Designation: E2728 – 11

Standard Guide for Water Stewardship in the Design, Construction, and Operation of Buildings[1]

This standard is issued under the fixed designation E2728; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide is intended to inform sustainable development in the building industry. It outlines ideal sustainability and applied sustainability for water management, consistent with Guide E2432. Both ideal sustainability and applied sustainability should inform decisions regarding water management.

1.1.1 Ideal sustainability is patterned on the hydrological cycle. This provides the concept goals and direction for continual improvement.

1.1.2 Applied sustainability outlines current best practices. This identifies available options considering environmental, economic, and social opportunities and challenges. The most appropriate option(s) are likely to vary depending on the location of the project.

1.2 Water management challenges differ enormously depending on the type of built environment and the available water resources.

1.2.1 The general demands of the built environment vary from very low density rural development to crowded urban development. Large cities present a particular challenge, with 400 cities worldwide housing over 1 million inhabitants.

1.2.2 Successfully meeting the challenges of uneven distribution of water around the world, depletion of groundwater, changing rainfall patterns, and other water industry trends requires sustainable solutions for the effective management of the entire water cycle.

1.2.3 Sustainable design, construction, and operation of water and wastewater services for the built environment are critical components of water stewardship and global sustainable water management.

1.3 Water stewardship encompasses both pollution prevention (quality issues) and conservation (quantity issues).

1.4 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2114 Terminology for Sustainability Relative to the Performance of Buildings

E2348 Guide for Framework for a Consensus-based Environmental Decision-making Process

E2432 Guide for General Principles of Sustainability Relative to Buildings

E2635 Practice for Water Conservation in Buildings Through In-Situ Water Reclamation

2.2 *Other Reference Documents:*

WaterSense [3]

WWAP World Water Assessment Programme[4]

3. Terminology

3.1 *Definitions*—For terms related to sustainability relative to the performance of buildings, refer to Terminology E2114.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *effluent, n*—wastewater, treated or untreated, that flows out of a treatment plant, sewer, industrial facility, or constructed source.

3.2.2 *emerging pollutant, n*—substances that have been recently discovered or determined to contaminate the environment.

3.2.2.1 *Discussion*—Emerging pollutants may include endocrinial disruptors, persistant organic pollutants, and pharmeceuticals.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from United States Environmental Protection Agency (EPA), Ariel Rios Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov/watersense.

[4] Programme Office for Global Water Assessment, UNESCO, Villa La Colombella - Località di Colombella Alta, 06134 Colombella (PERUGIA), Italy, http://www.unesco.org/water/wwap.

3.2.3 *Environmental Management System (EMS), n*—procedures for identifying, managing, and improving the environmental impacts of an organization, facility, product, or service, or a combination thereof.

3.2.3.1 *Discussion*—Fundamental to an EMS is implementation of a plan-do-check-act approach that documents current performance levels and facilitates continual improvement.

3.2.4 *green infrastructure, n*—an array of products, technologies, and practices that use natural systems, or engineered systems that mimic natural processes, to enhance overall environmental quality and provide utility services.

3.2.4.1 *Discussion*—As a general principal, Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, or recycle stormwater runoff, or a combination thereof; examples include: green roofs, porous pavement, rain gardens, and vegetated swales.

3.2.5 *hydrologic cycle, n*—the continuous circulation of water on, under, and over the Earth's surface.

3.2.6 *nonpotable water, n*—water that has not been treated for human consumption in conformance with applicable drinking water quality regulations.

3.2.7 *Persistent Organic Pollutant (POP), n*—an organic compounds of natural or anthropogenic origin that resists photolytic, chemical, and biological degradation and is characterized by low water solubility and high lipid solubility, resulting in bioaccumulation in fatty tissues of living organisms.

3.2.7.1 *Discussion*—POPs are transported in the environment in low concentrations by movement of fresh and marine waters and they are semi-volatile, enabling them to move along distances in the atmosphere, resulting in wide-spread distribution across the earth, including regions where they have never been used. The United Nations Environment Programme (UNEP) Governing Council, at its nineteenth session in February 1997, identified 12 POPs: Aldrin, Chlordane, Dieldrin, DDT, Endrin, Heptachlor, Hexachlorobenzene, Mirex, Toxaphene, PCBs, Dioxins, and Furans.

3.2.8 *potable water, n*—water that does not endanger the lives or health of human beings and that conforms to applicable regulations for drinking water quality.

3.2.9 *wastewater, n*—the spent or used water from a home, community, farm, or industry that contains dissolved or suspended matter.

3.2.10 *water efficiency, n*—refers to measures, practices, or programs that reduce the water used by specific devices and systems, typically without affecting the services provided.

3.2.11 *water stress, n*—refers to consumption of water that exceeds available water resources.

3.2.11.1 *Discussion*—UNEP considers countries where consumption exceeds 10 % of total supply to be in a water-stressed condition.

3.2.12 *watershed, n*—the land area that drains into a stream; the watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point.

3.2.13 *watershed approach, n*—coordinated framework for environmental management that focuses public and private efforts on the highest priority problems within hydrologically-defined geographic areas taking into consideration both ground and surface water flow.

4. Significance and Use

4.1 Supply of fresh water is limited and demand is increasing.

4.1.1 The United Nations Population Fund estimates that only 2.5 percent of the water on the Earth is fresh, and only about 0.5 percent is accessible ground or surface water.

4.1.2 While world population tripled in the 20th century, the use of water increased six-fold. The United Nations estimates that in the year 2017, close to 70 percent of the global population will have problems accessing fresh water. Additionally, more than 2 billion people around the world lack basic sanitation facilities.

4.1.3 According to WWAP, agriculture use accounts for 70 percent of annual worldwide water use, industrial use accounts for 22 percent and domestic use accounts for 8 percent (**1**).[5]

4.2 Increased demand has put additional stress on water supplies and distribution systems, threatening both human health and the environment.

4.3 Increased demand has intensified energy use and the associated greenhouse gas emissions. Significant energy is expended for treatment and distribution of water. According to WaterSense, American public water supply and treatment facilities consume about 56 billion kilowatt-hours (kWh) per year—enough electricity to power more than 5 million homes for an entire year. In California, an estimated 19 percent of electricity, 32 percent of natural gas consumption, and 88 billion gallons of diesel fuel annually power the treatment and distribution of water and wastewater (**2**).

4.4 The building industry diverts an estimated 16 percent of global fresh water annually (**3**). It is imperative that design and construction address water efficiency. The estimate of annual usage of available fresh water by the building industry accounts for the quantity of water that is required to manufacture building materials and to construct and operate buildings. It does not reflect the impact of the building industry on the quality of water.

4.5 This guide provides information regarding ideal sustainability and water use.

4.6 This guide provides general options for applied sustainability and water use.

5. Ideal Sustainability

5.1 *Stewardship*—Ideal stewardship would pattern use on natural cycles and processes.

5.1.1 *Quantity*—While water may be temporarily diverted from the hydrologic cycle, no measurable difference in total inflows and outflows to a site would be made.

[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

5.1.2 *Quality*—While water may be temporarily contaminated, such contamination would not exceed the natural purification capacity of the hydrologic cycle. No measurable degradation of water quality leaving a site would be made.

5.2 *Hydrologic Cycle:*

5.2.1 The Earth's water is continuously moving into and out of various reservoirs, including the atmosphere, land, surface water, and groundwater. The water moves from one reservoir to another by the physical processes including; evaporation, condensation, precipitation, infiltration, surface flow, and subsurface flow. In so doing, the water goes through different phases: liquid, solid, and gas. (See Fig. 1.)

5.2.2 The amount of time it takes to change the physical state of water can take less than a second or more than a million years. (See Fig. 2.)

5.2.3 Although many processes exist in nature to transform the physical state of water, the quantity of water remains the same as it is transported through the environment in a continuous cycle.

5.3 *Natural Purification*—As water moves through the hydrologic cycle it tends to be purified. Many separate processes contribute to this purification, including:

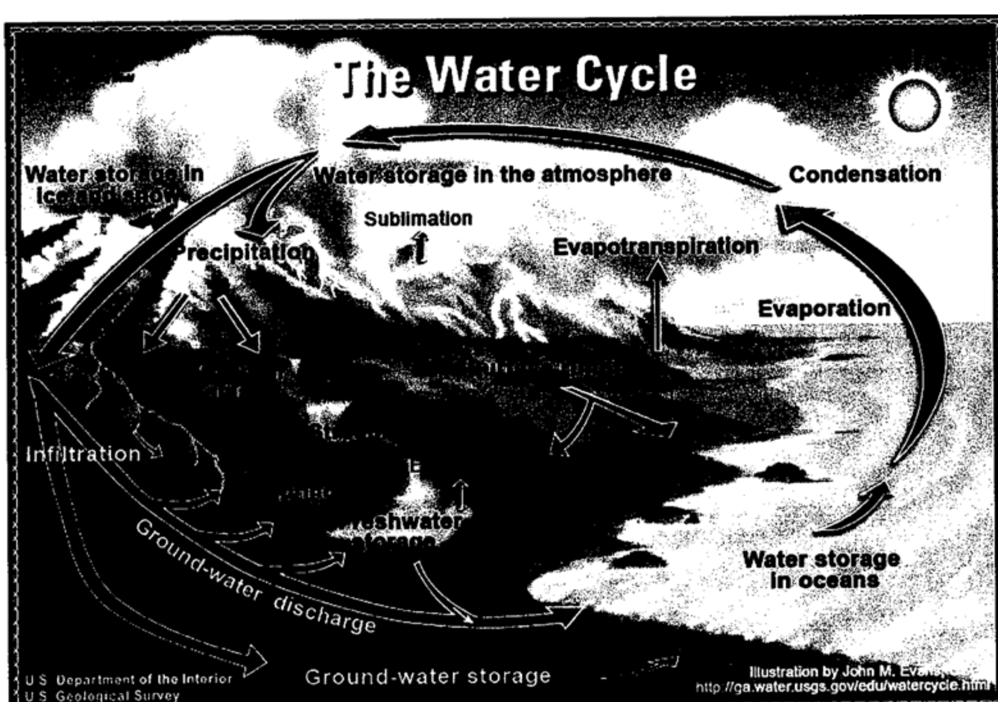
5.3.1 *Distillation*—Evaporation of sea water leaves salts behind. This world-wide distillation process results in rain water containing only traces of nonvolatile impurities, along with gases dissolved from the air.

5.3.2 *Aeration*—Surface flow that trickles over rocks allows volatile impurities, previously dissolved from mineral deposits or other sources, to be released into the air. Aeration also promotes rapid growth of microscopic plant and animal organisms that use certain water contaminants for food and energy.

5.3.3 *Sedimentation*—Solid particles settle to the bottom of slow moving or deep waterbodies, or both. Wetlands and streamside (riparian) forests are particularly important for removing fine sediments from runoff. As sediment-laden water moves across and through these ecosystems, 80 – 90 percent of the fine particles settle to the bottom or are filtered out. Other pollutants such as organics, metals, and radionuclides (radioactive elements) are often adsorbed by (stuck onto) silt particles. Settling of the silt removes these pollutants from the water.

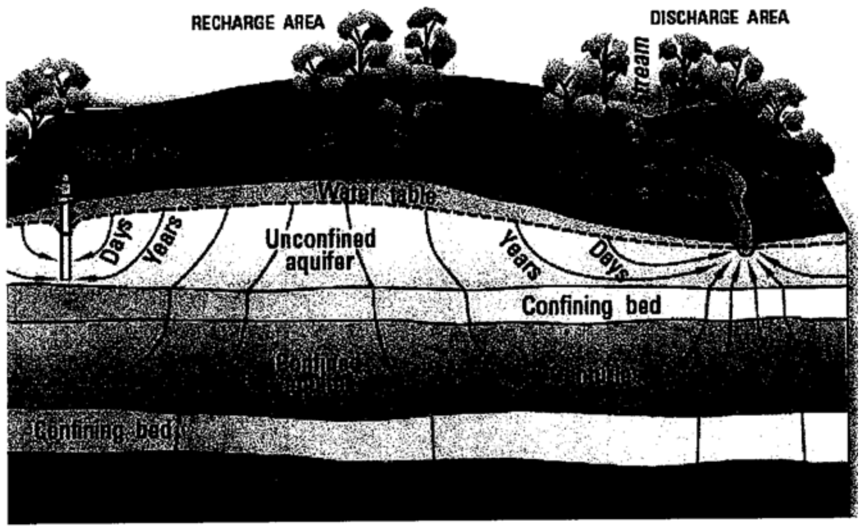
5.3.4 *Filtration*—When water moves through sand, suspended matter such as silt and clay is removed.

5.3.5 *Dilution*—Dilution with relatively pure water can reduce the concentration of many pollutants to harmless levels. However, small amounts of some pollutants can contaminate large quantities of water. For example, a single quart of hydraulic fluid can contaminate 250 000 gallons of ground water. Chemicals that leach into groundwater can remain there long after the chemical is no longer used. The pesticide dichlorodiphenyltrichloroethane (DDT) is still found in groundwater in the United States even though its use was banned more than 30 years ago. Like pesticides, volatile organic compounds (VOCs) are pervasive and commonly found in groundwater supplies. Twenty-nine percent of wells tested in urban areas contained multiple VOCs; overall a total



NOTE 1—U.S. Geological Survey, *The Water Cycle*, http://ga.water.usgs.gov/edu/watercvcle.html (accessed January 1, 2011).

FIG. 1 The Water Cycle



NOTE 1—U.S. Geological Survey, *The Water Cycle Discharge*, http://ga.water.usgs.gov/edu/watercyclegwdischarge.html (accessed January 1, 2011).

FIG. 2 Ground Water Flows Underground

of 46 different kinds of VOCs turn up in groundwater analyses. The health implications of these combinations of compounds are unknown (**4**).

5.3.6 *Bioremediation*—The layer of bacteria, fungi, and algae that covers underwater surfaces accumulate or break down, or both, organics and many pollutants. Healthy microbial assemblages in soil and on surfaces in water change the form (and possibly the toxicity) of pesticides and can remove heavy metals. Wetlands can remove 20 – 60 percent of heavy metals in the waters moving through them.

6. Applied Sustainability

6.1 Where ideal sustainability provides a concept goal, applied sustainability provides options for best practices. These options are based on current scientific knowledge and available technologies. They are informed by ideal sustainability.

6.1.1 There is still much that is not understood about how aquatic and terrestrial ecosystems provide water purification. Factors such as location, size, type of soil and vegetation, water flow (patterns and extremes), and the landscape in which the ecosystem exists are all important. But predicting how much and what type of materials and pollutants can be purified within a natural ecosystem—without permanently harming the ecosystem—is complex.

6.2 *Quantity Impacts*—Approximately one third of the world's population already lives in water stressed conditions. If present trends continue, two out of every three people on Earth will live in that condition by 2025 (**5**). According to the EPA, at least 36 states are anticipating local, regional, or statewide water shortages by 2013 (WaterSense).

6.2.1 *Conservation*—A successful water conservation program typically includes a comprehensive water management plan. This plan should provide clear information about how a facility uses its water, from the time it is piped onto the facility through its ultimate disposal. The plan should include information about source water, including local water and wastewater infrastructure capabilities, surface and ground water resources, watershed(s) related to the facility and the facilities' water sources, and community water demands. If the facility has an EMS, the water management plan should be a consistent part of the EMS. U.S. Federal Water Use Indices that may be useful in establishing a water budget for a facility are identified in Appendix X2.

6.2.2 Building design, construction, and operation that improves water conservation include a range of water efficient materials and methods. Examples are as follows:

6.2.2.1 *Water Efficient Fixtures and Equipment*—A variety of high efficiency options exist.

NOTE 1—In response to the requirements set forth in previous Executive Order (EO) 13123, which required federal agencies to reduce water use through cost-effective water efficiency improvements, U.S. Department of Energy Federal Energy Management Program (FEMP) developed BMPs for water. In response to EO 423 and to account for recent changes in technology in water use patterns the EPA's WaterSense Office has updated the original BMPs. The updated BMPs below were developed to help federal agency personnel achieve water efficiency goals of EO 13423 (**6**).

Some of the most common options are identified and described by the FEMP and include best management practices for:

(a) Toilets and Urinals
(b) Faucets and Showerheads
(c) Boiler/Steam Systems
(d) Single-Pass Cooling Equipment
(e) Cooling Tower Management
(f) Commercial Kitchen Equipment
(g) Laboratory/Medical Equipment

6.2.2.2 *Water Efficient Site Planning and Landscaping*—Water-efficient landscapes using native and other climate appropriate landscape materials can reduce irrigation water use by more than 50 percent. In many instances, after plant establishment, no supplemental irrigation will be necessary. Where necessary, water efficient irrigation should be incorporated. The American Society of Landscape Architects (ASLA) outlines sustainable approaches to landscaping in the ASLA Code of Environmental Ethics (**7**) and ASLA Public Policies (**8**).

6.2.2.3 Operation and Maintenance: A distribution system audit, leak detection, and repair program can help facilities reduce water losses and make better use of limited water resources. The American Water Works Association (AWWA) provides general information on water loss control and audit methodology (**9**).

6.2.3 *Alternate Water Sources*—Rainwater harvesting and water reclamation and reuse offer effective means of conserving the Earth's limited high-quality freshwater supplies while helping to meet the ever growing demands for water in residential, commercial, and institutional development. Refer to Practice E2635.

6.2.4 *Aquifer Recharge*—In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. In coastal areas, aquifers can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation. To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means. Aquifer recharge with treated wastewater is likely to increase in future because it can:

6.2.4.1 Restore depleted groundwater levels.

6.2.4.2 Facilitate water storage during times of high water availability.

6.2.4.3 Provide a barrier to saline intrusion in coastal zones.

6.3 *Quality Impacts*—Degradation of freshwater resources can affect the availability of potable water. It can have negative effects on human health. It can have negative effects on functionality of ecosystems. Water stewardship with regard to the quality of water should include: pollution prevention, remediation, watershed protection, ecosystem functionality, and integrated water resource management.

6.3.1 *Pollution Prevention*—Water is a universal solvent and so substances introduced at one point in the hydrologic cycle are likely to travel along with the water to the next point in the hydrologic cycle. Synthetic chemicals, from industrial byproducts to personal care products, often migrate to the hydrologic cycle. Pharmaceuticals, for example, are eventually excreted in altered or unaltered form, sending the compounds into the waterways. Additionally, emerging pollutants present new and varied challenges in both detection and remediation.

NOTE 2—Emerging pollutants are suspected of causing adverse effects in humans and wildlife. For example, pentabromobiphenylether, 4-nonylphenol, Cio-Cb chloroalkanes and the di(2-ethylhexyl)phthalate (DEHP) have been listed as priority hazardous substances in the field of water policy by EC Water Directive 2000/60/EC and the final EU decision No. 2455/2001/EC. Active hormonal substances (natural hormones are active at levels of ng/1) are being widely used in human and veterinary medicine such as estrogens, anti-inflammatory cortico-steroids and anabolic androgens (**10**).

6.3.1.1 Where substances may be introduced into the water infrastructure, the substances should not be detrimental to standard water treatment processes nor shall they create POPs.

6.3.1.2 Where materials may be introduced into natural water systems, the materials should not be detrimental to the functionality of the ecosystem. Consideration and assessment of potential pollutants should include substances that may dissolve in water and migrate through the hydrologic cycle or the food chain, or both; and it should include consideration of materials that are not biodegraded but may disintegrate into very small pieces causing problems for aquatic life.

6.3.2 *Remediation and Mitigation*—Where degradation is identified, efforts should be made to restore water quality and the condition of the natural resource.

6.3.3 *Watershed Protection*—Stormwater runoff and other discharges into a watershed can pollute water resources.

NOTE 3—An EPA 2004 report to Congress estimated that 850 billion gallons of storm water mixed with raw sewage pour into U.S. waters every year from older, combined sewer systems that were designed to overflow in wet weather. These combined systems, built by cities in the 19th and early 20th centuries, are now considered antiquated and a threat to public health and the environment, according to the EPA and environmental groups.

An additional 3 billion to 10 billion gallons of raw sewage spill accidentally every year from systems designed to carry only sewage, according to the 2004 report (**11**).

Facility design, construction and operation activities should proactively address potential impacts on the watershed.

6.3.4 *Ecosystem Functionality*—In the efforts to secure and manage fresh water for human needs, consideration should be provided to the water needs of freshwater species and ecosystems as well. Freshwater species are now five times more endangered than terrestrial species. Healthy freshwater ecosystems provide valuable natural services—such as water purification, plant and animal foods, flood control, recreation, nutrient cycling, and biodiversity maintenance—that are can be lost with improper water management (**12**). Care should be taken to maintain adequate water flows through the natural hydrologic cycle to maintain aquatic ecosystems. A wide range of human uses and transformations of freshwater or terrestrial environments has the potential to alter, sometimes irreversibly, the integrity of freshwater ecosystems (extracted from (**13**)). Refer to Table 1.

6.3.5 *Water Resource Management*—An integrated approach to freshwater management offers the most comprehensive means of reconciling competing demands. Watersheds or river basins provide the obvious boundaries in which to develop integrated plans - plans that must transcend political boundaries in many cases. A Consensus-based Environmental Decision-making (CBED) process may be helpful in developing a viable management plan. Refer to Guide E2348 for a CBED framework appropriate to environmental decisions that may affect a community or communities.

7. Keywords

7.1 building; green building; reclaimed water; sustainability; sustainable building; water conservation; water reuse; water stewardship

TABLE 1 Impacts of Building Related Activities on Aquatic Ecosystems

Activity	Potential Impact	Function at Risk
Population and consumption growth	Increases water abstraction and acquisition of cultivated land through wetland drainage. Increases requirement for all other activities with consequent risks.	Virtually all ecosystem functions including habitat, production and regulation functions.
Infrastructure development (dams, dikes, levees, diversions etc.)	Loss of integrity alters timing and quantity of river flows, water temperature, nutrient and sediment transport and thus delta replenishment, blocks fish migrations.	Water quantity and quality, habitats, floodplain fertility, fisheries, delta economies.
Land conversion	Eliminates key components of aquatic environment, loss of functions; integrity, habitat and biodiversity, alters runoff patterns, inhibits natural recharge, fills water bodies with silt.	Natural flood control, habitats for fisheries and waterfowl, recreation, water supply, water quantity, and quality.
Introduction of exotic species	Out competition of native species, alters production and nutrient cycling, loss of biodiversity.	Food production, wildlife habitat, recreation.
Release of pollutants to land, air, or water	Pollution of water bodies alters chemistry and ecology of rivers, lakes, and wetlands. Greenhouse gas emissions produce dramatic changes in runoff and rainfall patterns.	Water supply, habitat, water quality, food production. Climate change may also impact hydropower, dilution capacity, transport, flood control.

APPENDIXES

(Nonmandatory Information)

X1. ECOSYSTEMS VALUE

X1.1 The multiple roles of the aquatic ecosystems, called ecosystems services, confer an economic value to water (see Table X1.1). Global and per hectare values of ecosystems have been calculated based on the estimation of the indirect values of the aquatic ecosystems in flood control, groundwater recharge, shoreline stabilization and shore protection, nutrition cycling and retentions, water purification, preservation of biodiversity, and recreation and tourism (extracted from **(14)**).

TABLE X1.1 Aquatic Ecosystem Values

Ecosystem Type	Total Value per Hectare (US$/year)	Total Global Flow Value (US$ billion/year)
Tidal marsh/mangrove	6 075	375
Swamps/floodplains	9 990	1 648
Lakes/rivers	19 580	3 231
Total		**5 254**

X2. U.S. FEDERAL WATER USE INDICES

X2.1 U.S. FEMP developed water use indices as a guide for U.S. agencies. These are rough estimates of water usage at different types of sites and should only be used to assist in determining baseline data when no other information is available about a site's water usage. Data represents gallons/unit/per day. (See Tables X2.1-X2.5.)

TABLE X2.1 U.S. Federal Water Use Indices — Commercial[A]

User	Unit	Range	Typical
Airport	Passenger	4–5	3
Apartment House	Person	100–200	100
Boarding House	Person	25–50	40
Hotel	Guest	40–60	50
	Employee	8–13	10
Lodging House and Tourist Home	Guest	30–50	40
Motel	Guest	25–40	35
Motel with kitchen	Guest	25–60	40
Laundry (self-service)	Machine	400–650	550
Office	Employee	8–20	15
Public Lavatory	User	3–6	5
Restaurant (Including Toilet)			
Conventional	Customer	8–10	9
Short-order	Customer	3–8	8
Shopping Center	Parking Space	1–3	8–13
	Employee	2	10
Open Space			
Non-Turf	Acre		785
Turf	Acre		1571

[A] Energy Efficiency and Renewable Energy, *U.S. Federal Water Use Indices*, http://wwwl.eere.energv.gov/femp/water/printable_versions/water_useindices.html (accessed January 1, 2011).

TABLE X2.2 U.S. Federal Water Use Indices — Recreational[A]

User	Unit	Range	Typical
Apartment, Resort	Person	50–70	60
Bowling Alley	Alley	150–250	200
Camp			
Pioneer Type	Person	15–30	25
With Toilet and Bath	Person	35–50	45
Day, with Meals	Person	10–20	15
Day, without Meals	Person	8–18	13
Trailer	Trailer	75–150	125
Campground	Person	20–40	30
Country Club	Members	80–125	100
	Employee	10–15	50
Dormitory (bunk house)	Person	20–45	35
Fairground	Visitor	1–2	3
Picnic Park with Flush Toilets	Visitor	5–10	6
Swimming Pool and Beach	Customer	5–15	10
	Employee	8–15	10
Visitor Center	Visitor	4–8	5

[A] Energy Efficiency and Renewable Energy, *U.S. Federal Water Use Indices*, http://wwwl.eere.energv.gov/femp/water/printable_versions/water_useindices.html (accessed January 1, 2011).

TABLE X2.3 U.S. Federal Water Use Indices — Institutional[A]

User	Unit	Range	Typical
Assembly Hall	Seat	2–4	3
Medical Hospital	Bed	80–150	120
	Employee	5–15	10
Prison	Inmate	80–150	120
	Employee	5–15	10
Rest Home	Resident	5–120	90
	Employee	5–15	10
School, Day			
With Cafeteria, Gym, and Showers	Student	15–30	25
With Cafeteria Only	Student	10–20	15
Without Café and Gym	Student	5–15	10
School, Boarding	Student	50–100	75

[A] Energy Efficiency and Renewable Energy, *U.S. Federal Water Use Indices*, http://wwwl.eere.energv.gov/femp/water/printable_versions/water_useindices.html (accessed January 1, 2011).

TABLE X2.4 U.S. Federal Water Use Indices — Volume Conversion[A]

NOTE 1—Conversion factors for U.S. Federal Water Use Indices.

1 gallon (gal)	=	8.34 pounds
1 cubic foot (ft^3)	=	7.48 gallons
1 unit (Ccf)	=	748 gallons
1 acre-foot (AF)	=	325 851 gallons
1 acre-foot (AF)	=	43 560 cubic feet
1 million gallons/day (MGD)	=	1 121 acre feet/year

[A] Energy Efficiency and Renewable Energy, *U.S. Federal Water Use Indices*, http://wwwl.eere.energv.gov/femp/water/printable_versions/water_useindices.html (accessed January 1, 2011).

TABLE X2.5 U.S. Federal Water Use Indices — Metric Conversions[A]

NOTE 1—Conversion factors for U.S. Federal Water Use Indices.

1 acre	=	0.4 hectares
1 gallon	=	3.8 litres
1 cubic foot	=	0.3 cubic metres

[A] Energy Efficiency and Renewable Energy, *U.S. Federal Water Use Indices*, http://wwwl.eere.energv.gov/femp/water/printable_versions/water_useindices.html (accessed January 1, 2011).

X3. U.S. GEOLOGICAL SURVEY—ESTIMATED USE OF WATER IN THE UNITED STATES IN 2000 (15)

X3.1 Estimates of water use in the United States indicate that about 408 billion gallons per day (one thousand million gallons per day, abbreviated Bgal/d) were withdrawn for all uses during 2000. This total has varied less than 3 percent since 1985 as withdrawals have stabilized for the two largest uses—thermoelectric power and irrigation. Fresh ground-water withdrawals (83.3 Bgal/d) during 2000 were 14 percent more than during 1985. Fresh surface-water withdrawals for 2000 were 262 Bgal/d, varying less than 2 percent since 1985.

X3.2 About 195 Bgal/d, or 48 percent of all freshwater and saline-water withdrawals for 2000, were used for thermoelectric power. Most of this water was derived from surface water and used for once-through cooling at power plants. About 52 percent of fresh surface-water withdrawals and about 96 percent of saline-water withdrawals were for thermoelectric-power use. Withdrawals for thermoelectric power have been relatively stable since 1985.

X3.3 Irrigation remained the largest use of freshwater in the United States and totaled 137 Bgal/d for 2000. Since 1950, irrigation has accounted for about 65 percent of total water withdrawals, excluding those for thermoelectric power. Historically, more surface water than ground water has been used for irrigation. However, the percentage of total irrigation withdrawals from ground water has continued to increase, from 23 percent in 1950 to 42 percent in 2000. Total irrigation withdrawals were 2 percent more for 2000 than for 1995, because of a 16-percent increase in ground-water withdrawals and a small decrease in surface-water withdrawals. Irrigated acreage more than doubled between 1950 and 1980, then remained constant before increasing nearly 7 percent between 1995 and 2000. The number of acres irrigated with sprinkler and microirrigation systems has continued to increase and now comprises more than one-half the total irrigated acreage.

X3.4 Public-supply withdrawals were more than 43 Bgal/d for 2000. Public-supply withdrawals during 1950 were 14 Bgal/d. During 2000, about 85 percent of the population in the United States obtained drinking water from public suppliers, compared to 62 percent during 1950. Surface water provided 63 percent of the total during 2000, whereas surface water provided 74 percent during 1950.

X3.5 Self-supplied industrial withdrawals totaled nearly 20 Bgal/d in 2000, or 12 percent less than in 1995. Compared to 1985, industrial self-supplied withdrawals declined by 24 percent. Estimates of industrial water use in the United States were largest during the years from 1965 to 1980, but during 2000, estimates were at the lowest level since reporting began in 1950. Combined withdrawals for self-supplied domestic, livestock, aquaculture, and mining were less than 13 Bgal/d for 2000, and represented about 3 percent of total withdrawals.

X3.6 California, Texas, and Florida accounted for one-fourth of all water withdrawals for 2000. States with the largest surface-water withdrawals were California, which had large withdrawals for irrigation and thermoelectric power, and Texas, which had large withdrawals for thermoelectric power. States with the largest ground-water withdrawals were California, Texas, and Nebraska, all of which had large withdrawals for irrigation.

X4. EUGRIS CLASSIFICATION OF EMERGING POLLUTANTS

X4.1 See Table X4.1.

TABLE X4.1 Emerging Pollutant Compound Classes[A]

Pharmaceuticals	Examples
Veterinary and Human Antibiotics	Trimethoprim, erytromycine, lincomycin, sulfamethaxozole
Analgesics, Anti-Inflammatory Drugs	Codeine, ibuprofen, acetaminophen, acetylsalicylic acid, diclofenac, fenoprofen
Psychiatric Drugs	Diazepam
Lipid Regulators	Bezafibrate, clofibric acid, fenofibric acid
b-blockers	Metoprolol, propanolol, timolol
X-ray Contrasts	Iopromide, iopamidol, diatrizoate
Steroids and Hormones	Estradiol, estrone, estriol, diethylstilbestrol
Personal Care Products Fragrances Sun-Screen Sgents Insect Repellents	Nitro, polycyclic and macrocyclic musks, Benzophenone, methylbenzylidene camphor N,N-diethyltoluamide
Antiseptics	Triclosan, Chlorophene
Surfactants and Surfactant Metabolites	Alkylphenol ethoxylates, 4-nonylphnol, 4-octylphenol, alkylphenol carboxylates
Flame Retardants	Polybrominated diphenyl ethers (PBDEs), Tetrabromo bisphenol A, C10-C13 chloroalkanes Tris (2-chloroethyl)phosphate
Industrial Additives and Agents	Chelating agents (EDTA), aromatic sulfonates
Gasoline Additives	Dialkyl ethers, MethyW-butyl ether (MTBE)

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