The distance between the speaker and the receiver should be measured in feet.

Evaluation and Interpretation of Data

The impact of noise on face-to-face communication can be evaluated by using the chart in Figure B.7. Enter the side of the chart at the expected dB(A) noise level and the bottom at the expected average distance between speaker and listener. If the intersection of the two values falls above the "area

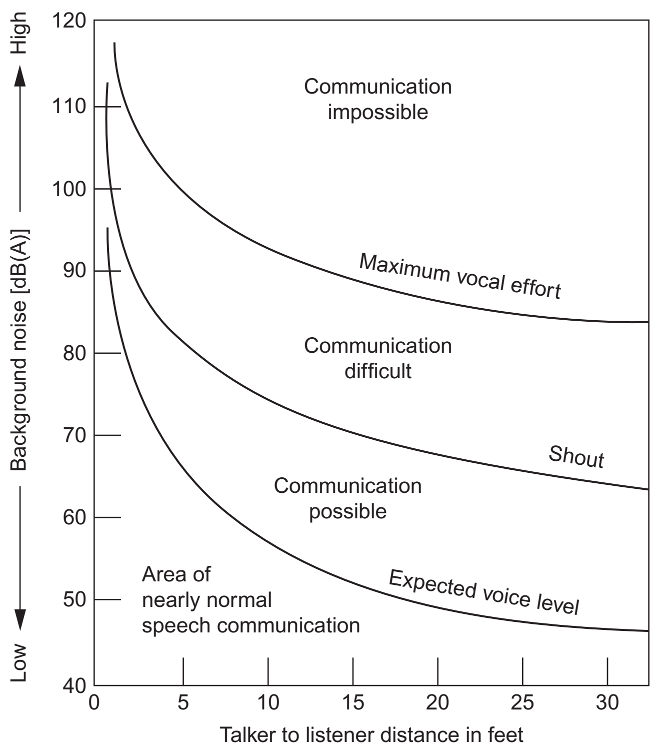

Figure B.7 ***A simplified chart that shows the quality of speech communication in relation to sound levels of noise (dB[A]) and the distance between the speaker and the listener.*** Source: *Miller, 1971.*

of nearly normal speech communication," then speech communication is being adversely affected.

In one-on-one personal conversation, the distance from speaker to listener is usually about 5 feet; nearly normal speech communication can proceed in noise levels as high as 66 dB(A). Many conversations involve groups; for this situation, distances of 5 to 12 feet are common and the intensity level of the background noise should be less than 60 dB(A). At public meetings and outdoor training sessions, distances between speaker and listener are often about 12 to 30 feet, and the sound level of the background noise should be kept below 55 dB(A) if nearly normal speech communication is to be possible (Miller, 1971).

In telephonic communication, background intensity levels above 65 dB become increasingly intrusive (see Figure B.8).

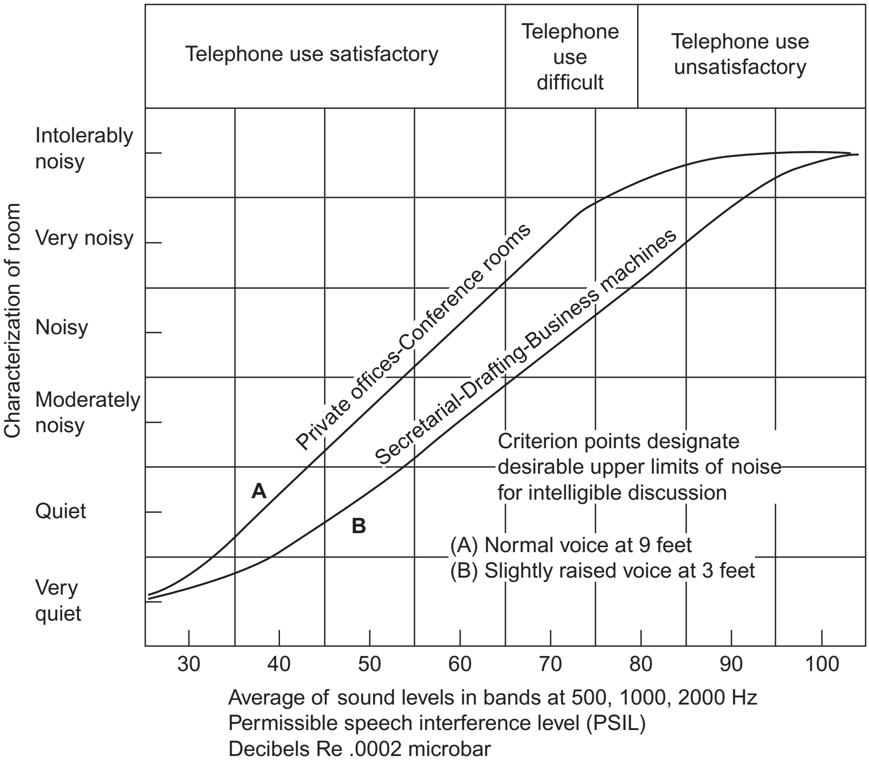

Figure B.8 ***Rating chart for office noise.*** *The data were determined by an octave-band analysis and correlated with subjective tests (Peterson, 1980).*

Special Conditions

There are special areas where communication which should not be disturbed takes place. These areas include training and testing areas, schools, churches, libraries, theaters, offices, hospitals, and research laboratories. Noise sources including air and land transportation should be isolated from these communication-sensitive areas, or the areas should be well insulated against external noise.

Geographical and Temporal Limitations

See discussion under physiological effects.

Mitigation of Impacts

To ensure intelligible communication, the noise sources and the personnel need to be isolated or insulated from one another. The special areas (see special conditions) where communication is especially sensitive should be well isolated and insulated against external noise. When it is unavoidable to have personnel who must communicate near high noise levels, special communication devices should be used (e.g., headsets).

Secondary Effects

As communication becomes more and more difficult to accomplish, impacts on psychological and performance effects may occur. Continued difficulties may lead to land-use changes, precipitating a series of socioeconomic and biophysical ramifications.

Performance Effects

Definition of the Attribute

Noise can affect the ability of humans to perform mechanical and mental tasks. Noise can adversely affect performance through:

- The increase in muscular tension that can interfere with movement
- The lapse in attention or a diversion of attention from the task at hand
- The masking of needed auditory signals
- The startle response to high-intensity noises

Mechanical tasks can range from simple mechanical assembly to more complex tasks. Lower order tasks, such as mechanical assembly or manual, routine-type activity, are least influenced by noise. However, tasks of this nature are altered in three essential ways by high-intensity noise. Although work output remains fairly constant, worker errors can increase (Miller, 1971), judgment of time intervals can become distorted, and a greater effort is necessary to remain alert (Kryter, 1985). Noise is most likely to affect the performance of tasks which are quite demanding and/or require constant alertness (U.S. Department of Commerce, 1970).

Mental tasks, such as problem solving and creative thinking, are more affected by noise. Higher order tasks requiring greater mental facilities (although dependent on the individual) are generally disrupted by lower noise intensities than mechanical tasks. It is important, therefore, to keep noise at a minimum in and near office areas (Figure B.8).

When a task (mental or mechanical) requires the use of auditory signals, speech or nonspeech, noise at any intensity level sufficient to mask or interfere with the perception of these signals will interfere with the performance of the task (Miller, 1971).

Activities That Affect the Attribute

The most important activities that can reach noise levels sufficient to affect performance are discussed here.

Construction

Construction projects create noise through the use of vehicles, construction equipment, and power tools. The noise levels are high enough to affect mental tasks. The mechanical tasks at the site are generally considered highly physical and probably would be unaffected by the noise levels. Construction adjacent to occupied buildings is a common source of problems.

Work Activities

The operation of all types of vehicles and machinery will create noise levels sufficient to affect human performance, primarily through distraction.

Military Training

Training exercises that use vehicles, weapons, and machinery create noise levels high enough to distract people.

Industrial Plant Activity

Machinery and power tools contained in industrial plants are a significant source of noise that affects mental and mechanical performance.

Sources of Effects

The sources of noise that can affect performance include the following.

Weapons

Weapons of all types generate noise levels that can interfere with and interrupt mental and complex, precise mechanical tasks.

Vehicles

Vehicles of all types are significant noise sources that can interfere with and interrupt task performance. In particular, aircraft can disrupt the mental tasks of large segments of communities.

Machinery

Machinery and power tools in industrial areas create high noise levels that could affect some complex and precise mechanical tasks.

Construction Equipment

Noise from this equipment can affect the mental tasks of personnel in the area.

Variables to Be Measured

The important variable of noise that affects task performance is loudness. As the loudness of noise increases, the effects of the noise on performance increase. First, mental tasks are affected; then, as the loudness further increases, complex and precise mechanical tasks become affected.

How Variables Are Measured

Loudness of noise is measured in terms of decibels. A detailed discussion of how to measure or project decibel levels can be found under physiological effects.

Evaluation and Interpretation of Data

In addition to the information about the impact of noise discussed earlier, Tables B.9 and B.10 provide criteria for the relative compatibility of mental tasks and various land uses.

Special Conditions

Special areas where mental tasks take place should not be disturbed. These areas include offices, conference areas, schools, indoor training areas, libraries, and research laboratories. In terms of mechanical tasks, it is difficult to be specific. Wherever complex, precise, and demanding mechanical tasks

Table B.9 Recommended Outdoor Criteria for Various Land Uses

	CHABA†		JSPM‡	
	L_{dn}	L_{eq}	L_{dn}	L_{eq}
Residential	55		64	
Hospitals	55		64	
Hotel, motel	60		64	
School/outdoor teaching areas		55		64
Church		60		64
Office buildings		70		69
Theater		70		69
Playground, active sports		70		74
Parks		60		69
Special purpose outdoor areas		⋆		⋆

⋆Outdoor amphitheaters or other critical land uses requiring special consideration should not allow new intruding noise to exceed a level 5 dB below the present L_{eq}.
†Guidelines for Preparing Environmental Impact Statements on Noise. Draft Report of CHABA Working Group Number 69 (Committees on Hearing and Bioacoustics, February 1977).
‡Planning in the Noise Environment, Joint Services Planning Manual (1978).
L_{dn}—Day/night average sound levels; a measure of the noise environment over a 24-hour day with a 10-dB penalty applied to nighttime (10:00 p.m. to 7:00 a.m.) activities.
L_{eq}—Equivalent sound levels; level of a constant sound with the same sound energy as a time-varying sound level.

Table B.10 Noise Criteria for Mental Tasks

Type of room	Maximum permissible level (measured when room is not in use)
Small private office	45 dB(A)⋆
Conference room	35–40 dB(A)
Secretarial offices (typing)	60 dB(A)
School rooms	30–35 dB(A)
Reading	40–45 dB(A)
Meditation	40 dB(A)
Studying	40–45 dB(A)
Individual creative activity	40–45 dB(A)

⋆ These figures are general guidelines. For specification purposes, Noise Criterion (NC) curves that cover the different frequency bands should be used (Beranek, 1960).

are performed, the environment should be protected from high-intensity noise sources.

Geographical and Temporal Limitations

See discussion under physiological effects.

Mitigation of Impact

The optimal method of reducing sound levels is through noise source reduction, isolation, or insulation. Methods of achieving noise reduction are discussed under physiological effects.

Secondary Effects

Continued exposure to noise may lead to land-use changes, precipitating a series of socioeconomic and biophysical impacts.

Social Behavior Effects

Definition of the Attribute

Social behavior refers to the individual's ability to mentally function in a normal manner on an interpersonal basis. Under certain conditions within communities, interpersonal relationships are altered when noise is of sufficient intensity. Areas of socialization may become restricted due to noise exposure. Outdoor areas are first to be affected, thus limiting socialization to residential interiors. Patterns of entertainment become confined and restricted. When one or more methods of basic auditory communication (face-to-face or telephonic) are masked, the channels for social interaction become limited. These results, in turn, affect personal attitudes and create annoyance.

Activities That Affect the Attribute

Many activities generate noise levels that could interfere with social behavior.

Construction

Construction projects generate sufficient noise to interfere with the social behavior of personnel and communities located near the site. In particular, new transportation routes to the site will introduce new noise levels to people living nearby, which, in turn, can adversely affect social behavior.

Work Activities

The operation of aircraft and surface vehicles and other equipment increases the noise level of the outside environment, where much socialization takes place. Social behavior inside structures can also be affected by these activities, if their noise levels are extreme.

Military Training

Training exercises that use vehicles, weapons, and machinery create noise levels sufficient to interfere with socialization between personnel. Noise from large-scale training exercises can also affect the community.

Industrial Plant

Machinery and activities in the plant are a significant source of noise which affects social behavior between personnel and in nearby communities.

Sources of Effects

Most noise sources are capable of influencing social behavior in community environments, particularly outdoors. In and around military air bases and airports, weapons, construction equipment, aircraft, helicopters, and ground transportation vehicles generate noise levels sufficient to interfere with interpersonal communication, thus affecting and limiting social behavior on the base and in surrounding communities. Social behavior inside structures is probably affected mostly by machines, heating and air-conditioning units, operating appliances, research equipment, or external noise sources with very high levels, such as aircraft, trucks, and construction equipment.

Variables to Be Measured

The important variables affecting this attribute are the same as those discussed under communication effect. As communication becomes difficult or impossible, social behavior and interpersonal relationships become limited, especially in the outdoor environment.

How Variables Are Measured

See discussion under communication effects and physiological effects.

Evaluation and Interpretation of Data

Evaluation techniques, as outlined under communication effects and psychological effects, should be applied to this attribute for both outdoor and indoor environments.

Special Conditions

Social behavior is important to people. Being able to socialize with friends, neighbors, and family is an essential human activity. Constant interruption of these activities can result in frustration and annoyance. Consequently, it is important to consider the impact of continuous or highly repetitive noise sources such as aircraft, weapons, and vehicles on social behavior in surrounding communities.

Geographical and Temporal Limitations

Socialization is normally expected to take place in the community and in and around living and entertainment areas. These areas then should be measured (inside and out) to determine if any noise sources are affecting social behaviors. One of the most prevalent noise sources is from transportation, both from routes through communities and from flight paths. These, too, must be measured.

Socialization occurs most often in the evening, in the early night hours, and on weekends. Measurement of noise during these periods should be emphasized for this attribute.

Mitigation of Impact

Social behavior is primarily affected by noise sources that create high noise levels in the outdoor environment. Useful mitigation techniques include source control, isolation of the sources from the community, or creation of barriers.

Secondary Effects

Continued exposure to noise may lead to land-use changes, precipitating a series of socioeconomic and biophysical impacts.

HUMAN ASPECTS

A critical aspect of the human environment is characterized by the way in which we interact with other people and the natural environment. Owing to the complexity of our activities and interrelationships, it is difficult to identify general parameters that describe the condition of human resources. The attributes that have been identified for this purpose are obviously not completely descriptive of all human activities and may appear to miss many important issues. Nevertheless, these few attributes have been chosen, because for most projects envisioned they will be able, if applied, to capture the major human (or community) elements of environmental impact.

Because of their generality, the attributes are difficult to measure and define, and as a general rule, an adequate assessment of impact on human resources will probably have to be undertaken by persons with special expertise in this area (sociologists or psychologists). One possible division of the attributes that should be examined is:

- Lifestyles
- Psychological needs
- Physiological systems
- Community needs

Lifestyles

Definitions of the Attribute

This attribute refers to the many social activities of humans. Such activities often take on structural characteristics that eventually cause them to be organizations. The makeup of organizations may vary, depending upon the characteristics, interests, and objectives of the organized population. Some common bases for these organizations are racial, ethnic, political, religious, and occupational. Another perspective of this attribute occurs in the form of informal interaction between friends, relatives, and coworkers.

Activities That Affect the Attribute

The major classifications of activities affecting this attribute include those which affect employment and job security, standards of living, community development, and recreational opportunity. Examples of these include population migration, transportation projects, large construction projects, water resources projects, and industrially related activities. A number of minor activities falling within these major categories could affect this attribute.

Sources of Effects

Changes or impacts that occur in this attribute will be dependent upon changes that occur in the population. For example, in a community where various activities have been established, the outmigration of a large portion of the population could disrupt a number of formal and informal activities. Examples of some of these activities are community athletic teams, schools, and church groups. Individual, informal interactions are also to be considered in this attribute.

The following example is given to illustrate how a significant change in population can cause changes in this attribute. If the population were predominantly elderly, the type of activities the population would be involved in might include hobby clubs, craft clubs, and card-playing clubs. If a large portion of this population were to migrate out of the area, the stability of some of these activities might be affected. Likewise, if many more people of the same age group, with the same interests, moved into the community, the stability of these groups might be strengthened. Also, if the population mix were changed significantly, perhaps by an influx of many younger people, the stability of such groups might be threatened, or, more importantly, present members of such groups might *feel* threatened.

Variables to Be Measured

The variables to be measured for this attribute cannot be precisely identified. The purpose in considering this attribute is to identify those instances in which a noticeable change would occur that would affect many people. The objective is to identify general changes in social activities and practices that would be caused by the proposed action.

How Variables Are Measured

The variables in this attribute cannot be precisely measured. One approach that can be taken to "measure" changes in this attribute would involve making a survey of the area to determine the number and kinds of social organizations and activities that exist before the proposed action takes place. Then, having determined the changes expected to occur in the population and the characteristics of that population, impacts on organizations and activities can be predicted in terms of how they may grow, desist, or experience noticeable alterations.

Some persons who might be good sources for predicting and interpreting impacts in this attribute are leaders and participants in the organizations, coaches of local athletic teams, community social and recreation leaders, and local political leaders.

Evaluation and Interpretation of Data

Interpretation of the impacts or changes in this attribute must be performed by the impact assessment, which should then be analyzed in conjunction with the opinions and assessment of the people mentioned above.

Geographical and Temporal Limitations

Usually, a geographical area larger than that of the immediate community must be included in the analysis, because impacts often occur outside of the area following changes within the community. The residence and work locations of those who take part in the activities that are considered a part of this attribute must be included in the geographic area.

The analysis should include a summarization of this attribute before the proposed action takes place and the anticipated changes that would result from the proposed activity. In addition to these considerations, to get a more realistic view of the total impacts, consideration must be given to what the condition of this attribute would be if the present situation, or the previous situation, were to continue, as well as to what changes would occur without the proposed action.

Mitigation of Impact

Although impacts to this attribute cannot be completely mitigated (with the exception of postponing the proposed action indefinitely), the effect of anticipated impacts could be lessened simply by forewarning participants that such changes are expected to occur. This will enable the organizations and participants in informal activities to prepare themselves to adjust to expected impacts.

Secondary Effects

Socioeconomic changes frequently may result in secondary or indirect impacts on the biophysical environment. These impacts need to be identified and assessed.

In the case of social changes, there may be environmental effects on air, water, land, and other resources, from increasing or decreasing the population in an area. Additional people cause increased demand for water, sewage treatment, and power; they require new housing, which takes land, shopping centers, and schools; and they require transportation, which increases traffic congestion and degrades air quality.

Psychological Needs

Definition of the Attribute

This attribute refers to the needs of human beings that can be distinguished from the physiological needs and relate primarily to emotional stability and security. Although this attribute could relate to such factors as instincts, learning processes, motivation, and behavior, these factors are not included in this attribute because of the difficulty in relating changes in outside factors to changes in these factors. Emotional stability and security are, therefore, the only two psychological needs that are considered in this attribute.

Activities That Affect the Attribute

The major classifications of activities that are likely to affect this attribute are essentially the same as those affecting lifestyles.

Sources of Effects

Changes in the degree of emotional stability and feelings of security within the individuals affected could occur from a number of activities. For example, in major construction or industrial project activities, it may be necessary for some people to be moved from their homes or businesses. Even though it is difficult to anticipate the effect of such relocation, experience has shown that such activities almost always have negative effects on the people involved. These effects will vary in their degree of permanency.

Also, when the proposed activity would involve increasing or decreasing the number of jobs or other opportunities (e.g., recreational) in an area, it can be assumed that such activities will either increase or decrease feelings of security, particularly for those who are directly affected by the change in job availability.

Feelings of concern for physical security may be affected by fear for personal safety from crime elements or from natural or human-induced disasters (e.g., from nuclear power plants or industrial facilities).

Variables to Be Measured

Although no specific variables are identified for this attribute, a general feeling of the degree to which the psychological needs of individuals and communities are being met can be obtained.

Evaluation and Interpretation of Data; How Variables Are Measured

Data concerning impacts of this attribute must be obtained from several sources. One source would be detailed plans of the proposed activities and identification of groups who might be affected in such ways as in the relocation example. This information could then be given to psychologists, who could best anticipate and interpret the changes that would occur as a result of the proposed activity. Impacts in this attribute cannot be measured, but can be identified as to whether the impacts are potentially beneficial or disruptive.

Other information may be obtained from personal surveys, or by consulting local counselors, clergy, and law enforcement officials. A good public involvement plan can assist in data acquisition (see Chapter 11).

Geographical and Temporal Limitations

The geographical area for this attribute must be that which contains people who believe they would be affected by it. This, therefore, could include areas within and outside of the immediate community.

The time limits for this attribute would be the same as for the other attributes in this section. The "before" time period should be that time shortly before instigation of the proposed activity. The "after" time period should include that time immediately after the proposed activity has been completed.

Mitigation of Impact

Some adverse impacts might be averted by including in the proposed activity funds an action plan that would permit assistance for those people who would be affected. For example, when a number of jobs are to be eliminated, a service could be set up in which those people who would be without jobs could obtain assistance in locating jobs in other areas. In problems caused by relocation, some program of assistance could be instituted in which people could be aided in finding housing and business locations similar to those they now have.

Fears for personal safety may be alleviated through planned safety programs coordinated with public interest groups.

Secondary Effects

See description under lifestyles.

Other Comments

Even though impacts that may occur in this attribute are difficult to identify, measure, and evaluate, the attribute is included in the impact assessment process because it is very important. Therefore, it is necessary to attempt to identify situations where such impacts might occur, even if only the possibility of potential impacts can be identified, with very little interpretation or evaluation. This attribute is useful, at least in trying to anticipate where impacts may occur and in identifying situations for which mitigation procedures may have to be planned and included in the proposed activity.

Physiological Systems

Definition of the Attribute

This attribute refers to anything that is a part of a person's body or that plays a part in a bodily function and is therefore related to physical health and well-being. It includes individual parts (organs) and whole systems, such as the transport, respiratory, circulatory, digestive, skeletal, and excretory systems. All parts of the human body that contribute to its effective, efficient functioning are included in this attribute.

Activities That Affect the Attribute

Major classifications of activities that can affect this attribute include construction; operational activities; military training and mission change; industrial; and research, development, testing, and evaluation. Any activity that can harm or threaten the efficient functioning of any part of the human body must be considered in light of its effect on this attribute.

Sources of Effects

The possible sources of impacts for this attribute are many. They range from activities performed in laboratories to construction activities that might impair the safety of individuals working in the area. This attribute considers any hazards that may impair the health or safety of any individual.

Variables to Be Measured

There is no list of variables that can be measured for this attribute. The purpose of this attribute is to identify potential sources of harm to people. Therefore, detailed elements and implications of the proposed activity must be examined to determine if any of those activities may be potentially harmful. A public involvement program (Chapter 11) can be valuable in identifying these factors.

How Variables Are Measured; Evaluation and Interpretation of Data

It would be helpful to rely upon the knowledge and skill of people who are familiar with the kinds of harm to this attribute that can occur. It is suggested that physicians be contacted and given a description of the proposed activity. The seriousness of the potential impacts can then be determined through professional opinion.

Special Conditions

It must be determined how many persons would be affected by the expected impacts. Although the impacts are not considered slight if they affect only a few, it may safely be said that seriousness will increase as the number of affected people increases.

Mitigation of Impact

Anticipated impacts in this attribute can be mitigated by taking whatever precautionary measures are necessary to avoid the impact. This may take the form of including in the proposed activity specific safety practices and protective devices.

Secondary Effects

Effects on physiological systems can also affect psychological needs, and may have additional economic ramifications if a significant number of workers or production is affected.

Community Needs

Definition of the Attribute

This attribute refers to some of the many services that a community requires. It includes such things as housing; water supply; sewage disposal facilities; utilities such as gas, electricity, and telephone; recreational facilities; and police and fire protection. The nature of change or impact that occurs in this attribute as a result of the proposed activity depends upon the type of change that is expected to occur in the population as a result of this proposed activity.

Activities That Affect the Attribute

Major classifications of activities that are likely to affect this attribute are essentially the same as those affecting lifestyles.

Sources of Effects

As changes in population and characteristics of the population occur, the needs or services required for that population will change, too. For example, in the general activity category of construction, a temporary force of construction workers may be required to perform the activity. If the construction workers and their families must settle in an area until the construction is completed, these workers and their families will require particular services, such as those mentioned in this attribute. Likewise, when they leave the community, the demand for these services will have been lessened, or perhaps even dissolved, thus leaving the community with a supply of services that is no longer needed, but for which public debt has been incurred.

Similarly, in industrial development activities, a number of people may be brought into an area on a permanent basis, and the community may find itself unprepared to provide the services and needs to this permanent addition to the population. Also, impacts can occur as a result of a change in military mission or a change in the number of training activities taking place on a particular military base. These impacts may result from fewer numbers of people requiring the services that have already been designed to serve a greater number of people. For example, a community may find itself with an oversupply of houses or have to decrease the number of personnel required for such activities as police and fire protection.

In these and other activities, there are particular subactivities that relate directly to the provision of some of these services. Therefore, any proposed activity that has to do with the provision of such services should be investigated as to the impact that would occur.

Variables to Be Measured

For the impact assessment procedure, variables that should be measured are those that indicate services in the community that are available as well as what services are needed. The community should be surveyed in order to determine: 1) the change in population and the characteristics of that population, 2) the number of houses and apartments available to meet the needs of the population if there will be an increase, 3) the number of homes supplied with water and sewage disposal and other facilities, 4) the number of personnel on the police force and the fire department, and 5) the number of acres of land devoted to recreational activities and the number of recreational activities available in the area.

How Variables Are Measured

Communities should be surveyed to determine what services are now available. For example, a survey should be made to determine the number of dwelling units (i.e., houses, apartments, and trailers) that are available and the number of those served with adequate water, sewage, and utility services. The availability of recreational facilities can be determined by noting the number of acres devoted to recreational usage and the number of recreational activities available. The number of police and fire protection personnel should be determined to indicate the level of service currently available to the population.

Various sources can be utilized for obtaining this information. Planning agencies often have information on all of these services. Police and fire department personnel are sources that can give an indication of the adequacy of these kinds of services.

After this information is obtained, it will be necessary to relate the present conditions to the change in population that is anticipated from the proposed activity. If the population will increase, it must be determined if there are enough facilities and services available to serve the incoming population. On the other hand, if there will be a decrease in population or an outmigration, the services provided by the community must be considered in light of the upcoming decrease in demand. Perhaps other uses can be made of those services no longer in demand in their usual functions.

Evaluation and Interpretation of Data

There are no standardized means of interpreting the variables within this attribute. For the purpose of an impact assessment, when anticipated changes in population of an area would cause serious problems in the services needed by the population, the situation must be further studied for the impact statement. Expert judgment may be useful in determining when a serious problem would result given an immigration or outmigration of a significant number of people in the community.

Geographical and Temporal Limitations

The geographical area to be considered in this attribute varies depending upon the proposed activity. The area to be considered depends upon where the affected population resides and works. Therefore, any area where people who would be affected by the services discussed herein reside or work must be considered in the determination of impact.

In determining the impact that occurs within this attribute, the analysis must be done for the area before and after the proposed activity is instituted. It is suggested that the "before" time period incorporate those conditions that exist or can be anticipated to exist shortly before the proposed activity is instituted. It is also suggested that the "after" time period be that time period shortly after the proposed activity or project has been completed and is in full operation.

Mitigation of Impact

Impacts in this attribute can be mitigated by including in the planning process for the proposed activity a plan for providing the services that have been identified as being needed or proposing alternative uses that can be made of services that will no longer be needed by the population.

Secondary Effects

See description under lifestyles.

ECONOMICS

The potential impact on the economic structure of changes resulting from project activities stems primarily from the direct effect of purchases of goods and services for project activities and the indirect effects arising from goods and services purchased from payrolls. These effects may be summarized by reference to three major attributes that reflect impact on industrial and commercial activities, the local government, and the individual. These attributes are:

- Regional economic stability
- Public sector revenue and expenditures
- Per capita consumption

Regional Economic Stability

Definition of the Attribute

This attribute indicates the ability of a region's economy to withstand severe fluctuations, or the speed and ease an economy demonstrates in returning to an equilibrium situation after receiving a shock. This is an *ex post* definition, whereas a surrogate *ex ante* definition is the diversity of a regional economy or the degree of homogeneity of the region's economic activities in contributing to the gross regional product. The more diverse an economy is and the more closely related it is to growth areas of the national economy, the more stable it is likely to be.

Activities That Affect the Attribute

Any activity that results in some input or output relationship with a local business or individual has an impact on the growth and stability of the regional economy. Direct purchases would have an effect, as would indirect purchases through payrolls. Proposed increases *or* decreases in either area are important causes of effects.

Sources of Effects

The severity of a change in stability is directly proportional to the degree of dependence of the regional economy on one affected business sector for income and employment. Thus, if one or a few industries or firms dominate a region's economy (measured by the share of gross regional product or proportion of total employment), that region is highly sensitive to factors affecting those industries. Hence, activities that decrease the industrial diversity in an area are reducing the stability of the region, especially when the key industries are locally important but declining nationally. "One-factory" towns and smaller cities dependent on a military installation are common examples.

Variables to Be Measured

Effects on the regional economy are indicated by the percentage of total regional economic activity affected by the activity. For example, if 25 percent of all retail sales in a county stem from agency personnel purchases, significant impacts can be anticipated from a change in personnel. Likewise, the agency's direct purchase of labor or other materials from the local economy should be examined as a percentage of local economic activity.

How Variables Are Measured

Considerable ingenuity must be exhibited by the individual who is measuring impact on regional economic stability. Variables to be examined would include employment in economic activity related to specific activities. Production and income variables might also be examined.

Evaluation and Interpretation of Data

There are no rules that would enable one to determine whether or not a given change is small or large. Instead, judgment must be exercised, with explicit reference to the basis for judgment. This approach would enable any reviewer to evaluate the facts and, perhaps, to disagree with the judgment—at least full consideration of the issues and the rationale for a conclusion will have been given.

Special Conditions

Stability and, perhaps, growth are two goals of a regional economy. They are usually incompatible because, in the long run, some specialization is required if a growth rate higher than that for the rest of the country is to be realized. Therefore, the unique or special characteristics of the regional economy must be considered. An economy with an agricultural base, for example, might be much more severely affected by the withdrawal of agricultural land for use in a project than if agricultural land were to be withdrawn from use in an industrial-based economy.

Geographical and Temporal Limitations

The same geographical and temporal limitations that exist for the per capita consumption attribute are applicable here.

Mitigation of Impact

Mitigation of negative effects can be achieved in one of two ways: either increasing the demand for the output of high-growth industries in the region or changing the distribution of demand for the output of different firms so that the resulting employment redistribution approximates more closely the situation at the national level (taking into account the potential for regional specialization).

Secondary Effects

Economic changes frequently result in secondary or indirect impacts on the biophysical environment. These impacts need to be identified and assessed.

In the case of economic effects, programs or actions that add or reduce revenue in an area will result in additional or decreased population and new economic activity in local communities. This may take the form of new or fewer retail outlets (stores, garages, etc.), increased or decreased service-oriented businesses, and land-use changes as new home developments, shopping centers, and other new construction are created or requirements for them are reduced. Most of these activities will have a secondary impact on air, water, and land attributes.

Public Sector Revenue and Expenditures

Definition of the Attribute

This attribute is an expression of the annual per capita revenues and expenditures of local and state governments and associated agencies in the region under study. Changes in this variable can be interpreted as a measure of the change in economic well-being of the public sector.

Activities That Affect the Attribute

Changes in the economic, social, or physical conditions of the area due to project activities may result in changes in public sector revenues and expenditures. The effects would be felt primarily through changes in employment, industrial or manufacturing activities, and the acquisition or release of real estate by agency action.

Sources of Effects

Tax receipts are directly affected by changes in personal income. For major federal projects, payments from the federal government to local governments to compensate for increased local expenses also may occur. Changes in land usage and, therefore, assessed value also affect revenues collected.

Numerous changes in the costs of services (and therefore in requirements for public expenditures) occur in such areas as education, transportation, public welfare, health, utilities, and natural resources as the direct result of an activity or indirectly through employment changes caused by the activity.

Variables to Be Measured

One measure of an impact is the average annual revenues and expenditures of the relevant government and its agencies in a defined geographic region over the lifetime of the project, assuming the project or activity has been undertaken, minus the same measure over the same timespan, but assuming the activity has not been undertaken (and everything else remains the same). In lieu of the annual average, one recent year may be chosen arbitrarily and the change in annual net revenue computed for that year.

Another set of variables would be a comparison, on a function-by-function basis, of the expenditures necessary to provide adequate public services with and without the project.

How Variables Are Measured

The geographic extent of the affected public sector must be defined *a priori*, usually as a local (town, city, or county) or state government. Changes in revenues and expenditures must then be estimated on an item-by-item basis. Tax revenue changes may be estimated as described in the section on measurement of variables in the per capita consumption attribute. Local sales tax rates should be used in lieu of state rates where pertinent, and the state or local income tax rates should be used in place of the composite national rate as described in the per capita consumption attribute. Effective state income tax rates can be found in publications pertaining to specific states or local areas, such as the *State and Metropolitan Area Data Book* released periodically by the U.S. Department of Commerce, or similar local or regional publications. Corporate tax receipts for local areas are generally not important.

The change in gasoline tax receipts is determined by calculating the percentage change in the number of vehicles in the area. This implies that the tax rate, the per mile gasoline consumption for each vehicle, and the total mileage per vehicle are constant. The percentage change in vehicles may also be assumed to be proportional to the change in personal income. Independent estimates may be made through interviewing automobile dealers or by multiplying population changes by a factor representing cars per capita. The preliminary value for motor fuel tax receipts can be based on the annual *Statistical Abstract of the United States*, taking the figures for state tax collections and excise taxes, where the state receipts must be multiplied by some proportion to determine the local share (this proportion may depend upon the gasoline sales, and hence, indirectly depends on the personal income in the area). Local data should replace the extrapolated state data where available. Since the gasoline tax receipts from some future year (under the assumption that the activity has not been undertaken) is the basis for the measurement; at a minimum, tax receipts for at least 2 past years should be linearly extrapolated to arrive at the desired figure.

Changes in payments to the local government or its agencies by individuals, businesses, and other agencies for particular goods or services (e.g., water and other public utilities) should be included on a specific basis. Transfer payments from outside sources that are direct or indirect compensations for incurred expenses should be based on the specific changes in these costs caused by the project activity, following standard reimbursement procedures. For example, compensation for increased educational expenses for military families is a transfer payment to the local area. Total changes in receipts from taxes, subsidies, and transfer payments due to the project activity should be summed to arrive at an aggregate figure.

Changes in local public expenses due to the activity may be assumed to be proportional to changes in the total personal income in the area, reflecting the number of consumers of a public good or service and the per capita level of consumption. The *Statistical Abstract of the United States* provides information on direct expenditures for state and local governments, and gives figures for public sector expenditures per $1000 of personal income. These ratios must be multiplied by the proportion of expenses accruing to the local government for each category: education, highways, and health. When available, these ratios should be calculated from local information for all types of public goods and services that change in the same proportion as total personal income. Some expenses, such as welfare payments, do not change proportionally and must be calculated through independent analyses. Among these expenditures are damages to public facilities or any other temporary or permanent costs identified as resulting from the project activity, but not through social or economic changes within the population. The percentage change in personal income in the impact area is determined from the per capita consumption attribute, and this proportion must be multiplied by the public sector expenses per unit of income. The resulting figures are the changes in public expenditures if the project occurs, and summing them gives the total change in expenses.

Evaluation and Interpretation of Data

The changes in public sector revenues and expenditures must be compared to determine whether or not there is a net gain or loss to the public sector subsequent to the project. The severity of the impact (either positive or negative) would remain a matter of individual judgment and would be partly subject to considerations of indebtedness of the community.

Special Conditions

The measurement can be improved if a more accurate estimate of future revenue and expenditure levels without the project can be determined. A detailed analysis, perhaps using multiple regression techniques, would improve these projections as well as help identify and evaluate more precisely the causal relationships between public sector revenues and costs and the direct impacts of the proposed activity.

Geographical and Temporal Limitations

In general, the same geographical and temporal limitations that exist for the per capita consumption attribute are applicable in this measurement situation. The geographical range of local governments and civilian public agencies with respect to the revenues and the expenditures must be determined in a manner similar to an analysis of the market and supply areas of a private sector business enterprise.

Mitigation of Impact

A negative impact can be mitigated if the project activities are designed either to reduce costs to the local community (e.g., demands for public sector goods and services, physical or economic damages to existing infrastructure) or to increase the direct or indirect payments to the local government.

Secondary Effects

See the description under regional economic stability.

Per Capita Consumption

Definition of the Attribute

Annual per capita consumption is the yearly use of goods and services by each person, derived by dividing the quantity of use by the number of people. This variable can serve as a direct measure of personal economic well-being.

Activities That Affect the Attribute

Increases (or decreases) in local employment, industrial expansion (or reduction or deletion), and construction all have the potential for affecting per capita consumption.

Sources of Effects

A change in demand for local goods or services results in increased or decreased money available for purchase of goods and services (disposable income). As another example, disposable income and, therefore, consumption may be affected by a changed tax base resulting from government project acquisition of formerly taxable land.

Variables to Be Measured

The baseline measure is the average amount that will be spent in each future year throughout the life of the project by each resident of the affected area for goods or services meant for personal consumption, assuming the project has not been undertaken. The variable indicating change is that same calculation, but under the assumption that the project or activity has been undertaken (with everything else exactly the same), minus the baseline measure.

How Variables Are Measured

Assuming that businesses are not at full capacity, a change in final output (in dollars) will be reflected in a change in all short-run costs, including labor wages. With constant returns to scale for inputs, the change is completely proportional, and output revenue and all costs will change proportionately to the change in production, based on the current ratio of these values. In addition to labor costs, profits that accrue to the owners of a business may change. A determination of how a profit change affects personal income in the region must be based on an individual analysis of each business, with consideration of the amount of profit per dollar of output and the location of the owners (where the changed income of nonlocal residents is not included). Thus, a coefficient for a particular industry may be determined, showing the ratio of local personal income (wages, salaries, profits) to the dollar output of the industry.

Changes in output due to project activity may be approximately determined by first noting all industries, firms, or individuals who supply some needed input to the activity and the amount of this input in dollars. Included as inputs are such goods and services as local raw materials, retail goods and services bought by project personnel and their families, and contributions to local charities.

Changes in the inputs (which are the outputs of the supplying firms) must be calculated or estimated with as much accuracy as possible. Assuming a constant, linear production function (constant input mix), the change in a supplying firm's output can be approximated by first determining the ratio of the activity's current requirements for the firm's output (in dollar terms) to the current total requirements for that activity (which need not be measurable in dollar terms). Multiplying this ratio by the change in activity, the change in the firm's output is determined. This is multiplied by the previously calculated personal income-output ratio to produce the desired figure.

Prices are assumed to be constant, but if a price change is expected to result from the activity, then the input-output ratio has to be recomputed based on the new price before being used. Direct employment changes, changes in the average wage rate (perhaps due to a change in the size of the labor force), or other changes directly caused by the proposed activity should be examined. Any additional information indicating how the total wage bill changes with a change in an activity should be used, if possible. For example, business failures or disruptions caused by the activity and resulting in employment changes should be included. Other determinants of personal income, such as proprietor's income, dividends, interest, transfer payments, and other personal costs and revenues may be assumed to be changes in the same proportion as output revenue unless specific information indicates otherwise. Attempts should be made to assess these ratios whenever possible.

The change in disposable income equals the change in personal income minus the change in personal tax payments. Assuming a constant effective income tax rate (due to small incremental changes in income), this rate times the change in personal income gives the total income tax change. The tax rate may be obtained from the tables of information pertaining to rates of state personal income taxes for different adjusted gross income levels, using the same filing basis (such as married couple with two dependents) for before and after the proposed activity. Changes in taxable property, together with the pertinent rate, give the property tax alteration.

The change in personal consumption is determined by a rough calculation of the coefficient of consumption applied to the change in disposable income. Thus, the proportion of disposable personal income spent on personal consumption expenditures, calculated from national data if local information is missing, may be assumed to apply to local disposable income. The Bureau of Economic Analysis of the U.S. Department of Commerce, compiles on the national income and product account (http://www.bea.gov/iTable/index_nipa.cfm). In the table on personal income and disposition of income, gives the pertinent data from which the necessary coefficient can be calculated for the appropriate data (approximately 0.9 for all years). Multiplying this by the change in disposable incomes provides an estimate of the initial change in consumption.

The most difficult data requirements involve the identification of all activities linked to the proposed activity through an input-output relationship and the determination of each coefficient indicating the dollar change in the supplying firm's (or individual's) output due to a unit change in the project activity (where this output relates to the particular activity being investigated). This information can come only from a detailed examination of project activity.

Evaluation and Interpretation of Data

The interpretation of these data must be based on exercised individual judgment. Judgments regarding high or low impacts should be made by persons performing the assessment. The reason for the judgment should also be stated.

Special Conditions

The analysis can be improved if a thorough input-output analysis is completed together with a detailed economic analysis of the change in personal income (and then in personal disposable income) that results from a change in the output of economic activities linked to the project. Where data are uncertain, an attempt should be made to use expected values, if possible.

Geographical and Temporal Limitations

The geographical area within which the change in consumption occurs must be determined *a priori*, but it should be defined by the spatial distribution of the affected labor force. Where project activities affect consumption outside the area (and hence, would not normally be included in the analysis), efforts should be made to separate locally important effects from the effects that are far removed from the project's impact.

The attribute measurement methodology presented assumes an average of the total annual changes over the lifetime of the project or activity. This is an arbitrary procedure, and temporal tradeoffs (time discounting) can be applied if desired. Calculations can be made for different years in the future with or without project changes, and the separate figures are aggregated by first multiplying them by arbitrarily assigned normalized weights. Another simple alternative is to choose a single future year to compare with and without project changes, implicitly weighting all other years as zero.

Mitigation of Impact

Any detrimental impacts can be mitigated best if direct linkages are established with area industries, businesses, or other economic activities, encouraging an inflow of money into the local economy.

Secondary Effects

See description given under regional economic stability.

RESOURCES

Resources include assets that can take many forms, including natural, cultural, economic, and historic. In many NEPA review situations, cultural resources may be of particular significance. These resources are discussed in Chapter 13. As used here, the term *resources* refers only to natural resources.

Natural resources include the land, air, water, vegetation, animal, and mineral resources that constitute our natural environment and provide the raw materials and spatial settings utilized in developing our familiar human-modified environment. These resources may be nonrenewable, such as metals and fuels, or renewable, such as water. Nonrenewable resources are of particular interest, since their consumption or utilization represents a commitment that is potentially irreversible or irretrievable, and constitute a special NEPA responsibility.

Since fuel resources hold a position of extreme importance, they are treated as a separate attribute. Also, since many of the other natural resources are discussed through other attributes (ecology, air, water, and land), another attribute emphasizes the remaining nonfuel resources that are utilized in either a natural or transformed state for products and materials in the development of the human environment. A third attribute considers the aesthetic qualities of natural and human-modified environments—modified through the use of natural resources.

These attributes are summarized as follows:

- Fuel resources
- Nonfuel resources
- Aesthetics

Fuel Resources

Definition of the Attribute

Fuel resources include all basic fuel supplies utilized for heating, electrical production, transportation, and other forms of energy requirements. These resources may take the form of fossil fuels (oil, coal, gas, etc.), radioactive materials used in nuclear power plants, or miscellaneous fuels such as wood, solid waste, or other combustible materials. Solar, wind, and hydroelectric energy resources or other energy sources currently in a developmental state are not addressed in this text.

Activities That Affect the Attribute

Since energy consumption relies almost entirely upon fuel resources, it is probable that almost any activity that consumes energy consumes substantial fuel resources as well. Actions requiring consumption of energy can be categorized into: 1) residential, 2) commercial, 3) industrial, or 4) transportation activities.

Residential activities include space heating, water heating, cooking, clothes drying, refrigeration, and air conditioning associated with the operation of housing facilities. Also included is the operation of energy-intensive appliances such as hair dryers and toasters.

Commercial activities include space heating, water heating, cooking, refrigeration, air conditioning, feedstock, and other energy-consuming aspects of building or physical plant operation. Facilities that consume particularly significant amounts of energy include bakeries, laundries, and hospital services.

Industrial activities that require large amounts of fuel resources include power plants, boiler and heating plants, and cold storage and air-conditioning plants. Other industrial operations that require process steam, electric drivers, electrolytic processes, direct heat, or feedstock may also have a heavy impact upon fuel resources.

Transportation activities involving the movement of equipment, materials, or personnel require the consumption of fuel resources. The mode of transportation may include aircraft, automobiles, buses, trucks, trains, pipelines, or watercraft.

Sources of Effects

Most presently utilized fuel resources are limited to the supplies of existing fossil and nonfossil fuels at or beneath the Earth's surface. The demand for these fuels in the United States far outstrips the production rates of domestic supplies; hence, much of the fuel resources consumed daily in the United States come from foreign sources. This places a dependence upon these foreign sources that bears heavily upon economic stability and has obvious strategic implications. Furthermore, known reserves of certain fuels—particularly natural gas—are limited to the extent that unless conservation measures are effected immediately these supplies will be consumed in the foreseeable future.

Variables to Be Measured

The most important variables to be considered in determining impacts on fuel resources are the rate of fuel consumption for the particular activity being considered and the useful energy output derived from the fuel being consumed. Various units may be utilized in describing consumption rates: Miles per gallon, cubic feet per minute, and tons per day are commonly used in describing the consumption of gasoline, natural gas, and coal, respectively. Similarly, the energy output of various fuel- and energy-consuming equipment and facilities may be described in many different units—horsepower, kilowatt-hours, and tons of cooling are a few examples.

A common unit of heat, the British thermal unit (Btu), may be applied to most cases involving fuel or energy consumption. The Btu is the quantity of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit. In the evaluation of transportation systems, for example, alternatives may be compared on a Btu per ton-mile basis.

Other variables of concern include the (short- and long-term) availability of fuel alternatives, cost factors involved, transportation and distribution, and storage system features required for each alternative.

Data on the consumption of fuel resources may be applied to almost any environmental impact analysis, but the depth and degree to which data are required depend upon the nature of the project under consideration. For an analysis of existing facilities or operations, sufficient information should be available from existing records and reference sources. Where alternative fuels or transportation systems are the focus of the proposed action, additional background information may be necessary to evaluate not only efficiencies but also cost-effectiveness and long-term reliability.

How Variables Are Measured

Because of the complexities in the nature of these variables, most are measured by engineers, specific resource experts, and other professionals, although the results may be applied by most individuals with a technical background.

Once the heat contents of fuels are known, comparisons may be made on the bases of the heat content of each required to achieve a given performance. An energy ratio can be established as the tool for comparison. The ratio is defined as the number of Btus of one fuel equivalent to 1 Btu of another fuel supplying the same amount of useful heat. Determination of energy ratios requires careful testing in laboratory or field comparisons and usually yields reliable results when conducted under impartial and competently supervised conditions. These ratios have been determined in various tests and are summarized in such publications as the *Gas Engineers Handbook* (Segeler, 1969).

The consumption of fuels on an installation may be determined from procurement and operational records. Measurements may be made by using conventional meters, gauges, and other devices.

Evaluation and Interpretation of Data

The fuel resource data will more than likely be used in an environmental impact analysis for the benefit of planners and decision makers for either: 1) evaluating the alternatives where either fuel consumption or fuel-consuming equipment or facilities are involved, or 2) determining the aspects of fuel and energy conservation that exist with regard to ongoing actions. These aspects include the irreversible and irretrievable commitments of resources resulting from the action, the short- and long-term tradeoffs, and the identification of areas for potential conservation and mitigation of unnecessary waste.

As previously discussed, the analysis should include aspects of efficiency, availability, cost of fuel and support facilities (transportation distribution, storage, etc.), and projected changes in these values that might occur in the future. Secondary effects should also be considered, such as environmental effects due to fuel production (mining, refining, etc.) and impacts on air and water quality from combustion and related pollution-control measures.

Special Conditions

If the activity results in additional demands or waste of fuels already in short supply, or nuclear fuel, expect public controversy to follow. Natural gas supplies, presently limited or unavailable in some areas, should be considered with special emphasis. Electric consumption, in most cases, bears directly upon fuel resources, the effects of which should be included in the analysis.

Geographical and Temporal Limitations

Concern for fuel resources typically peaks during summer (when air conditioning loads are high) and winter (when heating loads are high). Thus, projects in northern climates would be expected to have the greatest concern for heating fuels, while southern facilities would be more concerned with heavy cooling requirements in the summer, although exceptions to this general trend may occur due to localized demands or geographical or climatic effects. Proximity to natural supplies also may play an important role in fuel selection, since transportation may affect the availability and economic desirability of certain fuels.

Mitigation of Impact

Mitigation of impacts directly and indirectly attributable to fuel resources falls into two categories. The first pertains to mitigation by alternate fuel selection and is based on a number of complex variables—availability, cost, environmental effects, and pollution-control requirements, to name a few. Other factors to be considered in the selection are the short- and long-term effects of a particular choice, and the irreversible and irretrievable commitment of resources associated with the selection.

The second category of mitigation is associated with the conservation of fuel resources, regardless of the type or types of fuel being consumed. Such measures can be applied to new construction in the form of additional insulation and design to incorporate energy conservation features related to color, orientation, shape, lighting, and so on. The conservation of energy can be applied to existing facilities in the form of added insulation and programs to reduce loads on heating, cooling, and other utility consumption. Likewise, in the operation and maintenance of equipment, steps may be taken to further reduce fuel consumption by increasing efficiencies through proper equipment maintenance, reducing transportation requirements, and scheduling replacement of old equipment with newer, highly efficient models.

Secondary Effects

Conversion of fossil and nuclear fuels into useful energy can lead to secondary effects on the biophysical and socioeconomic environment. Air emissions occur during extraction, processing, and combustion processes. Water quality may be affected by spills, acid mine drainage, and thermal discharges. Land-use impacts include loss of habitat, land disturbance, erosion, and aesthetic blight. Solid waste problems resulting from mining and production activities include leachates, radioactive wastes, slags, and tailings. Chapter 12 discusses many of these environmental considerations.

Nonfuel Resources

Definition of the Attribute

This attribute considers the nonfuel resources that are utilized in either a natural or transformed state for products and materials in the development of the human environment. Various nonfuel products are manufactured from fuel resources and are included in the definition. Specific examples include wood and wood products, metals, plastics, and nonmetallic minerals and materials.

Activities That Affect the Attribute

Few, if any, activities do not depend on natural resources in some way. Any activity that consumes materials and supplies, requires equipment and machinery, utilizes land, or produces waste products may have an effect on natural resources. Various materials—including lumber, aggregates, cement, steel, and asphalt—are utilized in construction and repair activities. Operation of facilities depends on equipment that is manufactured and requires metallic and nonmetallic parts and components. Land use may deny access to minerals or other resources. Disposal of some waste may result in loss of valuable resources that could effectively be recycled, reclaimed, or reused.

Sources of Effects

In order to develop and maintain our present lifestyles, many nonrenewable resources are being consumed at rates that indicate depletion of many critical materials within the century, or, in some cases, within a few decades. Furthermore, some of these materials in short supply are controlled by foreign powers, which results in even further complications, and dependency and strategic implications become important.

Variables to Be Measured

For the impact assessment procedure, a study should be made that will: 1) identify the activities or points of consumption of natural resources, 2) indicate the consumption rates, and 3) reveal the quantities and content of wastes resulting from those activities.

How Variables Are Measured

Qualitative determinations relating specific activities and resource consumption may be made on the basis of firsthand knowledge of the activities and their mode of accomplishment, and a general knowledge of resources and resource management. Once these relationships are identified, the information may be utilized repeatedly, as it will remain valid until changes in the activity or its mode of accomplishment occur.

Consumption rates are somewhat more difficult to quantify and technical expertise may be required. Depending on the kind of activity and the type of resource, the rates may be reported in such various terms as pounds per year or tons per day. Based upon purchasing data and other records, input-output models may be constructed which depict the total effect of the resource utilization.

Content and quantities of waste products resulting from an activity may be determined from field studies during which actual waste samples are classified and analyzed, or may be estimated on the basis of the same input-output models discussed earlier or by simpler procedures (e.g., emission factors).

Evaluation and Interpretation of Data

After determination of the points of resource consumption, quantities involved, and waste products produced, an evaluation may be made of the total impact by considering each of the resources being consumed in light of its individual status—abundance, importance, availability, economics, origin, energy to produce, recycle potential, and other factors. Lifecycle thinking should be incorporated (i.e., looking at an activity with regard to the resource requirements for the life of a project from origin to completion, operation, and eventual disposal).

Special Conditions

Special conditions may arise due to resource availability and price that can affect natural resources markets. Natural scarcities do exist for many resources, and these availabilities can be further jeopardized by embargoes or other supply interruptions (e.g., strikes). Although prices can actually assist in resource allocation in a free-market, supply-and-demand situation, efforts to artificially increase prices through such means as cartels, price-gouging, or cartel-like actions may occasionally place specific resources in a position of increased importance.

Geographical and Temporal Limitations

Specific geographical considerations include the origin of specific resources and the strategic implications associated with resource control. Also, transportation consumes fuel resources and should be considered in choosing alternatives (e.g., specification of a particular type of wood or building product that is unavailable locally). Seasonal aspects affect some resources (vegetation, mining, etc.), but most temporal limitations on resources are artificially produced.

Mitigation of Impact

Adverse impacts on natural resources and resource consumption can be minimized by economizing on resource requirements, development and use of substitutes, and recycling of scrap materials. These mitigations can all be considered as forms of conservation resulting in the use of fewer raw materials per unit of output. Specific programs might include recycling of tires, glass, paper, metals, petroleum waste, construction and demolition debris, and general solid waste. These areas not only provide potential for conservation of materials, but some may be used for energy conversion, resulting in fuel conservation as well.

Secondary Effects

In addition to energy consumption, other environmental effects may be related to the consumption of resources. Activities associated with the extraction, transportation, and processing of materials to produce the finished products may have an impact on air, water, land, and ecology. Other social and economic factors may be affected as well.

Aesthetics

Definition of the Attribute

The aesthetic attribute may be used to describe impacts on the environment that are apprehended through the senses—sight, taste, smell, hearing, and touch. Although treated in part in other attributes (e.g., odors in air and the entire category of noise), tolerance levels based on aesthetic criteria are often somewhat different, in addition to the fact that aesthetic perceptions generally require the consideration of all the senses simultaneously.

Visual perception is perhaps the most familiar of the areas, and the ensuing discussion emphasizes visual aesthetics and natural and human-modified landscapes.

Activities That Affect the Attribute

Generally, any activity that will alter the quality or distinguishable characteristic of the perceived environment can be considered as having an effect on aesthetics. Visual perception may be altered by activities involving construction, forestry and recreation management, transportation, water resource and land-use planning, and other activities involving landscape and scenic vista modification. Other aesthetic perceptions (hearing, smell, etc.) may be affected by industrial activities, burning, aircraft operations, waste discharges, and various facility operation and maintenance activities.

Sources of Effects

The activities that affect aesthetics do so by creating changes in the aesthetic characteristics of the environment as they are perceived by individuals (examples of characteristics include color, texture, scale, harmony, etc.). These perceptions are explained more fully here.

Variables to Be Measured

Individual perceptions and values for defining beauty make it difficult to quantify aesthetic impacts. Perception of ugliness, however, is more nearly agreed upon. In most cases, aesthetic criteria can be formulated by persons who have had experience in design and have acquired a sensitivity to the characteristics of the natural setting and structures that make them pleasing or displeasing to the human senses. Measurement techniques for identifying and describing aesthetic impacts are basically of two types:

1. Subjective: The qualitative analysis procedures based on the developer's best knowledge of design characteristics.
2. Objective: The quantitative analysis procedures based on established thresholds. The essence of this methodology includes design standards, architectural controls, sign ordinances, and landscape criteria. As an example, natural landscape aesthetics may be analyzed using the variables as follows: (Bagley, 1973; Litton, 1971):
   - **a.** *Landscape character* in terms of the landscape setting
     - **i.** Boundary definition: physical, vegetative, topographic, etc.
     - **ii.** General form and terrain pattern
     - **iii.** Vegetation patterns
     - **iv.** Features: hills, valleys, cliffs, promontories

v. Water and land interfaces: conditions and quality
vi. Weather patterns
vii. Cultural interfaces: artificial objects, transportation facilities, structures, etc.
viii. Natural and human-made acoustical features: sound absorption, falling water, birds

b. Macro (major) components
- **i.** Unity: the cohesion of the parts into a single harmonious unit, described by the presence or absence of a single dominant factor and complementing subordinate elements, contributing to a pleasant total composition
- **ii.** Variety: diversity without confusion, more than one element contributing richness; the maximum opportunity for visual stimulus
- **iii.** Vividness: quality lending to sharp visual impression-distinction

c. Micro (minor) descriptive elements
- **i.** Texture: identifying quality or disposition of the vista (e.g., rocks, trees, grass, and cultivated crop patterns), soft, sharp, flowing, rough
- **ii.** Color: may be described in terms of hue, lightness, and saturation
- **iii.** Contrast: diversity of adjacent parts in color, shape, or texture
- **iv.** Uniformity: similarity among features
- **v.** Scale: proportion of one object compared to another, particularly important in considering modified landscapes

d. Changing qualities
- **i.** Distance: proximity to components in the vista
- **ii.** Observer position: aesthetic qualities of a given area may vary with viewer location
- **iii.** Speed of observation: duration of viewer's observance
- **iv.** Time: daily and seasonal changes
- **v.** Observer's state of mind: expectations, values, mood

How Variables Are Measured; Evaluation and Interpretation of Data

Due to the nature of aesthetics and human perception, significant features are often difficult to quantify. Many methods, however, have been developed in an attempt to establish standards of comparison to arrive at a basis for determining which type of landscape (for most persons) is more desirable than another. These methods take two general forms:

1. A relative numerical weighting of each of the various intrinsic and extrinsic landscape resources as individual components and as a composition reflecting the presence and relationships of the descriptive elements listed earlier. These procedures attempt to quantify visual relationships, place a value on aesthetic resources, and describe the implications of changes on the landscape in terms of scenic quality, as ranked with other environmental changes.
2. The nonnumerical methodologies tend to place emphasis on ranking of visual attributes according to the same elements as the numerical scheme, but evaluate the aesthetic elements in terms of comparative analysis based on established criteria. They do not assign numerical weights but may, in some cases, assign a position or negative value. In addition, most studies can be categorized as:
   a. *Visual methodologies*: Visual components of the environment are inventoried and assessed by the planning staff, decision makers, or consultants.
   b. *User-analysis methodologies*: These are designed for attempting to find out how the general public feels about various aesthetic and potential impacts, and used as inputs to assessments.

Special Conditions

Since the value, importance, or expression of beauty is relative to the variable of perception, it is important to note that the following conditions bear significantly on the degree of aesthetic impact:

- The observer's state of mind: Factors of current perceptual setting and environmental lifestyle, coupled with past experiences and future expectations, can produce varying impressions of aesthetic quality.
- The observer's background: Cultural, economic, ethnic, and social background can determine perceived aesthetic qualities.
- Context of the observation: The setting of an observation may bear upon its acceptability (e.g., is a structure otherwise acceptable, but "out of place"?).

Mitigation of Impact

Aesthetic impacts are frequently controversial. While it is generally agreed that everyone would like to enjoy clean air, pristine waters, scenic vistas, and serenity in their everyday living, economics and other "facts of life" do not always make this possible. However, many adverse aesthetic impacts may be minimized once an aesthetic inventory is provided to planners and designers, so that desirable features associated with a project might be maintained and enhanced or incorporated into the project, and undesirable features of the project redesigned or eliminated.

Secondary Effects

Aesthetic qualities may be associated closely with land-use characteristics—an association leading to potential secondary impacts on almost any other biophysical or socioeconomic attribute. Aesthetic impacts not only reflect upon psychological needs, but frequently may be related to land prices, economic security, and community needs.