

CHAPTER 11

Selective Glossary of Hydrology and Environmental Sustainability-related Terms

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(Note: Cross-referenced terms are shown in *italics*)

A

- ablation (glacial):** all processes, which include melting, evaporation (sublimation), wind erosion, and **calving** (breaking off of ice masses), that remove snow or ice from a glacier or snowfield. The term also refers to the amount of snow or ice removed by these processes.
- acre-foot (AF):** AF, a-f, ac-ft, aft. The volume of water necessary to cover one acre to a depth of one foot. Equal to 43,560 cubic feet or 325,851 gallons, or 1,233 cubic meters.
- adaptive management:** sustainable-management practices for *ecosystems* and species that are responsive to uncertainties and ecological fluctuations, as well as being reversible and flexible.
- adjudication:** judicial process to determine the extent and priority of the rights of all persons to use water in a river or *aquifer system*.
- agricultural drought:** see *drought*.
- albedo:** portion of incoming *solar radiation* that is reflected by a surface.
- alluvial aquifer:** aquifer formed by material laid down by physical processes in a river channel or on a *floodplain*.
- alpha radiation:** radiation consisting of positively charged helium nuclei. Alpha-emitting substances in natural water are mainly radium and radon which are members of the uranium and thorium series. See also *radioactivity*.
- altithermal period:** period of high temperature, particularly the one from 8000 to 4000 B.P. (before the present era), which was apparently warmer in summers, as compared with the present, and with the precipitation zones shifted poleward. Also called the *hypsihermal period*.
- analytical model:** model that uses closed-form mathematical solutions to the governing equations applicable, for example, to ground-water flow and transport processes.
- anisotropy:** condition of having different properties in different directions.
- appropriation:** under Kansas law, this is the right to use water for a *beneficial use* or the acquisition of such a right gained through the process of diverting water and putting it to a *beneficial use*.
- appropriative rights:** appropriative *water rights*, generally found in western states, are created by *diversion* of water and putting it to *beneficial use*. Appropriative water rights have a priority based on the date of first usage. In times of shortage, *junior appropriators* are cut off while *senior appropriators* receive their full allotment.
- appurtenant:** existing as part of a broader property right. A surface *water right* may exist as part of the rights associated with ownership of land bordering a body of water or a ground water right may exist as part of the rights associated with ownership of the overlying land.
- aquiclude:** body of earth material of low *hydraulic conductivity* that can absorb water, but cannot transmit it at a rate sufficient for economic extraction by wells.
- aquifer:** one or more geologic formations containing sufficient saturated porous and permeable material to transmit water at a rate sufficient to feed a spring or for economic extraction by a well.
- aquifer (hydraulic) diffusivity:** ratio of aquifer *transmissivity* to *storativity* (or *hydraulic conductivity* to *specific storage*); it indicates how fast a transient change in *head* will be transmitted throughout the *aquifer system*.
- aquifer system:** *heterogeneous* body of interbedded permeable and poorly permeable material that functions regionally as a water-yielding unit; it comprises two or more permeable beds separated at least locally by *confining beds* that impede vertical ground water movement but do not greatly affect the regional *hydraulic continuity* of the system; includes both saturated and unsaturated parts of permeable materials.
- aquifer yield:** see *yield*.
- aquifuge:** body of earth material which is impervious to water and unabsorbative.

aquitarde: hydrogeological unit of much lower permeability than an aquifer (two or more orders of magnitude less) that will not sustain a water supply.

arid: said of a climate characterized by dryness, variously defined as rainfall insufficient for plant life; less than 10 inches (254 mm) of annual rainfall.

artesian ground water: see *confined ground water*.

artesian well or **artesian spring:** well or spring that taps ground water under pressure beneath an *aquifuge* or *aquiclude* so that water rises (though not necessarily to the surface) without pumping. If the water rises above the surface, it is known as a *flowing artesian well*.

artificial recharge: deliberate act of adding water to a ground water aquifer by means of a recharge project, also the water so added. Artificial recharge can be accomplished via injection wells, spreading basins, or in-stream projects.

atmosphere (An): standard unit of pressure representing the pressure exerted by a 29.92-inches (760-mm) column of mercury at sea level at 45 degrees latitude and equal to 14.696 pounds per square inch (psi) or 101.325 kilopascals.

atmosphere (The): envelope of air surrounding the earth and bound to it by the earth's gravitational attraction. Studies of the chemical properties, dynamic motions, and physical processes of this system constitute the field of *meteorology*.

atomic number: see *isotope*.

available water (or **moisture**): portion of water in a soil that can be absorbed by plant roots. It is the amount of water released from a wet soil between *field capacity* and the *permanent wilting percentage*.

B

bank storage: change in storage in an aquifer resulting from a change in stage of an adjacent surface-water body.

baseflow or **base flow:** streamflow derived mainly from ground water seepage into the stream.

baseflow node: artificial point located in the channel centerline of a stream for the purpose of allocating a proportional amount of the *baseflow* to be considered when evaluating a new application in Kansas Ground-water Management Districts 2 (Equus Beds) and 5 (Big Bend) to appropriate water from a proposed *point of diversion* located within 2 miles of the node.

basin: see *drainage basin*.

basin yield: see *yield*.

beneficial use: use of water, such as domestic, municipal, agricultural, mining, industrial, stock watering, recreation, wildlife, *artificial recharge*, power generation, or contamination remediation that provides a

benefit. *Water rights* not put to *beneficial use* are subject to forfeiture. Historically, very few uses of water have been declared nonbeneficial by courts.

beta radiation: radiation consisting of electrons or positrons. See also *radioactivity*.

biochemical cycle: chemical interactions among the *atmosphere*, *biosphere*, hydrosphere, and lithosphere. Examples are the *carbon*, oxygen, nitrogen, phosphorus, sulfur, and *hydrologic cycles*.

biological diversity (biodiversity): variety of living organisms at all levels, from genes to species, populations and communities, including the variety and hierarchy of habitats and *ecosystems* that contain different biological communities.

biomass: total dry organic matter or stored energy content of living organisms that is present at a specific time in a defined unit (community, *ecosystem*, crop, etc.) of the earth's surface.

biome: large, easily recognized community unit formed by the interaction of regional climates with regional biota and *substrates*. Examples include the tundra biome, the grassland biome, the desert biome, etc.

biosphere: portion of earth and its *atmosphere* that can support life. The part (reservoir) of the global *carbon cycle* that includes living organisms (plants and animals) and life-derived organic matter (*litter*, *detritus*). The **terrestrial biosphere** includes the living biota (plants and animals) and the litter and soil organic matter on land, and the **marine biosphere** includes the biota and detritus in the oceans.

biota: see *carbon cycle*.

BOD: Biochemical Oxygen Demand. A measure of the amount of oxygen required to neutralize organic wastes.

brackish water: see *saline water*.

boundary condition: mathematical expression of a state of the physical system that constrains the equations of the *mathematical model*.

Brundland Commission: see *WCED*.

C

calibration (model application): process of refining the model representation of the hydrogeologic framework, hydraulic properties, and *boundary conditions* to achieve a desirable degree of correspondence between the model simulation and observations of the ground-water system.

caliche: zone or accumulation near the surface, more or less cemented by secondary carbonates of calcium (Ca) or magnesium (Mg) precipitated from the soil solution. It may occur as a soft thin soil horizon, as a hard thick bed beneath the *solum*, or as a surface layer exposed by erosion. It also is called **hardpan**, **calcareous duricrust**, or **calcrete**.

capillary fringe: unsaturated zone immediately above the *water table* containing water in direct contact with the *water table*.

capillary potential: see *soil-water potential*.

capture: water withdrawn artificially from an aquifer derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes. The decrease in discharge plus the increase in recharge is termed capture. Capture results in reduced surface flows.

carbon cycle: all parts (reservoirs) and fluxes of carbon; usually thought of as a series of the four main reservoirs of carbon interconnected by pathways of exchange. The four reservoirs, regions of the earth in which carbon behaves in a systematic manner, are the *atmosphere*, *terrestrial biosphere* (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). Each of these global reservoirs may be subdivided into smaller pools ranging in size from individual communities or *ecosystems* to the total of all living organisms (**biota**). Also defined as carbon exchanges from reservoir to reservoir by various chemical, physical, geological, and biological processes.

carrying capacity: (1) the maximum number of organisms that an area or habitat can support without reducing its ability to support the same number of organisms in the future; (2) the amount of biological matter the system can yield, for consumption by animals or humans, over a given period of time without impairing its ability to continue producing, or the number of animals it can support without being degraded; (3) the maximum population of a given species that can be supported indefinitely, in a particular region, allowing for seasonal and random changes, without any degradation of the natural resource base that would diminish the maximum population in the future; (4) the maximum intensity of use an area will continuously support under a management program without inducing a permanent change in the biotic environment.

catena: sequence of soils of about the same age, derived from similar parent material and occurring under similar climatic conditions, but having different characteristics due to variation in relief and in drainage.

CERCLA: Comprehensive Environment Response, Compensation, and Liability Act. Also known as **Superfund**. The Act gave EPA the authority to clean up abandoned, leaky hazardous waste sites.

chlorofluorocarbons (CFCs): family of inert gases, including CFC-11, CFC-12, and CFC-13. These chemicals are used in refrigeration, air conditioning, packaging, and insulation or as solvents or aerosol

propellants. These gases are of concern for two reasons. First, in the upper *stratosphere* they result in ozone degradation. Second, they are also potent *greenhouse gases*. CFCs are currently regulated under the Montreal Protocol on Substances that Deplete the Ozone Layer.

climate: generalized weather at a given place on earth over a fairly long period (usually decades); a long term average of weather. Compare *weather*.

climate change: long-term fluctuations in temperature, precipitation, wind, and all other aspects of the earth's climate. External processes, such as *solar-irradiance* variations, variations of the earth's orbital parameters (eccentricity, precession, and inclination), lithosphere motions, and volcanic activity, are factors in climatic variation. Internal variations of the climate system also produce fluctuations of sufficient magnitude and variability to explain observed climate change through the *feedback* processes interrelating the components of the climate system.

climatic year: 12-month period used in the collection of precipitation data. Climatic years begin July 1 and end the following June 30, and are designated by the calendar year in which the climatic year ends.

climax: in ecology, the final stable or equilibrium stage of development that a community, species, flora, or fauna attains in a given environment. The major world climaxes correspond to *biomes*.

conceptual model: interpretation or working description of the characteristics and dynamics of the physical system.

cone of depression: cone-shaped lowering of the *water table* or *potentiometric surface* around a pumped well.

confined aquifer: aquifer that is bounded above and below by formations of significantly lower *hydraulic conductivity*.

confined ground water: ground water lying beneath an *aquiclude* or an *aquifuge*. Confined ground water is **artesian** if the water levels in wells are above the top of the aquifer.

confining bed: term which replaces the terms *aquiclude*, *aquitard*, and *aquifuge*, and defined as a body of "impermeable" material stratigraphically adjacent to one or more aquifers. In nature, however, the confining bed's *hydraulic conductivity* may range from nearly zero to some value distinctly lower than that of the aquifer.

conjunctive operation or use: operation of a *ground-water basin* in coordination with a surface-water system. Often the purpose is to *artificially recharge* the basin during years of above-average precipitation so that the water can be withdrawn during years of below-average precipitation, when surface supplies are below normal.

conservation: management of water resources so as to eliminate waste or maximize efficiency of use.

conservation of matter: see *mass balance*.

conservation storage: storage of water in a reservoir for later release for useful purposes such as municipal and industrial water supply, water quality, or irrigation.

consumptive use: use that makes water unavailable for other uses, usually by permanently removing it from local surface or ground-water storage as the result of *evaporation* and/or *transpiration*. Does not include evaporation losses from bodies of water.

contaminant plume: zone of polluted ground water downgradient from a point source of pollution.

continuous cropping: one crop planting following soon after harvest, without seasonal *fallowing*.

contour cropping: use of tillage that follows the contours of a slope, rather than up and down a slope. It helps prevent erosion and *runoff*.

crop residue: organic material that remains in the field following harvest.

crop rotation: successive planting of different crops in the same field over a period of years, usually to reduce the pest population or to prevent soil exhaustion.

cropping patterns: yearly sequence and spatial arrangement of crops or alternating crops and *fallow* within a given area. The fallow crop may be natural or planted.

cubic foot per second (cfs): rate of discharge representing a volume of one cubic foot ($28.317 \times 10^{-3} \text{ m}^3$) passing a given point during 1 second. This rate is equivalent to approximately 7.48 gallons (0.0283 m^3) per second.

curie (Ci): unit in reporting radioactivity in water, defined as 3.7×10^{10} radioactive disintegrations per second (the approximate specific activity of 1 gram of radium in equilibrium with its disintegration products). This unit is very large for the purpose of expressing natural radioactivity levels, and for this reason such data are often expressed in *picocuries* (*pCi* or $\text{curies} \times 10^{-12}$). See *radioactivity*.

current meter: device for measuring water velocity, consisting of a propeller that turns at a rate dependent on the water velocity.

curve number: Natural Resources Conservation Service-developed technique to estimate storm runoff from watersheds with various kinds of soil and land use.

D

Darcy's equation or law: formula stating that the flow rate of water through a porous medium is proportional to the *hydraulic gradient*. The factor of proportionality is the *hydraulic conductivity*.

dead storage reserves: see *ground-water storage reserves*.

Delphi method: method of seeking consensus among a panel of evaluators on questions that involve value judgments of relative worth.

dendrochronology: dating of past events and variations in the environment and the climate by studying the annual growth rings of trees. The approximate age of a temperate forest tree can be determined by counting the annual growth rings in the lower part of the trunk. The width of these annual rings is indicative of the climatic conditions during the period of growth; wide annual rings signify favorable growing conditions, absence of diseases and pests, and favorable climatic conditions, while narrow rings indicate unfavorable growing conditions or climate.

depletion time: time indicating how long it would take the *watershed* or the ground-water system to dry out if surface runoff or ground-water replenishment (*re-charge*) were stopped from the instant t onward and if outflow was maintained at the rate it had at that instant. The depletion time is defined as $V(t)/Q(t)$, where $V(t)$ equals volume of water stored and $Q(t)$ equals outflow at time t . Depletion times of surficial waters are usually of the order of hours to weeks. They may run into months or years if the river basin includes large lakes. Depletion times of aquifers are usually of the order of tens to hundreds, and often thousands of years. As a consequence, rivers react quickly to precipitation and to the abstraction of water, whereas ground-water systems react very sluggishly to these events.

desertification: progressive destruction or degradation of vegetation cover especially in arid and semiarid regions bordering existing deserts. Overgrazing of rangelands, large-scale cutting of forests and woodlands, drought, and burning of extensive areas all serve to destroy or degrade the land cover. The climatic impacts of this destruction include increased *albedo* leading to decreased precipitation, which in turn leads to less vegetation cover; increased atmospheric dust loading could lead to decreased monsoon rainfall and greater wind erosion and/or atmospheric pollution.

detritus: parts of dead organisms and cast-off fragments and wastes of living organisms.

dew point: temperature at which condensation occurs for a given amount of water vapor.

discharge: volume of water (and suspended sediment in surface water) that passes a given location within a given period of time.

discharge area: area in which water is lost naturally from the saturated zone.

dispersivity: scale-dependent aquifer parameter that determines the degree to which a dissolved constituent will spread in flowing ground water.

dissolved oxygen (DO): amount of oxygen gas dissolved in a given quantity of water at a given temperature and atmospheric pressure. It is usually expressed as a concentration in parts per million or as a percentage of saturation.

distributed-parameter models: models that account for spatial variations in parameters throughout the system.

diversion: physical removal of surface water from a channel. Also the act of bringing water under control by means of a well, pump, or other device for delivery and distribution for a proposed use.

divide (drainage divide): boundary between one *drainage basin* and another.

drainage area: of a stream at a specified location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface *runoff* from precipitation normally drains by gravity into the stream above the specified location.

drainage basin: hydrologic unit consisting of a part of the surface of the earth covered by a drainage system made up of a surface stream or body of impounded surface water plus all tributaries. The *runoff* in a drainage basin is distinct from that of adjacent areas. A **river basin** is similarly defined.

drawdown: lowering of the ground-water surface or the *piezometric pressure* caused by pumping, measured as the difference between the original ground-water level and the current pumping level after a period of pumping.

drought: (1) interval of time, generally of the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply (*meteorological drought*); (2) a condition that occurs only when available soil moisture is inadequate to meet evaporative demand by plants (*agricultural drought*); (3) a period of below-normal streamflow (*hydrological drought*).

E

Earth Summit: see *UNCED*.

ecological or ecosystem functions: processes among and within the various biological, chemical, and physical components of an *ecosystem* that consist of specific activities or flows, such as nutrient cycling, biological productivity, hydrology, and sedimentation; dynamic and sequential interactions that characterize the evolution of the *system*, such as exploitation, conservation, release, and reorganization; and the cumulative effect of these processes and interactions, such as the ability of ecosystems to support life. Ecological functions that are currently perceived to support and protect the human activities of production and con-

sumption or affect overall well-being in some way, thus impacting on human welfare and even existence.

ecosystem: biological communities that interact with the physical and chemical environment as a unified *system*, while simultaneously interacting with adjacent ecosystems and with the *atmosphere*.

ecotone: transitional zone in which one type of *ecosystem* tends to merge with another ecosystem.

effluent: any substance, particularly a liquid, that enters the environment from a point source. Generally refers to wastewater from a sewage-treatment or industrial plant.

effluent stream: stream or reach of a stream whose flow is being increased by inflow of ground water. A *gaining stream*.

El Niño: irregular changes in the ocean currents off the west coast of South America that result in prolonged increases in sea-surface temperatures along the coast of Peru and in the equatorial eastern Pacific Ocean. El Niño has been linked to distant atmospheric features having diverse effects, such as the Indian monsoon, shrimp production in Louisiana, and wildland fires in the United States.

elevation head: see *hydraulic head*.

environment: sum of all external conditions affecting the life, development, and survival of an organism.

environmental sustainability: widely espoused goal that seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the *sinks* for human wastes are not exceeded, in order to prevent harm to humans. Environmental sustainability means *natural capital* must be maintained, both as a provider of inputs (“sources”), and as a *sink* for wastes. This means holding the scale of the human economic subsystem to within the biophysical limits of the overall ecosystem on which it depends. Environmental sustainability needs sustainable production and sustainable consumption. On the sink side, this translates into holding waste emissions within the assimilative capacity of the environment without impairing it. On the source side, harvest rates of renewables must be kept within regeneration rates. Nonrenewables cannot be made fully sustainable, but quasi-environmental sustainability can be approached for nonrenewables by holding their depletion rates equal to the rate at which renewable substitutes can be created. See also *sustainable development*.

ephemeral flow: when water flows in a channel only after precipitation.

epilimnion: warm, less-dense top layer in a stratified lake. Compare *hypolimnion*.

evaporation: process of liquid water becoming water vapor, including vaporization from water surfaces, land

surfaces, and snow fields, but not from leaf surfaces. Compare with *transpiration*.

evapotranspiration: sum of *evaporation* and *transpiration*.

externalities: social benefits and social costs not included in the market price of an economic good.

F

fallow: period during which land is left to recover its productivity (reduced by cropping) mainly through accumulation of water, nutrients, attrition of pathogens, or a combination of all three. During this period, the land may be bare or covered by natural or planted vegetation. The term may be applied to the land itself or to the crop growing on it.

feedback mechanism: sequence of interactions in which the final interaction influences the original one. Also see *positive feedback* and *negative feedback*.

field capacity: quantity of water held back by soil or rock against the pull of gravity. It is sometimes limited to a certain drainage period (2 or 3 days), thereby distinguishing it from *specific retention*, which is not limited by time.

finite-difference method: numerical technique for solving a system of equations using a rectangular mesh representing the aquifer and solving for the dependent variable in a piece-wise manner.

finite-element method: numerical technique for solving a system of equations using an irregular triangular or quadrilateral mesh representing the aquifer and solving for the dependent variable in a continuous manner.

firm yield: see *safe yield*.

firn: material that is transitional between snow and glacier ice. It is formed from snow after passing through one summer melt season and becomes glacier ice after its permeability to liquid water falls to zero.

floodplain or flood plain: land bordering a stream, built up of sediments from overflow of the stream and subject to inundation when the stream is at flood stage.

flow duration curve: graph of stream discharge versus the percentage of time that the flow exceeds that stream discharge.

flowing artesian well: see *artesian well*.

flux: refers to the rate of flow; it is the quantity of material or energy transferred through a system or a portion of a system in a unit time and is called *mass flux*. If the moving matter is a fluid, the flux may be measured as volume of fluid moving through a system in a unit time and is called *volume flux*. For most applications, we desire to know the flux per unit area of a system rather than the flux of the entire system; the flux per unit area is called the *flux density*.

flux density: see *flux*.

food chain: sequence of organisms, each of which uses the next lower member of the sequence as a food source.

fractal: object that has variation that is self-similar at all scales, in which the final level of detail is never reached and never can be reached by increasing the scale at which observations are made.

free ground water: *unconfined* ground water whose upper surface is a free *water table*.

G

gaging station: site on a stream, lake, reservoir, or other body of water where direct systematic observations of hydrologic data are obtained.

Gaia hypothesis: proposal that the earth is alive and can be considered a system that operates and changes by *feedback* of information between its living and non-living components. The idea that life on earth helps sustain its own environment.

gaining stream: stream reach in which the *water table* adjacent to the stream is higher than the water surface in the stream, causing ground water to seep into the stream, increasing its flow.

gamma radiation: radiation consisting of electromagnetic wave-type energy similar to X-rays. See also *radioactivity*.

General Circulation Models (GCMs): large-scale computer models used to predict the response of the climate system to a carbon dioxide (CO₂) increase or other stresses. Generally, the atmosphere, land, and oceans are divided into a number of discrete layers, with each layer consisting of a two-dimensional grid of thousands of points. The model then solves equations for the transport of heat, momentum, moisture (in the atmosphere and land), and salinity (in the ocean) on this three-dimensional grid. The typical resolution is 4° latitude by 5° longitude.

Geographic Information Systems (GIS): computer-based systems for storing and manipulating geographic (spatial) information.

Ghyben-Herzberg principle: principle that accounts for the existence of a body of freshwater floating on sea water within an aquifer because of the different densities. Generally speaking, freshwater extends to a depth about forty times the height that the freshwater table is found above sea level. Conversely, a lowering of the freshwater table by 1 ft (0.3 m) will cause sea water to rise 40 ft (12.19 m) within the aquifer.

gravitational potential: see *soil-water potential*.

greenhouse effect: popular term used to describe the roles of water vapor, carbon dioxide, and other *trace gases* in keeping the earth's surface warmer than it would be

otherwise. These “*radiatively active*” gases are relatively transparent to incoming *short wave radiation* but are relatively opaque to outgoing *long wave radiation*. The latter radiation, which would otherwise escape to space, is trapped by these gases within the lower levels of the atmosphere. The subsequent reradiation of some of the energy back to the surface maintains surface temperatures higher than they would be if the gases were absent. There is concern that increasing concentrations of greenhouse gases, including carbon dioxide, methane, and manmade *chlorofluorocarbons*, may enhance the greenhouse effect and cause global warming.

greenhouse gases: gases, including water vapor, carbon dioxide, methane, nitrous oxide, *chlorofluorocarbons*, and *ozone*, that insulate the earth, letting sunlight through to the earth’s surface while trapping outgoing radiation. Also see *greenhouse effect* and *trace gas*.

gross alpha activity: see *radioactivity*.

gross primary production (or productivity): total amount or weight of organic matter created by *photosynthesis* over a defined time period (total product of *photosynthesis*). Abbreviated GPP.

ground water: subsurface-water body in the zone of saturation or (more commonly, available ground water is defined as) that portion of the water beneath the surface of the earth that can be collected with wells, tunnels, or drainage galleries, or that flows naturally to the earth’s surface via seeps or springs.

ground-water basin: geologically and hydrologically defined area that contains one or more aquifers that store and transmit water and will yield significant quantities of water to wells.

ground-water-flow model: application of a *mathematical* model to represent a site-specific *ground-water flow system*.

ground-water flow system: set of ground-water flow paths with common *recharge* and *discharge areas*. Flow systems are dependent on both the hydrogeologic characteristics of the soil/rock material and landscape position. Areas of steep or undulating (hummocky) relief tend to have dominant *local-flow systems* (discharging in nearby topographic lows such as a pond or stream.) Areas of gently sloping or nearly flat relief tend to have dominant *regional-flow systems* (discharging at much greater distances than local systems in major basin topographic lows or oceans.)

ground-water hydrograph: see *hydrograph*.

ground-water mining: pumping ground water from a basin at a rate that exceeds *safe yield*, thereby extracting ground water that had accumulated over a long period of time.

ground-water overdraft: pumpage of ground water for *consumptive use* in excess of *safe yield*.

ground-water storage: (1) quantity of water in the saturated zone, or (2) water available only from the storage as opposed to *capture*.

ground-water-storage reserves: sum of live and dead storage reserves; *live storage reserves* are situated above the aquifer outlet or *discharge area* and can be depleted by natural discharge drainage and also recovered by pumping; *dead storage reserves* can be recovered only by pumping after the live reserves have been exhausted.

H

hard water: see *hardness*.

hardness: water-quality parameter that indicates the level of alkaline salts, principally calcium and magnesium, and expressed as equivalent calcium carbonate (CaCO_3). Hard water is commonly recognized by the increased quantities of soap, detergent, or shampoo necessary to lather.

head: see *hydraulic head*.

head loss: see *hydraulic head*.

hectare (ha): one hectare equals 2.47 acres. One square kilometer equals 100 hectares. One square mile equals 259 hectares.

heterogeneous: material property that varies with the location within the material. See also *homogeneous*.

Holocene: most recent epoch of the *Quaternary period*, covering approximately the last 10,000 years.

homogeneous: material is homogeneous if its hydrologic properties are identical everywhere.

human capital: see *natural capital*.

human-made or reproducible capital: economic assets, such as buildings, equipment, plants and machinery, tools, financial assets, skilled labor, that are produced by the economy and capable of contributing to long run economic potential or welfare, usually measured in terms of the present value of the income, or welfare, it generates.

humus: decomposed organic material.

hydraulic conductivity: factor of proportionality in *Darcy’s equation* relating flow velocity to *hydraulic gradient* having units of length per unit of time. A property of the porous medium and the fluid (water) content of the medium. See also *permeability*, *intrinsic permeability*.

hydraulic continuity: property of the rock framework on a given time scale whereby a change in *hydraulic head* in any point of the region can cause a *head* change in any other point of the same region by means of pressure transfer through the rock pores and within a time interval measurable at that time scale.

hydraulic gradient: slope of the *water table* or *potentiometric surface*. The change is *static head* per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in *head*.

hydraulic head or **(static) head:** height that water in an aquifer can raise itself above an (arbitrary) reference level (or datum), and is generally measured in feet. When a borehole is drilled into an aquifer, the level at which the water stands in the borehole (measured with reference to a horizontal datum such as sea level) is, for most purposes, the hydraulic head of water in the aquifer. This term defines how much energy water possesses. Ground water possesses energy mainly by virtue of its elevation (*elevation head*) and of its pressure (*pressure head*). See also *hydrostatic head*. When ground water moves, some energy is dissipated and therefore a *head loss* occurs.

hydraulic potential: see *soil-water potential*.

hydrogeology: see *hydrology*.

hydrograph: graph showing stage, flow, velocity, or other characteristics of water with respect to time. A *stream hydrograph* commonly shows rate of flow; a *ground-water hydrograph* shows water level or head.

hydrologic budget or **balance:** accounting of the inflow to, outflow from, and storage in a hydrologic unit such as a *drainage basin*, *aquifer*, soil zone, lake, or reservoir; the relationship between evaporation, precipitation, runoff, and the change in water storage, expressed by the *hydrologic equation*.

hydrologic cycle: cyclic transfer of water vapor from the earth's surface via *evapotranspiration* into the atmosphere, from the *atmosphere* via precipitation back to earth, and through *runoff* into bodies of water.

hydrologic equation: equation that balances the *hydrologic budget*.

hydrological drought: see *drought*.

hydrology: study of the characteristics and occurrence of water, and the *hydrologic cycle*. Hydrology concerns the science of surface and ground waters, whereas *hydrogeology* principally focuses on ground water, though the terms are commonly used interchangeably.

hydrostatic head: height above a standard datum of the surface of a column of water or other liquid that can be supported by the (*hydro*) *static pressure* at a given point.

(hydro)static pressure: pressure exerted by or existing within a liquid at rest with respect to adjacent bodies.

hypolimnion: bottom layer of cold water in a lake. Compare *epilimnion*.

hyporheic zone: interstitial habitat penetrated by riverine animals and extending to no more than a few meters

below the water/substratum interface in streams, in most cases centimeters away from the river channel. This biologically active zone is in direct and frequent contact with both the stream and the ground water. The hyporheic zone may be regarded as an *ecotone* between the surficial streambed (approximately top 15 cm) and the true ground waters that constitute the *phreatic zone*. Being a transition zone, the spatial extent of the hyporheic zone is not precisely delineated.

hypothermal period: period about 4,000 to 8,000 years ago when the earth was apparently several degrees warmer than it is now. More rainfall occurred in most of the subtropical desert regions and less in the central midwest United States and Scandinavia. It is also called the *altithermal period* and can serve as a past climate analog for predicting the regional pattern of climate change should the mean earth surface temperature increase from an increase in atmospheric carbon dioxide concentration.

I

induced infiltration or **induced recharge:** recharge to ground water by infiltration, either natural or human-made, from a body of surface water as a result of the lowering of the ground-water *hydraulic head* below the surface-water level.

infiltration (soil): movement of water from the ground surface into the soil.

influent stream: stream or reach of stream that loses water into the ground. Also known as a *losing stream*.

infrared radiation: see *longwave radiation*.

injection well: well used for injecting water or other fluid into a ground-water aquifer. See also *artificial recharge*.

insolation: solar radiation incident on a unit horizontal surface at the top of the *atmosphere*. It is sometimes referred to as *solar irradiance*. The latitudinal variation of insolation supplies the energy for the general circulation of the atmosphere. Insolation depends on the angle of incidence of the solar beam and on the *solar constant*.

instream use: use of water that does not require withdrawal or diversion from its natural watercourse; for example, the use of water for navigation, recreation, and support of fish and wildlife.

instrumental value: value, or "worth," of something in terms of an "instrument" for satisfying individuals' needs and preferences; for example, the instrumental value of *biodiversity* derives from the role that the mix of micro-organisms, plants, and animals plays in providing ecological services and resources vital to human welfare.

integrated watershed management: process of formulating and implementing a course of action involving natural and human resources in a watershed, taking into account the social, political, economic, and institutional factors operating within the watershed and the surrounding river basins and other relevant regions to achieve specific social objectives. Typically this process would include (1) establishing watershed-management objectives, (2) formulating and evaluating alternative resource-management actions involving various implementation tools and institutional arrangements, (3) choosing and implementing a preferred course of action, and (4) thorough monitoring of activities and outcomes, evaluating performance in terms of degrees of achievement of the specified objectives. See also *watershed approach*.

interbasin transfer: physical transfer of water from one *watershed* to another.

interflow: see *underflow*.

inter-generational equity: extent to which the economic opportunities available to the current generation are also available to future generations; for example, whether activities undertaken by the current generation that lead to irreversible loss of *biodiversity* and increasing ecological scarcity today will affect adversely future generations' welfare, and even threaten their existence.

intra-generational equity: extent to which the economic opportunities available to the current (or a future) generation are equally available to all members of that generation; for example, whether the gains from irreversible loss of *biodiversity* and increased ecological scarcity are enjoyed disproportionately by some human populations and societies, and the costs borne disproportionately by others.

intermittent flow: surface water flowing only during periods of seasonal runoff.

interrupted flow: water flowing alternatively on the channel surface in some stream stretches and disappearing underground in others.

intrinsic permeability: quantitative measure of fluid-transmitting ability of a porous medium that is related to the size and interconnectedness of the void openings. See also *permeability*.

intrinsic value: having value, or "worth," in itself, regardless of whether it serves as an "instrument" for satisfying individuals' needs and preferences; for example, many more arguments for preserving biodiversity are based on the premise that organisms should be "saved" from extinction because all living entities have a fundamental intrinsic worth.

isohyet: line that connects points of equal rainfall.

isopleth: line that connects points of equal amounts of a quantity such as *evapotranspiration*, chloride concentration, etc.

isotherm: line that connects points of equal temperature.

isotope: refers to the fact that a chemical element in the periodic table may have two or more species that behave nearly identically chemically but have different atomic masses and physical properties. One of two or more atoms that have the same *atomic number* (i.e. the same number of protons in their nuclei) but differing in the number of their neutrons. Isotopes are **radioactive** (parent) if they decay spontaneously to another (daughter) element. Isotopes are **stable** if they do not decay. Radioactive isotopes such as tritium (^3H) and carbon-14 (^{14}C) are used to determine how long water containing these isotopes has been out of contact with the earth's atmosphere, and thus underground.

isotropic: said of a medium whose properties are the same in all directions. See *anisotropy*.

J

junior appropriator: holder of a surface- or ground-water right that was acquired subsequent to other water rights on the same stream or aquifer.

K

Kansas Water Appropriation Act: act that established the general principle that all water within the state is dedicated to the use of the people of the state subject to the control and regulations of the state as set forth in the act. The law provides that water appropriated must be put to *beneficial use*, and that among appropriators, the first one in time should be the first in right. This act was enacted on June 28, 1945.

kriging: estimation method that assumes that the best estimate is a weighted average of one or more sample points. Kriging is the method of analysis by which optimal values of the weights are determined.

L

lacustrine: pertaining to or formed in a lake or lakes.

laminar flow: type of flow in which the fluid particles (i.e. small "parcels" of fluid, bigger than molecules but small in relation to the passageway through which the fluid is flowing) all move smoothly more or less in the same direction as the bulk of the fluid. Laminar flow typically occurs when fluid is moving very slowly through small openings (like capillary tubes) or in very thin sheets.

lapse rate: rapidity with which temperature decreases with altitude. The normal lapse rate is approximately 3.5 degrees F per 1,000 feet (6.5 degrees C per kilometer) change in altitude. The dry adiabatic lapse rate is about 5.4 degrees F per 1,000 feet (9.8 degrees C per kilometer), and the wet adiabatic lapse rate varies between 2

and 4 degrees F per 1,000 feet (3.6 to 6.9 degrees C per kilometer).

latent heat: energy transferred from the earth's surface to the *atmosphere* through the *evaporation* and condensation processes.

lentic system: nonflowing or standing body of freshwater, such as a lake or pond. Compare *lotic system*.

litter: undecomposed plant residues on the soil surface.

Little Ice Age: cold period that lasted from about A.D. 1550 to about A.D. 1850 in Europe, North America, and Asia. This period was marked by rapid expansion of mountain glaciers, especially in the Alps, Norway, Ireland, and Alaska. There were three maxima, beginning about 1650, about 1770, and 1850, each separated by slight warming intervals.

littoral zone: of the seashore, between the high and low tide marks. Pertaining to the shallower life zone near the shore, out to the usual limit of influence of wave action, tides and daylight.

live storage reserves: see *ground-water storage reserves*.

local flow system: see *ground-water flow system*.

longwave radiation: radiation emitted in the spectral wavelength greater than 4 micrometers corresponding to the radiation emitted from the earth and atmosphere. It is sometimes referred to as *terrestrial radiation* or *infrared radiation*, although somewhat imprecisely.

losing stream: stream reach in which the water table adjacent to the stream is lower than the water surface in the stream, causing infiltration from the stream channel, recharging the ground-water aquifer and decreasing the streamflow.

lotic system: flowing body of freshwater, such as a river or stream. Compare *lentic system*.

lumped-parameter models: models that ignore spatial variations in parameters throughout an entire system.

M

mass balance: application of the principle of the *conservation of matter*. For example, the mass of a glacier is not destroyed or created; the mass of a glacier and all its constitutive components remains the same despite alterations in their physical states. The mass balance of a glacier is calculated with the input/output relationships of ice, *firn*, and snow, usually measured in water equivalent. Output includes all ablative processes of surface melting, basal melting, evaporation, wind deflation, **calving**, and internal melting. Input includes direct precipitation, avalanching, and the growth of superimposed ice.

mass flux: see *flux*.

mass curve or Ripple diagram: cumulative plot of reservoir inflow on the ordinate against time on the abscissa which permits simple graphical evaluation of reservoir yield. Widely used in surface water engineering design.

mathematical model: mathematical equations expressing the physical system and including simplifying assumptions. The representation of a physical system by mathematical expressions from which the behavior of the *system* can be predicted.

matric potential: see *soil-water potential*.

Maximum Contaminant Level (MCL): maximum level of a contaminant allowed in water by Federal law. Based on health effects and currently available treatment methods.

mean sea level: average height of the sea surface, based upon hourly observation of the tide height on the open coast or in adjacent waters that have free access to the sea. In the United States, it is defined as the average height of the sea surface for all stages of the tide over a 19-year period. Mean sea level, commonly abbreviated as MSL and referred to simply as sea level, serves as the reference surface for all altitudes in upper atmospheric studies.

mesic environment: habitat with a moderate amount of water.

meteorological drought: see *drought*.

meteorology: see *atmosphere*.

metric ton: 1,000 kilograms (kg). One metric ton = 1.1 U.S. (or short) ton.

micromhos per centimeter ($\mu\text{mhos/cm}$): see *specific conductance*.

Milankovitch theory: astronomical theory formulated by the Yugoslav mathematician Milutin Milankovitch that associates climate change with fluctuations in the seasonal and geographic distribution of *insolation* resulting from three changes in the geometry of the earth's orbit. One is that the path of the earth around the sun forms an ellipse, the shape of which changes over a period of about 100,000 years. The second is that the rotational axis of the earth is tilted with respect to the plane of its orbit; the tilt is now 23.5°, but it has varied several degrees over a period of 41,000 years. The third phenomenon is a wobble in the axis of rotation, an event that seems to recur every 21,000 years. The Milankovitch theory has gained acceptance primarily because young marine sediments exhibit cycles of 23, 000, 42,000, and 100,000 years—very close to the cycles Milankovitch calculated.

milligrams per liter—mg/L: milligrams per liter of water. This measure is equivalent to *parts per million (ppm)*.

mineral intrusion: movement of water from an aquifer containing mineralized or salty water into a freshwater stream, lake, or aquifer.

Minimum Desirable Streamflows (MDS): under Kansas water law, streamflows that maintain or preserve *instream uses* of water quality, fish, wildlife, aquatic life, recreation, and aesthetics from unacceptable stream depletions by future consumptive appropriations. Minimum desirable streamflows will not be preferred to *vested* and *senior appropriation* rights filed prior to their enactment nor will they be maintained through all drought conditions.

mining: as it pertains to water, the process, deliberate or inadvertent, of extracting ground water from a source at a rate so that the ground-water level declines persistently, threatening actual exhaustion of the supply.

MINK study: study of the likely effects of increasing temperatures on the agricultural economy of the Missouri, Iowa, Nebraska, and Kansas region.

misfit river: river that appears to be too small for its present valley. This may be because its head waters have been captured and so are reduced; a change of climate has occurred and the amount of water has decreased; or the valley has been enlarged by glaciation. Sometimes known as an **underfit river**.

model: assembly of concepts in the form of mathematical equations that portray understanding of a natural phenomenon.

modeling: investigative technique that uses a mathematical or physical representation of a *system* or theory that accounts for all or some of its known properties. Models are often used to test the effects of changes of system components on the overall performance of the system.

monitoring well: non-pumping well used primarily for drawing water-quality samples; also for measuring ground-water levels.

N

natural capital: characterization of environmental resources as assets in the economy that have the potential to contribute to economic productivity and welfare; for example, the value of a natural resource as an economic asset depends on the present value of its income, or welfare, potential. Natural capital is distinguished from other forms of capital, namely *human* or *social capital* (people, their capacity levels, institutions, cultural cohesion, education, information, knowledge), and *human-made capital* (houses, roads, factories, ships).

natural recharge: naturally occurring water added to an aquifer. Natural recharge generally comes from snowmelt and precipitation or storm runoff.

negative feedback: interaction that reduces or dampens the response of the *system* in which it is incorporated.

net primary production (or productivity): part of the *gross primary production* that remains stored in the producer organism (primarily green plants) after deducting the amount used during the process of respiration. Abbreviated NPP.

nonconsumptive use: use that leaves the water available for other uses. Examples are hydroelectric power generation and recreational uses.

nonpoint source: source of water pollution that originates from a broad area, such as agricultural chemicals, applied to fields, or acid rain.

normal: average value of a meteorological variable (such as precipitation or temperature) over a fixed period of years, usually recognized as standard. In the United States, 30-year normals are frequently used.

NPDES permit: permit issued under the National Pollutant Discharge Elimination System for companies discharging pollutants directly into the waters of the United States.

numerical methods: set of procedures used to solve the equations of a *mathematical model* in which the applicable partial differential equations are replaced by a set of algebraic equations written in terms of discrete values of state variables at discrete points in space and time. There are many numerical methods. Those in common use in ground-water models are the *finite-difference method*, the *finite-element method*, the boundary-element method, and the analytical-element method.

numerical model: model that uses *numerical methods* to solve the governing equations of the applicable problem.

O

observation well: non-pumping well used primarily for observing the elevation of the *water table* or the *piezometric pressure*; also to obtain water-quality samples.

open system: system in which energy and matter are exchanged between the system and its environment, for example, a living organism. Compare closed system, isolated system.

osmotic potential: see *soil-water potential*.

output: modeling, all information that is produced by the computer code.

overdraft: (1) pumping of ground water for *consumptive use* in excess of *safe yield*; (2) the condition of a *ground-water basin* where the amount of water withdrawn exceeds the amount of water captured over the basin over a period of time. The use of water in excess of the *perennial yield*.

ozone: molecule made up of three atoms of oxygen (O₃). In the *stratosphere*, it occurs naturally and it provides a protective layer shielding the Earth from *ultraviolet radiation* and subsequent harmful health effects on humans and the *environment*. In the *troposphere*, it is a

chemical oxidant and major component of *photochemical smog*.

P

palynology: science of reconstructing the past flora and past climate from pollen data obtained from lake and bog sediments. The fossil pollen record is a function of the regional flora and vegetation at a given time and location.

Pampas: see *prairie*.

parts per million (ppm): see *milligrams per liter*.

perched water table: *water table* of a relatively small ground-water body lying above the general ground-water body.

percolation: laminar-gravity flow through unsaturated and saturated earth material.

perennial flow: year-round flow.

perennial yield: maximum quantity of water that can be withdrawn annually from a ground water supply under a given set of conditions without causing an undesirable result.

perfect (verb): under Kansas water law, the actions of a water user to bring an *appropriation* right into final form by the completion of diversion works and application of water to the proposed use in accordance with the approved *water-right* application.

perihelion: point at which an object, travelling in an elliptical orbit around the sun, is at its closest to the sun.

permanent wilting percentage or **point:** water content of soil when indicator plants growing in that soil wilt and fail to recover when placed in a humid chamber.

permeability: (1) ability of a material (generally an earth material) to transmit fluids (water) through its pores when subjected to pressure or a difference in *head*. Expressed in units of volume of fluid (water) per unit time per cross section area of material for a given *hydraulic head*; (2) description of the ease with which a fluid may move through a porous medium; abbreviation of *intrinsic permeability*. It is a property of the porous medium only, in contrast to *hydraulic conductivity*, which is a property of both the porous medium and the fluid content of the medium.

pH: measure of the relative acidity or alkalinity of water. Defined as the negative log (base 10) of the hydrogen ion concentration. Water with a pH of 7 is neutral; lower pH levels indicate an increasing acidity, while pH levels above 7 indicate increasingly basic solutions.

phenology: study of periodic biological phenomena with relation to climate, particularly seasonal changes, such as the time that certain plants and trees come into leaf and flower, and the date of the first and last appearance

of animals and birds in a particular habitat. These phenomena can be used to interpret local seasons and the climatic zones.

photochemical smog: air pollution caused by chemical reactions among various substances and pollutants in *the atmosphere*.

photosynthesis: manufacture by plants of carbohydrates and oxygen from carbon dioxide and water in the presence of chlorophyll with sunlight as the energy source. Oxygen and water vapor are released in the process. Photosynthesis is dependent on favorable temperature and moisture conditions as well as on the atmospheric carbon dioxide concentration. Increased levels of carbon dioxide can increase net photosynthesis in many plants.

phreatic zone: same as **zone of (ground-water) saturation**. Was originally used to designate water in the upper part of the zone of saturation.

phreatophyte: plant whose roots generally extend downwards to the water table and customarily feed on the *capillary fringe*. Phreatophytes are common in *riparian habitats*. Term literally means “well” plant or water-loving plant. Common examples in Kansas are salt cedar, cottonwoods, and willows.

picocuries (pCi): see *curie*.

piezometer: small-diameter well open at a point or short length in the aquifer to allow measurement of *hydraulic head* at that point or short length.

piezometric pressure: pressure corresponding to the height to which water would rise in an observation well penetrating an aquifer.

piezometric surface: surface defined by a pressure head and position (elevation above a standard datum, such as sea level). For an *unconfined aquifer*, it is equal to the elevation of the water table. For a *confined aquifer*, it is equal to the elevation to which water would rise in a well penetrating and open to the aquifer. This term is now replaced by *potentiometric surface*.

planning horizon: range of time during which the *system* under study has to be operated. An aquifer with negligible annual recharge containing a million *acre-feet* (1.2335 km³) of recoverable ground-water stocks has a zero *sustainable yield* if the planning horizon is infinite. For a 100-year-time (planning) horizon, the same aquifer has a 10,000 acre-foot sustainable yield; for a 10-year horizon, a 100,000 acre-foot sustainable yield.

playa: flat-floored bottom of an undrained desert basin, becoming at times a shallow muddy lake after heavy rainfall; or the flooding of a river which on evaporation may leave a deposit of salt or gypsum. A salt pan. The Great Basin in Nevada and Utah in the western United States has many playas.

Pleistocene: earlier of the two epochs of the *Quaternary Period* starting 2 to 3 million years before the present and ending about 10,000 years ago. It was a time of glacial activity.

pluvial: pertaining to precipitation.

point of diversion: point at which water is diverted or withdrawn from a source of water supply.

point source: source of pollution that originates from a single point, such as an outflow pipe from a factory.

porosity: fraction of bulk volume of a material consisting of pore space.

positive feedback: interaction that amplifies the response of the *system* in which it is incorporated.

Potential Evapotranspiration (PET): maximum amount of soil *evaporation* and *transpiration* from a well-irrigated crop for a given set of environmental conditions.

potential gradient: see *soil-water potential*.

potentiometric surface: imaginary surface representing the *static head* of ground water and defined by the level to which water will rise in a well. The *water table* is a particular potentiometric surface.

prairie: gentle undulating, almost flat, generally treeless, grassy plains of North America, covering the southern regions of Alberta, Saskatchewan, and Manitoba in Canada and central United States from the foothills of the Rocky Mountains about as far east as Lake Michigan. The light summer rains with local droughts and high summer temperatures encourage a rich growth of grass, but few trees. They form the North American equivalent of the *Pampas* of South America, the *Steppes* of Eurasia, and the *Veldt* of South Africa.

precautionary principle: caution, “margins of error,” or “safeguards” should be invoked for those human interventions in the natural environment where (i) our understanding of the likely consequences are limited, and (ii) there are threats of serious or irreversible damage to natural systems and processes.

pressure head: see *hydraulic head*.

primary productivity: see *gross primary productivity* and *net primary productivity*.

prior appropriation: doctrine for prioritizing water rights based upon dates of appropriation (“first in time, first in right”). Common for allocating water rights in the western United States.

Q

Quaternary Period: latest period of geologic time, covering the most-recent 2,000,000 years of the earth’s history. It is divided into two epochs: the *Pleistocene*—2 million years ago to approximately 10,000 years ago—and the *Holocene*—the period from approximately 10,000 years ago to the present. The

Quaternary Period is the artificial division of time separating prehuman and human periods. It contains five ice ages and four interglacial ages, and temperature indications seem to show sharp and abrupt changes by several degrees.

R

radioactivity: release of energy and energetic particles by changes occurring within atomic or nuclear structures. Radioactive energy is released in various ways such as *alpha radiation*, *beta radiation*, and *gamma radiation*. Radioactivity data are expressed in terms of concentration of specific nuclides. General measurements of *total* or *gross alpha* or beta and gamma activity also are often reported. The radioactivity of water is usually expressed in terms of the rate of radioactive disintegration (*curies*) per liter of water.

radiatively active gases: gases that absorb incoming solar radiation or outgoing *infrared radiation* thus affecting the vertical temperature profile of the atmosphere. Most frequently cited as being radiatively active gases are water vapor, CO₂, methane, nitrous oxide, *chlorofluorocarbons*, and *ozone*.

radiosonde: balloon-borne instrument for the simultaneous measurement and transmission of meteorological data up to a height of approximately 30,000 meters (100,000 feet). The height of each pressure level of the observation is computed from data received via radio signals.

rating curve: plot of discharge as a function of gage height. Data for a rating curve are obtained by *current meter* measurements of discharge.

RCRA: Resource Conservation and Recover Act—Federal legislation requiring that hazardous waste be tracked from “cradle” (generation) to “grave” (disposal).

recharge: to add water to an aquifer, either naturally or by artificial means; also the water added to an aquifer.

recharge area: area that contributes water to an aquifer. Normally considered to be the natural area of recharge, as contrasted with a constructed recharge basin.

recurrence interval: average amount of time between events of a given magnitude. For example, there is a 1% chance that a 100-year flood will occur in any given year; a runoff peak discharge which has a 5-year recurrence interval can be expected to be equaled or exceeded once every 5 years on the average. This is the same as saying that the peak discharge has a 20% chance of being equaled or exceeded once in any given year ($100\%/5 = 20\%$).

regional flow system: see *ground-water flow system*

regulated flow: surface flow downstream from a dam or other flow control structure.

reservoir capacity: amount of water a surface reservoir is capable of storing.

reservoir storage: water stored in a surface reservoir.

residence time: size of any specific reservoir or pool of mass (e.g., carbon) divided by the total flux of mass into or out of that pool.

return flow: part of water that is not consumed and returns to its source or another body of water.

return period: see *recurrence interval*.

riparian: of, or pertaining to, rivers and their banks.

riparian habitat: natural home of plants and animals occurring in a thin strip of land bordering a stream or river. Dominant vegetation often consists of *phreato-phytes*.

riparian rights: surface-water rights assigned on the basis of land ownership along a stream reach common in the western United States.

river basin: see *drainage basin*.

risk assessment: evaluation of the potential for exposure to contaminants and the associated hazard.

riverine system: entire river network, including tributaries, side channels, sloughs, intermittent streams, etc.

root zone: subsurface zone extending from the land surface to the maximum depth penetrated by roots.

runoff: drainage or flood discharge that leaves an area as surface flow or as pipeline flow, having reached a channel or pipeline by either surface or subsurface routes. Generally, surface water entering river, lakes, or reservoirs.

S

safe yield: (1) rate of surface-water *diversion* or ground-water extraction from a basin for *consumptive* use over an indefinite period of time that can be maintained without producing negative effects; (2) the annual extraction from a ground-water unit which will not, or does not, i. exceed the average annual recharge; ii. so lower the water table that permissible cost of pumping is exceeded; iii. so lower the water table as to permit intrusion of water of undesirable quality; or iv. so lower the water table as to infringe upon existing water rights; (3) the attainment and maintenance of a long-term balance between the amount of ground water withdrawn annually and the annual amount of recharge; (4) the maximum quantity of water that can be guaranteed from a reservoir during a critical dry period. Synonymous to *firm yield*.

saline water: water containing more than 10,000 parts per million (ppm) of dissolved solids of any type. *Brackish water* contains between 1,000 and 10,000 ppm of dissolved solids.

salinity: amount of dissolved salts in a given volume of water.

saltwater intrusion: movement of saltwater into freshwater aquifers.

saturated thickness: vertical thickness of an aquifer that is saturated with water.

self-organization: capacity of *ecosystems* to develop and evolve in a dynamic fashion within the constraints set by energy flow and *biogeochemical cycling*; ecosystems are formed in response to these fluxes, are maintained and developed by them, and will respond continuously to them through numerous *feedbacks*.

semiarid: said of a type of climate in which there is slightly more precipitation (10–20 inches [254–508 mm]) than in an *arid* climate, and in which sparse grasses are the characteristic vegetation.

senior appropriator: owner of a surface-water right whose right was acquired prior to other rights holders on the same stream.

sensitivity: in model application, the degree to which the model result is affected by changes in a selected model input representing hydrogeologic framework, hydraulic properties, or boundary conditions.

shortwave radiation: radiation received from the sun and emitted in the spectral wavelengths less than 4 micrometers. It is also called *solar radiation*.

silviculture: management of forest land for timber.

simulation: in ground-water-flow modeling, one complete execution of a ground-water-modeling computer program, including input and output.

sink: as used in resource management, a process whereby, or a feature from which, water or other substances are extracted from the system.

soil horizon: layer of soil or soil material approximately parallel to the land surface and differing from adjacent genetically related layers in physical, chemical, and biological properties or characteristics such as color, structure, *texture*, consistency, kinds and number of organisms present, degree of acidity or alkalinity, etc.

soil moisture: water in the root zone.

soil-water potential: energy with which water is held in a soil at any water content. It is the potential energy per unit quantity (unit mass, unit weight, or unit volume) of water in a system, compared to that of pure (no solutes), free water (no external forces other than gravity) at the same location (which represents the reference state of zero value). Potential energy is the energy of the water that is potentially available to be released when the water moves from one position to another. Because water is held in the soil by forces of adsorption, cohesion, and solution, soil water is not usually capable of doing as much work as pure free water; hence, the soil-water potential is normally negative. The soil-water potential can be considered as the sum of component potentials

such as *matric* or *capillary potential* (resulting from the capillary and adsorptive forces due to the soil matrix), *gravitational potential* (resulting from relative elevation differences), *osmotic potential* (resulting from the presence of solutes; it comes into play whenever a membrane or diffusion barrier is present that transmits water more readily than salts or solutes), and others. A soil-water *potential gradient* (which is the change of energy potential with distance) is required to cause fluid to flow. For some applications, certain combinations of component potentials are used so often that for ease of referring to them it is desirable to give the combination a name. For liquid water flow in soils, it is convenient to combine component potentials that serve as driving forces—pressure, matric, and gravitational potentials, and call the combination by the name of *hydraulic potential*. If the unit quantity is measured as weight, then the units of hydraulic potential are energy per unit weight, which are exactly equal to the units of *hydraulic head*.

solar constant: rate at which solar energy is received just outside the earth's *atmosphere* on a surface that is normal to the incident radiation and at the mean distance of the earth from the sun. The current value is 0.140 watt/cm².

solar irradiance: see *insolation*.

solar radiation: see *shortwave radiation*.

solum (plural: **sol**): upper and most weathered part of the soil profile; the A and B *soil horizons*.

solute-transport model: application of a model to represent the movement of constituents dissolved in ground water.

specific conductance: measure of the ability of a water to conduct an electrical current, expressed in *micromhos per centimeter* at 25°C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in *milligrams per liter*) is about 65% of the specific conductance (in micromhos/cm). This relation is not constant from supply to supply, and it may even vary in the same source with changes in the composition of the water.

specific discharge: for ground water, the rate of discharge of ground water per unit area measured at right angles to the direction of flow.

specific retention: ratio of the volume of water that a given body of rock or soil will hold against the pull of gravity to the volume of the body itself. It is usually expressed as a percentage. Compare with *field capacity*.

specific storage: volume of water released from or taken into storage per unit volume of the porous medium per unit change in head. It is the three-dimensional

equivalent of *storage coefficient* or *storativity*, and is equal to *storativity* divided by aquifer *saturated thickness*.

specific yield: fraction of a saturated bulk volume consisting of water that will drain by gravity when the water table drops; specific yield is less than *porosity* because some water is too strongly absorbed to the earth material to drain. The ability of an *unconfined or water-table aquifer* to store water is measured by its specific yield. Specific yield can be several orders of magnitude larger than the *storage coefficient*, thus producing more water when developed.

stage: elevation of stream surface above a defined datum, usually mean sea level.

steady-state flow: characteristic of a flow system where the magnitude and direction of *specific discharge* are constant in time at any point.

Steppes: see *prairie*.

stochastic: in subsurface fluid flow, consideration of subsurface media and flow parameters as random variables.

stochastic model: in subsurface fluid flow, a model representing ground-water parameters as random variables.

stochastic process: process in which the dependent variable is random (so that prediction of its value depends on a set of underlying probabilities) and the outcome at any instant is not known with certainty.

storativity or storage coefficient: volume of water released per unit area of aquifer and per unit drop in head. Storage coefficient is a function of the compressive qualities of water and matrix structures of the porous material. A *confined aquifer's* ability to store water is measured by its storage coefficient. Storativity is a more general term encompassing both or either storage coefficient and/or *specific yield*.

storm curve number: see *curve number*.

stratosphere: region of the upper atmosphere extending from the *tropopause* (8 to 15 km altitude) to about 50 km.

stream hydrograph: see *hydrograph*.

stream reach: specific portion of the length of a stream.

streamflow: discharge that occurs in a natural channel. A more general term than *runoff*, streamflow may be applied to discharge whether or not it is affected by *diversion* or regulation.

strong sustainability: view that, given the limits to substitution between some natural capital and other economic assets (such as *reproducible* or *human-made capital*), as well as the problems of irreversibility, uncertainty of threshold effects and the potential scale

of social costs associated with loss of certain environmental assets, *sustainable development* cannot be assured without imposing some conditions on the depletion of natural capital; for example, if some minimum level of *biodiversity* is essential for *ecosystem functioning* and resilience, preserving the economic opportunities available to future generations requires the prevention of biodiversity loss that threatens this minimum threshold level.

sublimation: transition of water directly from the solid state to the gaseous state, without passing through the liquid state; or vice versa.

substrate: (i) that which is laid or spread under; an underlying layer, such as the subsoil; (ii) the substance, base, or nutrient on which an organism grows; (iii) compounds or substances that are acted upon by enzymes or catalysts and changed to other compounds in the chemical reaction.

subsurface water: all water below the land surface, including *soil moisture*, *capillary fringe* water in the *vadose zone*, and *ground water*.

summer fallow: special case of fallowing in which all vegetative growth is prevented by shallow tillage in conjunction with or without herbicides during the summer months, in place of growing a crop, in order to store water for use by the next crop.

Superfund: see *CERCLA*.

surface-water diversion: see *diversion*.

sustainable development: economic and social development that increases the welfare of current generations without affecting adversely the welfare of future generations; for example future generations have economic opportunities that are at least as large as earlier generations. See *strong sustainability* and *weak sustainability*. Sustainable development by its very nature is a multidimensional concept. This concept involves not only the management and conservation of the natural resource-base, but also the social, institutional, technological, and cultural changes involved. Though it is extremely difficult to conceptualize ideally what sustainable development means, definition of sustainable development has to be sufficiently broad to be able to capture the various dimensions involved. See also *environmental sustainability*.

sustained (sustainable) yield: volume of ground water that can be extracted annually from a ground water basin without causing adverse effects.

systems analysis and **systems:** is the study of systems, groups of interacting, interdependent parts linked together by complex exchanges of energy, matter, and information. There is a key distinction between “classical” science and system science. Classical (or reductionist) science is based on the resolution of phenomena into isolatable causal trains and the search

for basic, “atomic” units or parts of the system. Classical science depends on weak or nonexistent interaction between parts and essentially linear relations among the parts, so that the parts can be added together to give the behavior of the whole. These conditions are not met in the entities called systems. A “system” is characterized by strong (usually nonlinear) interactions between the parts, feedbacks (making resolution into isolatable causal trains difficult or impossible), and the inability to simply “add-up” small-scale behavior to arrive at large-scale results. Ecological and economic systems obviously exhibit these characteristics of systems, and are not well understood using the methods of classical, reductionist science. One might define “systems analysis” as the scientific method applied both across and within disciplines, scales, resolutions, and system types.

T

terrestrial radiation: see *longwave radiation*.

texture (soil): relative proportions of sand, silt, and clay particles in a mass of soil.

thalweg: line of maximum depth in a stream. The thalweg is the part that has the maximum velocity and causes cutbanks and channel migration.

thermal pollution: reduction in water quality caused by increasing its temperature, often due to the disposal of waste heat from industrial or power generation processes. Thermally polluted water often undergoes biological changes that render it less valuable for drinking, recreation, habitat, or industrial use.

thermocline: fairly thin zone in a lake that separates an upper warmer zone (*epilimnion*) from a lower colder zone (*hypolimnion*).

thermohaline: refers to the combined effects of temperature and salinity that contribute to density variations in the oceans.

total dissolved solids (TDS): quantity of minerals (salts) in solution in water, usually expressed in milligrams per liter.

trace gas: minor constituent of *the atmosphere*. The most important trace gases contributing to the *greenhouse effect* are water vapor, carbon dioxide, *ozone*, methane, ammonia, nitric acid, nitrous oxide, ethylene, sulfur dioxide, nitric oxide, dichloro-fluoromethane or Freon 12, trichlorofluoromethane or Freon 11, methyl chloride, carbon monoxide, and carbon tetrachloride.

Tragedy of the Commons: idea that no one takes responsibility for things that everybody owns, generally associated with Garrett Hardin.

transition curve or **growth curve** or **response curve:** graph indicating the fraction of ground-water

pumpage derived from ground-water storage or a surface-water source plotted against time.

transmissivity: flow capacity of an aquifer measured in volume per unit time per unit width. Equal to the product of *hydraulic conductivity* times the *saturated thickness* of the aquifer.

transpiration: vaporization of water given off by plants.

tropopause: boundary between the troposphere and the stratosphere (about 8 km in polar regions and about 15 km in tropical regions), usually characterized by an abrupt change of *lapse rate*. The regions above the troposphere have more increased atmospheric stability than those below. The tropopause marks the vertical limit of most clouds and storms.

troposphere: inner layer of the atmosphere below about 15 km, within which there is normally a steady decrease of temperature with increasing altitude. Nearly all clouds form and weather conditions manifest themselves within this region, and its thermal structure is caused primarily by the heating of the earth's surface by *solar radiation*, followed by heat transfer by turbulent mixing and convection.

turnover rate: fraction of the total amount of mass (e.g., carbon) in a given pool or reservoir that is released from or that enters the pool in a given length of time. The turnover rate of carbon is often expressed as gigatons carbon (GtC)/year.

U

ultraviolet (UV) radiation: type of *shortwave radiation* that is damaging to plants and animals, including humans. The amount of UV radiation that reaches the earth depends on the amount of stratospheric *ozone*. An increase in UV radiation due to a decrease in stratospheric ozone will pose a direct threat to human health (increased cataracts, immune suppressions, and skin cancers) and will have a negative impact on plant yields for many species.

UNCED: United Nations Conference on Environment and Development. Held in Rio de Janeiro, June, 1992. Also referred to as the *Earth Summit*.

unconfined (or water-table) aquifer: aquifer in which the water table is at the upper boundary of the ground-water-flow system that is at atmospheric pressure.

unconsolidated deposits: sediment that is loosely arranged or unstratified, or whose particles are not cemented together.

underfit river: see *misfit river*.

underflow: (1) ground-water flow within a streambed below a surface stream; (2) lateral movement of water through the soil zone, also known as *interflow*.

unsaturaze zone: see *vadose zone*.

upconing: process by which saline water underlying freshwater in an aquifer rises upward into the freshwater zone as a result of pumping water from the freshwater zone.

V

vadose zone: unsaturated (not completely filled with water) zone lying between the earth's surface and the top of the ground water. Also known as *unsaturated zone* and *zone of aeration*.

Veldt: see *prairie*.

vested right: right to continue the use of water having actually been used for a beneficial use on or before June 28, 1945, when the *Kansas Water Appropriation Act* became effective.

void: pore space or other openings in rock. The openings can be very small to cave size and are filled with water below the *water table*.

volative organic compound (VOC): organic chemical that volatilizes (evaporates) relatively easily when exposed to air.

volume flux: see *flux*.

W

wadi: steep-sided valley, rocky ravine, river bed, or gully that is usually dry in a semi-desert or desert area of the Sahara and the Arab countries of southwest Asia.

waldsterben: German word meaning forest death and used to describe the rapid decline and death of large areas of trees. It is thought to be a result of ozone pollution that damages the leaves of trees, resulting in stunted growth and an inability to regenerate. More than half of Germany's forests are affected, as well as extensive areas in most other European and Scandinavian countries. The main cause is considered to be pollution from vehicle exhausts.

water demand: amount of water used over a period of time at a given price.

water quality: physical, chemical, and biological characteristics of water and how they relate to it for a particular use.

water potential: see *soil-water potential*.

water right: any *vested* or *appropriation* right under which a person may lawfully divert and use water. It is a real property right *appurtenant* to and severable from the land on or in connection with which the water is used; such water right passes as an appurtenance with a conveyance of the land by deed, lease, mortgage, will, or inheritance.

water table: upper boundary of a free ground-water body, at atmospheric pressure.

water transfer: legal change in a *water right* reflecting some combination of a change in ownership of *diversion*, place of use, and/or type of use to another.

Water Use Efficiency (WUE): ratio of crop *biomass* accumulation or yield to the amount of water used in *evapotranspiration*.

water vapor: water present in *the atmosphere* in gaseous form; the source of all forms of condensation and precipitation. Water vapor, clouds, and carbon dioxide are the main atmospheric components in the exchange of *terrestrial radiation* in the *troposphere* serving as a regulator of planetary temperatures via the *greenhouse effect*. Approximately 50 percent of the atmosphere's moisture lies within about 1.84 km of the earth's surface, and only a minute fraction of the total occurs above the *tropopause*.

water-vapor feedback: process in which an increase in the amount of water vapor increased the *atmosphere's* absorption of *longwave radiation*, thereby contributing to a warming of the atmosphere. Warming, in turn, may result in increased evaporation and an increase in the initial water vapor anomaly. This feedback, along with carbon dioxide, is responsible for the *greenhouse effect* and operates virtually continuously in the atmosphere.

water year: 12-month period of which the U.S. Geological Survey reports surface-water supplies. Water years begin October 1 and end the following September 30, and are designated by the calendar year in which the water year ends.

watershed: that surface area which drains to a specified point on a water course, usually a confluence of streams or rivers.

watershed approach: is the application of *integrated watershed management* in the planning and implementation of resource management and rural development projects or as part of planning for specific resource sectors such as agricultural, forestry, or mining. Imbedded in this approach is the linkage between uplands and lowlands in both biophysical and socioeconomic contexts.

WCED (World Commission on Environment and Development): United Nations commission, also known as the *Brundtland Commission*, which garnered almost worldwide political consensus on the urgent need for sustainability; its findings are pub-

lished in the widely acclaimed report "Our Common Future" (1987).

weak sustainability: view that sustainable development can be assured through the conservation of aggregate capital alone; that is, although *natural capital* is being depleted, it is being replaced with even more valuable *human-made capital* and thus the value of the aggregate stock—comprising both human-made and the remaining natural capital—is increasing over time in terms of its ability to maintain or enhance human welfare.

weather: day-to-day variation in atmospheric conditions. Compare *climate*.

weather generator (stochastic): program that generates weather values for daily precipitation, temperatures, and solar radiation based on observed historical patterns.

weather modification: deliberate modification of weather so as to increase precipitation and thereby increase water supplies. **Cloud seeding** is the most common method of weather modification.

well yield: see *yield*.

wetland: land with a wet spongy soil, where the *water table* is at or above the land surface for at least part of the year.

Y

yield: amount of water that can be supplied from a reservoir, *aquifer*, *basin*, or other *system* during a specified interval of time. This time period may vary from a day to several years depending upon the size of the system involved. *Well yield:* maximum pumping rate that can be supplied by a well without drawing the water level in the well below the pump intake. *Aquifer yield:* maximum rate of withdrawal that can be sustained by an aquifer. *Basin yield:* maximum rate of withdrawal that can be sustained by the complete hydrogeologic system in a basin without causing unacceptable declines in *hydraulic head* anywhere in the system or causing unacceptable changes to any other component of the *hydrologic cycle* in the basin.

Z

zone of aeration: see *vadose zone*.