UTAH Master Naturalist

Watershed Investigations

Manual



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Welcome to Utah Master Naturalist!

Utah Master Naturalist was developed to help you initiate or continue your own personal journey to increase your understanding of, and appreciation for, Utah's amazing natural world. We will explore and learn about the major ecosystems of Utah, the plant and animal communities that depend upon those systems, and our role in shaping our past, in determining our future, and as stewards of the land.

Utah Master Naturalist is a certification program developed by Utah State University Extension with the partnership of more than 25 other organizations in Utah. The mission of Utah Master Naturalist is to develop well-informed volunteers and professionals who provide education, outreach, and service promoting stewardship of natural resources within their communities. Our goal, then, is to assist you in assisting others to develop a greater appreciation and respect for Utah's beautiful natural world.

"When we see the land as a community to which we belong,
we may begin to use it with love and respect." - Aldo Leopold

Participating in a Utah Master Naturalist course provides each of us opportunities to learn not only from the instructors and guest speakers, but also from each other. We each arrive at a Utah Master Naturalist course with our own rich collection of knowledge and experiences, and we have a unique opportunity to share that knowledge with each other. This helps us learn and grow not just as individuals, but together as a group with the understanding that there is always more to learn, and more to share.

This manual is your literary companion as you journey through a Utah Master Naturalist course. **Ideally, you'll become very familiar with the contents of this manual before the course starts**. That way, we can focus on applying this knowledge while we are out on field excursions. I hope you enjoy your time as a participant in a Utah Master Naturalist course, and that it truly helps you on that journey through our natural world.

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Table of Contents

Introduction

A water crisis has been brewing in Utah for some time. Utah is the second driest state in the nation, receiving an average of 13 inches of precipitation each year (Utah Division of Water Resources). Utah also has the second highest per capita consumption of water (293 gallons per person per day), 81% of which is used for irrigation (USGS Water Usage Data), in the United States.

Coupled with this high per capita water use, Utah's population growth is more than twice the national average - 29.6% versus 13.2% (U.S. Census Bureau Data). The population of Utah is expected to double prior to 2050. With 83% of Utah's population concentrated along the Wasatch Front, Utah is ranked as the sixth most urbanized state in the nation (Governor's Office of Planning and Budget). St. George, in the driest parts of Utah, has, at times, been the fastest growing metro area in the U.S. The population of St. George and the surrounding Washington County reached 126,000 people in 2006, which is an increase of 40% from 2000 (Deseret Morning News, 4/5/07). By 2015, St. George's population had reached 150,000 people, and the growth rate had slowed to 20% in the previous decade. Still, this is a large growth rate in a place that receives only 2-3 inches of rain each year.

Utah periodically experiences short-term droughts. However, due to factors including increased temperatures, less snowpack, and a growing population, it is projected that the Wasatch Front and St. George areas of Utah may not have enough water to meet their needs by 2025 (Salt Lake Tribune 2/22/07). If we look at water supplies, the demand will only increase while the ability to store and deliver water will become increasingly difficult.

Land use, such as residential development, often occurs within or near aquatic ecosystems, resulting in destruction of, or conflict with, these resources. In Washington County, the Staples family bought 44 acres of land next to a dry creek bed, which they developed into six houses. A few years after the houses were completed, intense rainstorms spurred a flashflood warning in the area. High volumes of water and mud flowed down the creek bed to the houses, which had, luckily, been evacuated. After the flashflood, one home was destroyed and the other five were uninhabitable; only one house was insured with flood insurance. Even though the area was a beautiful place to build homes the lack of familiarity with the functions of the creek bed were mostly to blame for this disaster.

A lack of knowledge about watershed functions and health has also led to significant alteration and damage to Utah's waters. Many non-native invasive species have been introduced to Utah's aquatic systems, sometimes intentionally. The common carp, which was introduced to Utah Lake in 1881 as an alternative to overfished native fish species, has caused rampant habitat destruction and has outcompeted native fish. Pollution, especially non-point source pollution, has had detrimental effects on not only the system in which it enters, but also to the rest of the watershed downstream. Sometimes, there are even conflicts related to multiple uses of our aquatic systems, such as providing habitat to aquatic wildlife versus building a dam. Approximately 70% of Utah's lakes are reservoirs, or artificial lakes created from damming rivers, many of which are used heavily for recreational purposes. Much of the damage done to water sources could have been prevented if a more detailed knowledge of aquatic ecosystems had been available.

Although environmental issues are prominent within Utah's politics, government regulation has sometimes been detrimental to environmental management. Despite having a state budget surplus of $1.6 billion in 2007, the Utah Department of Environmental Quality, the state agency charged with "safeguarding human health and quality of life by protecting and enhancing the environment," was asked to make budget cuts and has made $6.2 million in cuts since 2002. As a result, the state will not be able to maintain its environmental programs, which will likely result in the U.S. Environmental Protection Agency stepping in to assume control (Salt Lake Tribune 1/23/07). Meanwhile, areas of Utah have some of the worst air quality in the nation– Utah Division of Air Quality results from July 2, 2007, listed Salt Lake, Provo, and Ogden as the second, third and fourth dirtiest air in the nation. Ironically, the appropriations subcommittee asking UDEQ to make cuts considered it a "healthy exercise."

There is, at times, an apparent lack of consideration for alternatives to development. In a 2007 interview on Access Utah, a Utah Public Radio Program, Utah State Senator (District 6 - Salt Lake City) and Majority Leader Michael Waddoups stated that "we get as much water… as most of the rest of the country gets, but we get it all in the winter and it falls in the mountains, so we need to store it." It is unfortunate that one of our state's leaders can make such an uninformed statement. The mountain ranges in Utah get as much precipitation as much of the rest of the country, but WE (i.e., all of Utah) do not. In making the argument for development of the Bear River to meet water needs, Senator Waddoups also stated that he had not, in fact, read any of the recommendations by any of the groups who oppose the development of the Bear River. The Utah Rivers Council's recommendations include promoting conservation and transferring agricultural water shares to residential shares instead of simply building more reservoirs.

The Bear River Development Project, which proposes several new reservoirs along the Bear River, is still ongoing, and is expected to be completed in 2035. To illustrate the effects of perpetual water diversions, a team of Utah researchers led by Dr. Wayne Wurtsbaugh estimated in 2016 that Great Salt Lake, at the end of the Bear River Watershed, is about half of its expected area and 11 feet lower on average due to diversion of water for agricultural, industrial, and urban uses. This suggests a clear disconnect between policies and available water resources in Utah.

Important Naturalist Perspectives

What is a **naturalist**? Is a naturalist someone who has received formal training in natural history? Or, is a naturalist someone who simply appreciates nature? Knowledge of natural history helps us understand and explain what we see, but a lack of knowledge does not necessarily exclude someone from being a naturalist.

The only requirement for becoming a naturalist is a sense of curiosity. Perhaps the greatest tools that we can use to satisfy our curiosity are our five senses, for it is with these senses that we observe nature. While an absence of any one or two of these senses does not preclude one from being a naturalist, as we will see with E. O. Wilson, using and honing these senses are essential. Many naturalists use other tools to capture a particular moment in nature in order to revisit it again. These tools might include writing in journals, taking photographs, painting landscapes, or even collecting and identifying parts of nature to possibly learn more about it at a later time using reference materials. Each one of us has interests and abilities that are brought out and enhanced by using these tools.

No naturalist, living or dead, was born with an in-depth knowledge of the natural world. The pursuit of knowledge undertaken through exploring and learning about our natural world is a pursuit all of you, and the people listed below, were willing to initiate:

<u>E. O. Wilson</u>

Edward Osborne Wilson was born in Birmingham, Alabama, on June 10, 1929. Throughout his life, E. O. Wilson was fascinated with nature and eventually specialized in the study of ants. He soon expanded his research and started surveying all the ant species within Alabama. In 1949, he specialized in the study of fire ants and published his first paper while still an undergraduate. He earned his B.S. and M.S. degrees at the University of Alabama, and a Ph.D. from Harvard in 1955.

At Harvard, he became noted for his work dealing with the taxonomy of ants, as well as classifying species based on genetic divergence initiated by competition. Within a year, he was appointed to the faculty, and eventually as the curator of entomology of the University Museum where he worked until his retirement. Wilson's research extended beyond America into the South Pacific and Australia. His comparative studies were so complete that he soon earned the title of "Dr. Ant." His findings went further than life cycles and ecology, and he learned how ants, and other insects, communicated through the use of various chemicals known as pheromones. Recently, that research was instrumental in developing bio-control methods to attempt managing many insect species populations.

In 1967 he co-authored the *Theory of Island Biogeography*, which indicated that in order for species to succeed and remain diverse, there must be sufficient space for life functions and connecting corridors between wild areas. This theory affected the development and management of wildlife preserves.

In 1975, Wilson published a book entitled *Sociobiology: The New Synthesis*. Wilson defined **sociobiology** as "the systematic study of the biological basis of all social behavior." By applying evolutionary principles to understanding the social behavior of animals, including humans, Wilson established sociobiology as a new science field. He argued that all animal behavior, even that of humans, is influenced by genes and never entirely of free will. He called this concept the "genetic leash." By 1978, his book, *On Human Nature*, started to earn him more respect, and he was awarded a Pulitzer Prize. He is the author of several books (*The Ants* 1990; *The Diversity of Life* 1992; *Consilience* 1998; *Naturalist* 1994) and many articles (Sociobiology; The Insect Societies; The Diversity of Life; etc.) A few select quotes will reveal his admiration, and concern, for nature:

> "Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal."
>
> "If all mankind were to disappear, the world would regenerate back to the rich state of equilibrium that existed ten thousand years ago. If insects were to vanish, the environment would collapse into chaos."
>
> "Perhaps the time has come to cease calling it the "environmentalist" view, as though it were a lobbying effort outside the mainstream of human activity, and to start calling it the real-world view."

What most people don't know is that E. O. Wilson suffered from several physical setbacks throughout his life. As a child, he lost most of his hearing, possibly through a congenital defect, and then lost all sight in his right eye as a result of a fishing accident in which the spine of a fish pierced his pupil. In addition, Wilson was mildly dyslexic. As a result of these physical shortcomings, Wilson admitted that he was a terrible birder and herpetologist because he couldn't see or hear the birds or frogs. Even when faced with these difficult realizations, Wilson did not give up. Although he only had sight in his left eye, his vision proved to be better than 20/20. Eventually, Wilson realized that, by good fortune, he was well-adapted to finding minute crawling and flying insects and spent the rest of his careers studying, among many other things, ants.

According to E.O. Wilson, what makes a Naturalist? Above all else, E. O. Wilson advocates spending time in nature as the most important ingredient in becoming a naturalist.

<u>Rachel Carson</u>

Rachel Carson was born in Springdale, Pennsylvania, May 27, 1907. As most noteworthy naturalists, she spent much of her youth wandering the wetlands and forests of the family 65-acre farm. She developed a gift for writing as a child and was published in a children's magazine at age 10. This skill continued as she entered Pennsylvania College in 1925 where she eventually majored in biology. Four years later, she graduated and continued studies at Johns Hopkins University where she earned her M.A. in zoology in 1932.

Her writing skills as a naturalist helped her earn a position at the U.S. Bureau of Fisheries where she regularly wrote a radio script for a show entitled "Romance Under the Waters." This endeavor allowed Carson to continue her study of the ocean and broadcast her knowledge to the general public in layman's terms. It was here that opportunities were opened for her to express her ideals about conservation as she stated that people should consider always “the welfare of the fish as well as that of the fisherman.” Her ideas soon began to be published by syndicated newspapers.

In 1941 she authored her first book, *Under the Sea-Wind*. This was followed by other books and publications relating nature, conservation, and the sea. By 1951 she published *The Sea Around Us*, which was translated into 32 languages, and made the New York best-seller list for 81 weeks. By this time, writing had become her passion and, although she became chief editor for all Fish and Wildlife publications, she resigned her government position the next year to concentrate on educating the public through her books.

Fame was lauded upon her at the release of her 1962 book, ***Silent Spring***, where she documented the dangers to wildlife and the public caused by chemical pesticides such as DDT. The book was so powerful, and controversial, that President Kennedy read it and soon had a congressional committee investigating its claims. Although Carson was derided by the agrochemical industry, DDT was eventually banned and she became known as the mother of the modern environmental movement. In 1992, a panel of distinguished Americans declared *Silent Spring* the most influential book of the past 50 years.

Carson once stated, “Man’s endeavors to control nature by his powers to alter and to destroy would inevitably evolve into a war against himself, a war he would lose unless he came to terms with nature.” She died of cancer April 14, 1964, at the age of 57.

<u>John Wesley Powell</u>

Born March 24, 1834, in New York, John Wesley Powell left the school system at a young age to study with a local naturalist, George Crookham, after his parents moved the family to Ohio. Powell’s appreciation for nature quickly developed into a curiosity for plants, animals, geology and archaeology. The Powell family had strong anti-slavery beliefs and, by 1846, chose to farm in Wisconsin to avoid conflicts with neighbors. It was an excellent locale for 12 year-old John to explore the local woodlands and establish a fondness for the Native American cultures he met there. Perhaps the most notable physical feature of Powell was the loss of his right arm during the Civil War. Although that injury eventually ended his career in the military, it never seemed to present much of a hurdle regarding his future as an explorer, naturalist, and educator.

In 1869, he became the first white explorer to run boats through the Grand Canyon. This 3-month adventure to provide maps and survey information was perilous. Several boats and provisions were lost in the treacherous rapids along this 900-mile journey. He repeated this trip in 1871, adding a photographer and scientists to his crew. This second expedition produced valuable scientific information regarding principles of geology. The Green River also held allure for Powell. He studied its tributaries and descended down the Grand Staircase area. He also investigated the Virgin River area, sections of which are now included in Zion National Park. These river trips soon established Powell as a legend across the country and there was a demand for him to speak across the nation. The early 1870s provided him with opportunities to learn a great deal about the cultures of the Utes, Shoshone, and other Utah tribes while exploring through the State.

Eventually, he moved back to Washington, D.C., where he helped organize the U.S. Geological Survey in 1879, assisting in the development of national topographic maps. He also became the Director of Ethnology at the Smithsonian Institution, a position he held until his death in 1902.

By 1888, he became one of the founders of the National Geographic Society, and had authored several publications, including: “Canyons of the Colorado”; “Introduction to the Study of Indian Languages”; “Truth and Error, or the Science of Intellection”, and “Lands of the Arid Region.”

John Wesley Powell was, throughout his childhood, self-taught in the fields of botany, zoology, and geology. Later in life, after receiving several college degrees and while working as a professor at Illinois Wesleyan University, Powell still believed that being in nature itself was the most effective way to learn about the living world. As such, he used field trips as his main teaching method.

Powell developed a deep connection to the beauty of the Grand Canyon. He believed one could not possibly begin to appreciate or understand the beauty of the Grand Canyon without first seeing it in person. Additionally, in order to truly see the Grand Canyon, one must spend vast amounts of time exploring it. To him, words and pictures could not begin to adequately describe the place.

John Wesley Powell died in Maine on September 3, 1902, at the age of 68.

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Environmental Education

At this point, you might be asking yourself why we are learning about environmental education, especially if you are not employed as an educator? The answer to this question is fairly straightforward: Even if your occupation is not in education, the skills of an educator still apply to you. An educator is anyone who enjoys sharing their knowledge with others. So, if you enjoy volunteering at a local nature center or preserve, or you like to spend time outdoors exploring and sharing nature with family or friends, then you ARE an educator. By enrolling in the Utah Master Naturalist Program, you have made a commitment to become better stewards of Utah's natural world, and sharing your knowledge with others is an essential part of fulfilling that commitment.

Ultimately, we need to keep reminding ourselves why educating others about nature is important. Environmental education has tremendous potential to promote the conservation of our natural world by facilitating understanding and a greater appreciation for these resources, and the important ecological services it provides. A goal of environmental education, therefore, is to convey knowledge and experiences that promote greater environmental responsibility.

Promoting environmental responsibility requires that the audience:

1. **understands (perceives and feels) the state of the environment**;
2. is **motivated to respond** to the needs of the environment; and,
3. is **provided information and/or action skills** needed to respond to your message.

When developing and delivering education programs, therefore, consider how your message promotes support for the conservation and management of natural areas by **identifying the importance** of:

1. **natural resources or areas** to visitors and their quality of life;
2. **ecological health** at your site and at other natural areas for a sustainable future; and
3. **support for organizations** that conserve natural areas.

Hopefully, our efforts will help others understand the value of wild things and wild places, and share that enthusiasm with even more people. Only in this way will we be able to promote the conservation of natural areas, and the plants and wildlife they support, for future generations.

What is Environmental Education?

The first formal definition of **environmental education** (EE) was written by William B. Stapp, and appeared in the very first issue of the Journal of Environmental Education in 1969:

> "Environmental education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution." - *W. B. Stapp, 1969*

Stapp's definition emphasized knowing the facts about the environment as well as gaining an awareness of not only the problems that are faced, but also potential solutions to these problems. In addition, Stapp insisted that environmental education must also motivate people to take action to solve these problems.

Environmental Education gained international recognition in the 1972 U.N. Conference on the Human Environment held in Stockholm, Sweden. At this conference, environmental education was identified as a means to address the environmental issues worldwide. In 1975, this recommendation was addressed at the International Environmental Workshop in Belgrade, Yugoslavia. Participants at the United Nations Educational, Scientific, and Cultural Organization (UNESCO) workshop proposed a global framework for environmental education, which is referred to as the Belgrade Charter. The Charter's goal statement for environmental education, as seen below, has been generally accepted by environmental education professionals.

> "The goal of environmental education is to develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations, and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones."
> - *The Belgrade Charter, 1976*

A couple years after the Belgrade Charter was established, the world's first intergovernmental conference on environmental education adopted the Tbilisi Declaration (1978). The Tbilisi Declaration was based on the Belgrade Charter, and defined three main goals for environmental education:

1. To foster clear awareness of, and concern about, economic, social, political, and ecological interdependence in urban and rural areas;
2. To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment;
3. To create new patterns of behavior of individuals, groups, and society as a whole toward the environment.

These goals have served as the foundation upon which much of the environmental education work that has been done since. So, in addition to teaching about nature or the environment, environmental education also includes promoting environmental literacy, an increased sense of stewardship, and taking action. Based upon the definitions and goals of environmental education established in the Tbilisi Declaration, there are five major objectives of environmental education:

Awareness - to help social groups and individuals acquire an awareness of, and sensitivity to, the total environment and its allied problems.

Knowledge - to help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems.

Attitudes - to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.

Skills - to help social groups and individuals acquire the skills for identifying and solving environmental problems.

Participation - to provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems.

In addition, guiding principles were established to state that environmental education should:

1. consider the environment in its totality—natural, anthropogenic, technological and social (economic, political, cultural-historical, ethical, esthetic);
2. be a continuous lifelong process, beginning at the preschool level and continuing through all formal and nonformal stages;
3. be interdisciplinary in its approach, drawing on the specific content of each discipline in making possible a holistic and balanced perspective;
4. examine major environmental issues from local, national, regional, and international points of view so that students receive insights into environmental conditions in other geographical areas;
5. focus on current and potential environmental situations while taking into account the historical perspective;
6. promote the value and necessity of local, national, and international cooperation in the prevention and solution of environmental problems;
7. explicitly consider environmental aspects in plans for development and growth;
8. enable learners to have a role in planning their learning experiences and provide an opportunity for making decisions and accepting their consequences;

9. relate environmental sensitivity, knowledge, problem-solving skills, and values to every age, but with special emphasis on environmental sensitivity to the learner's own community in their early years;
10. help learners discover the symptoms and causes of environmental problems;
11. emphasize the complexity of environmental problems and thus the need to develop critical thinking and problem-solving skills;
12. utilize diverse learning environments and a broad array of educational approaches to teaching, learning about and from the environment with due stress on practical activities and first-hand experience.

The North American Association for Environmental Education's *Excellence in Environmental Education: Guidelines for Learning (Pre K-12)* identifies a core set of principles that should serve as a foundation for all environmental education:

Systems - Understanding each part of a system may be easy to do, but in order to understand the system as a whole we must first understand the relationships and interactions among the parts. Everything from the Milky Way Galaxy down to individual cells can be considered a system.

Interdependence - Quality of life for people is inextricably linked to environmental quality. Everything that we do affects the natural world, so in order to begin understanding these effects we must consider ourselves to be part of the natural world rather than outside it.

Sense of place - Beginning to learn about systems close to where we live allows us to explore and understand our immediate surroundings and then, eventually, expand our knowledge to larger systems and broader issues.

Integration and infusion - Environmental education works best when it is integrated with other disciplines, such as social sciences and language arts, rather than being treated as an entirely separate discipline.

Roots in the real world - The best way for people to develop an understanding of the natural world is to have a direct experience with the environment and the issues surrounding it.

Lifelong learning - The skills developed through environmental education, such as critical and creative thinking, decision making, and communication, are important for learning not just in school, but throughout our entire lives.

<u>Education vs. Advocacy</u>

Remember, the major objectives of environmental education are promoting awareness, knowledge, developing skills and attitudes (or values) related to the environment, and, finally, participating in environmental issues and solutions. Therefore, the basic premise of environmental education involves assisting people in making their own informed decisions about issues. **Advocacy**, in contrast, is the promotion of a predetermined idea, cause, or policy.

As an example, we might discuss the different perspectives related to the Bear River Development Project, such as how the goal is to meet the water needs of a growing population, or the potential impacts on the Great Salt Lake Ecosystem. But, as soon as we encourage people to write to their state representatives to vote in a particular manner, or even promote our own personal viewpoints, our efforts become advocacy. As another example, we may educate the public as to the loss of wetlands in Utah and their values to the environment, but if we tell them to not buy a house that was built on a wetland, that is advocacy.

<u>Goals and Objectives</u>

Environmental education cannot possibly succeed without establishing a goal. The **goal** can be thought of as the overall vision of what we want to accomplish or learn. Imagine leading students on a field trip without having any idea of what is to be learned. It would be a disaster from the start. For instance, a goal might be: “To understand adaptations to living in aquatic environments.”

How, exactly do we go about achieving our goal? How will we know if we have achieved that goal? **Objectives** are quantifiable steps by which we measure our success. For instance, objectives for our aquatic adaptations goal could include:

1. Collect three different aquatic invertebrates and examine them under the microscope, identifying body parts with unique adaptations for aquatic life.
2. Find three aquatic plants and describe their adaptations to living in saturated soils.
3. Examine a model of a fish and point out three features of its body that aid in swimming.

SMART Objectives: *(NAAEE, 2008, Nonformal Environmental Education Programs: Guidelines for Excellence)*

When developing goals for an educational program it’s important that objectives fit within a framework that maximizes learning potential. In creating learning objectives it is best to follow the SMART characteristics:

Specific - Describes an action, behavior, outcome, or achievement that is observable.

Measurable - Details quantifiable indicator(s) of progress toward meeting the goal (e.g., 70% of participants..., five or more...).

Audience - Names the audience (e.g., workshop participants, community members) and describes outcomes from the perspective of the audience (i.e., what the audience will be able to do).

Relevant - Is meaningful, realistic, and ambitious; the audience can (given the appropriate tools, knowledge, skills, authority, resources) accomplish the task or make the specified impact.

Time-bound - Delineates a specific time frame.

When writing objectives, we should use verbs that fit the educational level of our audience. In the table below important learning characteristics (top line) that should be incorporated in learning plans. Complexity of the action increases as we move down each column. *(Benjamin Bloom, 1956,Taxonomy of educational objectives: The classification of educational goals)*

Know	Comprehend	Apply	Analyze	Synthesize	Evaluate
Define	Discuss	Demonstrate	Distinguish	Design	Appraise
Record	Explain	Employ	Debate	Construct	Assess
List	Differentiate	Illustrate	Diagram	Create	Judge
Name	Identify	Translate	Calculate	Propose	Predict

Many of the audiences we interact with will have differing educational needs. Think about the difference between 4th and 5th graders in Utah. There are clearly established core curriculum objectives that state their educational needs. Even with a difference of only 1 year between the two audiences, there are major differences in educational needs.

Sometimes it’s very effective to let the audience set their own expectations for a program. By asking the audience what they would specifically like to learn about on, for instance, an interpretive tour of a riparian habitat, we are better able to meet the audience’s goals for the program.

Lastly, be flexible! If a group’s expectations are not being met, adjust the content of your program to fit their needs if you are able. This is especially easy to do for a program that has been delivered many times to several different audiences.

Learning Environments

Creating an environment for learning requires that all participants feel safe and comfortable. Building such an environment can be done by providing the following:

Physical Safety - It is important to establish a teaching environment in which the physical safety of a participant is not at risk. This often requires being able to gauge the abilities and limitations of one's audience. For instance, an interpretive tour for children might be planned close to existing facilities whereas adult might be more capable of walking greater distances. Even among adults, it is important to gauge the audience's abilities. It is poor planning to allow participants to lag behind and miss parts of the program because they cannot keep up.

Emotional Safety - When planning and delivering an educational program, it is also important to consider the emotional safety of the participants. This is perhaps most important when working with children. All audience members should be encouraged to participate in the program without fear of criticism or rejection. As an example, instead of responding to a participant's answer with "no, that's wrong," try something more like "that's close!" and then help the person work toward the answer that you are looking for. In addition, be patient while a student answers a question.

Establish Guidelines - Establishing guidelines at the beginning of a program in order to ensure the physical and emotional safety of the participants, such as staying in a group and allowing everyone a chance to speak without interruption, ensures that all participants are aware of the rules. One method that works well with children is to state the guidelines and then ask them to raise their hand if they agree to abide by the guidelines. At this point, the program cannot start unless ALL of the participants raise their hands. Then, if a child is observed violating one of the guidelines, we can gently remind them that they agreed to avoid that particular behavior.

Group Dynamics - Every group acts in a different way. Depending on the size and composition of the group, it may flourish or, in the case of a large group of 13 year-old boys, may descend into a re-enactment of Lord of the Flies in a short period of time. Personal experience suggests that individuals in smaller groups have a greater opportunity for learning. Also consider creating diverse groups based on gender and ability. Emphasizing interdependence among a group by making it necessary to use a diverse set of skills often promotes collaborative learning. Another simple technique in promoting effective group enthusiasm (at least among children) is allowing each group to create a group (or "team") name.

Learning Styles

There is no single approach to effective environmental education because the best strategies for effectively communicating will depend on the particular needs, backgrounds, and interests of your audience. Different approaches or styles of education, therefore, may be more effective with some audiences than with others. Young children, for example, are typically more responsive to forms of education that include active involvement. Even adults vary in learning styles. There are three principal learning styles, which describe the approaches or ways of learning that work best for different individuals. These include:

Auditory learners – learn by listening and respond well to verbal lectures and interactive discussions. Auditory learners key in on tone of voice, pitch, speed and other nuances to interpret the message. Written information may have little meaning until it is heard.

Visual learners – learn by seeing and look for cues and information provided in body language, facial expressions, or visual displays to help them assimilate information.

Tactile/kinesthetic learners – learn by moving, doing, and touching and respond best to a hands-on approach, such as actively exploring the physical world around them. They may find it hard to sit still for long periods and may become distracted by their need for activity and exploration.

Although there may exist a dominant form of learning that an individual responds to, most people use all of these forms of learning simultaneously. Incorporating multiple learning strategies in environmental education, therefore, will increase the likelihood that your education program will be successful in getting your message across.

Instructional Techniques

There are several instructional methods that we can use to promote environmental literacy:

Hands-on observation & discovery - students investigate or observe the natural world through kinesthetic means. This often includes collecting samples, holding objects, or observing organisms in their natural habitat.

Cooperative learning - working together as a group helps foster mutual responsibility and often helps students to be more patient and less critical.

Community-based action research & problem solving - students investigate real environmental issues or problems within their community and propose potential solutions.

Investigating environmental issues - similar to community-based action research, but students can address environmental issues (and potential solutions) beyond the scope of their community, such as loss of rainforest habitat in the Amazon.

Service learning - volunteering with a particular organization on a project is often effective in giving students an opportunity to apply knowledge in a real-life setting.

Simulations & models - taking part in a simulation or holding a model places a student in another "world." A simulation of predator-prey dynamics allows the student to become the predator or prey and may lead to a greater understanding of the process.

Case studies - case studies involve presenting students with an issue or problem, for which they must find a solution. Case studies help develop analytical and problem solving skills.

Problem-based learning - using real-world problems as examples can help students develop critical thinking and problem-solving skills.

Project-based learning - students participate in real-world projects, often in groups, and then create presentations describing results, including what was learned. This often results in a deeper understanding of subject matter, increased self-direction and problem solving skills, and improved research skills.

Interviewing - students learn from other people outside the classroom by asking them a series of questions. Interviewing aids in developing communication skills, because the student must interact with his/her interviewee and bring the information back to the class in such a way that is easily understood.

Storytelling - storytelling is the original form of teaching. Some societies still teach only through storytelling. Storytelling helps listeners develop a personal awareness of nature– a sense of wonder or mystery.

Instructional Delivery

Instructional delivery is defined as: "A process in which teachers apply a repertoire of instructional strategies to communicate and interact with students around academic content and to support student engagement." Basically, a teacher develops a set of teaching strategies to help students learn. Learning strategies should be tuned to the students specifically by following these elements:

Role modeling. every environmental educator is a role model to his or her students. Many students, especially children, learn by example. Because children are incredibly perceptive, we must be sure we truly believe in what we are teaching prior to teaching it to students. In leading by example, educators have the great opportunity, and responsibility, of making the connection between ideal and reality. Rudyard Kipling said "No printed word, nor spoken plea can teach young minds what they should be. Not all the books on all the shelves – but what the teachers are themselves."

Demonstrating enthusiasm. It is always important to demonstrate an appropriate amount of enthusiasm as an educator. If we are not enthusiastic about a subject, our students will not be. Getting excited about nature will foster excitement in our audience. However, excessive amounts of enthusiasm may seem disingenuous. It often takes some work to gauge the amount of enthusiasm necessary to motivate an audience.

Establishing a connection. It is always important to establish a connection with your participants. Students, especially children, will be much more receptive and responsive if we make the extra effort to make a personal connection while teaching. Something as simple as being at the same level as the student, whether that means standing, kneeling, or sitting on the ground, helps students feel more comfortable interacting with an educator. Revealing "secrets" about the natural world might light a spark in the students' minds as to the wonderful mystery of nature. A "secret" might also help students feel like you're sharing some deep, personal knowledge about nature.

Guide students toward answers. Instead of simply providing information, ask students questions to get them thinking. Help guide the students toward answers that you are looking for. Helping students figure it out for themselves not only promotes participation, but also provides for a sense of accomplishment.

Public speaking is difficult for some people. Consider that many Americans list public speaking as their #1 fear on surveys, with death coming in at #2. Being a good interpreter requires the ability to communicate effectively with an audience. Fortunately, there are tips that can help you to deal with anxiety associated with speaking in public:

- **Be prepared**. Your audience expects you to have something worthwhile to tell them. So you need to know what it is you want to communicate. And, although you can't know everything, that's okay. Learn from questions and build your knowledge base.
- **Be organized**. A poorly organized presentation will generate confusion as to your message. Your audience may lose interest and some individuals may become aggravated. Poor organization may result in questions that diverge from your message, and that you are poorly equipped to answer. However, a well-organized presentation will send a clear message and generate questions on your theme that you likely will be prepared to answer.
- **Practice, but avoid memorizing**. Memorized presentations tend to be flat and dry in their delivery and, if you forget something, you may have trouble getting your talk back on track. Visual aids will help remind you of content in your presentation. Incorporating a few good lines and stories will engage the audience and personalize your presentation.
- **Be responsive**. Your audience has come to listen to you, so give them your energy. Make lots of eye contact and encourage their questions. Be relaxed in your delivery and let the audience know that "I'm glad you're here and I'm happy to share this place with you."
- **Be confident**. If you wear a uniform, wear it proudly. Feeling good about yourself and your appearance always helps build confidence. If you have some trouble during the presentation, don't fret. Move on and maybe even joke about it. Relax and enjoy yourself and remember that your audience wants you to do well. They've come to hear what you have to say and they are on your side.

Children can be a handful, especially when there are a lot of them. As the educator, you are in charge, so it is your responsibility to maintain control (of yourself as well as the children). Remember that children are not adults, so don't expect them to act as adults and maintain your composure. Some tips to assist you in maintaining appropriate behavior include:

- **Make your expectations of behavior clear early in the program**
- **Set specific limits on behavior -** stay on the trail, stay with your buddy
- **Give problem children something to do -** hold your props
- **Make your presence known -** stand next to problem children
- **Solicit help from other adults in managing problem children**
- **Don't make empty threats -** be consistent in how you handle problems
- **Don't yell -** yelling means you've lost control
- **Keep an upbeat attitude -** you're the adult
- **Model the behavior you want children to exhibit**

Access for Persons with Special Needs

We have a responsibility to ensure that all people, irrespective of their physical abilities, have the opportunity to learn about nature. Statistics reveal that 37% of the U.S. population has significant mobility, visual, hearing, or learning impairments. The number of people who are 65 years or older is about 10 percent and is increasing rapidly, and certain areas of Utah have a large percentage of older citizens.

There are three broad categories of accessibility that need to be considered when planning to increase access for persons that possess special needs. These include:

Attitudinal access - the first step in promoting greater access to environmental education for persons with physical disabilities or other special needs includes promoting an attitude of inclusiveness among staff, volunteers, and the general public.

Physical access - increasing the numbers and quality of opportunities, such as nature trails and wildlife viewing locations available to individuals that are physically challenged.

Communication access - including methods of sharing the secrets of nature with people that possess communication disabilities, such as verbal, hearing, or vision, as well as learning disabilities.

Detailed information on how to increase access to environmental education opportunities for individuals with special needs is a large subject and beyond the scope of this presentation. Becoming aware that these needs exist is the first step to increasing access and promoting environmental awareness among all members of society. There are several organizations in Utah that promote increased access to the outdoors for persons with disabilities, including, but not necessarily limited to:

Common Ground Outdoor Adventures, Logan, http://www.cgadventures.org/
National Ability Center, Park City, http://www.discovernac.org/
SPLORE, SLC, http://www.splore.org/

Age Groups

Effective education for children requires a fundamentally different approach than for adults because perceptions and intellectual abilities of children differ from those of adults. These abilities vary with age and stage of growth.

For our purposes, it is useful to examine three categories of child development, which are defined by intellectual development and age in the *Interpreter's Handbook*. These are:

The **pre-school** developmental stage encompasses the age group of 2-6 years, which is roughly pre-school through 1st grade for most children. Children in this developmental stage are primarily self-oriented, so when you ask a question, a dozen hands will go up, not with answers, but with statements such as - "I have a turtle." Children in this phase do not question fantasy and believe in fairies and the like, and they also tend to view most things, including inanimate objects, as alive. And remember, these are young children, so keep it simple.

Techniques that work with this age group include play, fantasy, and activities to explore the senses.

Effective strategies include:

- **games and play**
- **puppets**
- **songs**
- **stories (told or read)**
- **sensory exploration**

During the **grade-school** stage (7-11 years), children respond best to direct personal experience. For this reason, this stage is often referred to as "concrete operational." This stage also begins the developmental transition where the child begins to create order out of a complex world. Early in this phase, children are capable of recognizing simple concepts, such as time relationships (dinosaurs vs. current wildlife) and grouping items into simple categories (plants, animals, and rocks). Later in this phase, children are able to understand more complex relationships, such as the idea that fish and great blue herons are both components of a wetland community. Children in this stage can grasp the moral consequences of their actions and the actions of others. Consequently, children in this stage are quick to recognize the value of recycling, the impacts of pollution, and the need to conserve habitat for wildlife.

Techniques that work with this age group should incorporate concrete experiences. In group presentations, participation (such as answering questions) and humor are important.

Effective strategies include:

- **activities and games to teach concepts**
- **exploration and discovery**
- **sharing and empathizing**
- **participation in stories, puppets, skits, and characters**
- **devices that can be manipulated**
- **physical and sensory involvement**
- **questioning strategies and metaphors**

Adolescents (12-15 years) are approaching the full capabilities of the adult. Adolescents are able to understand complex relationships, such as the pros and cons of damming rivers. They also are able to view and weigh issues from different perspectives. Children at this age want to be viewed as adults, and want to express their opinion. They also prefer to take an active role in programs. The decision to actually participate in a program, however, is heavily influenced by the concern with peer-approval.

Techniques that work well with this group include programs that provide opportunity for active participation by more than one or a few individuals. Exploration and discovery or the involvement in an ongoing project, such as monitoring the quality of water or conducting inventories of organisms from seine net samples, are example of strategies that don't isolate individuals in the spotlight, and that provide a sense of worth in their participation.

Effective strategies include:

- **exploration and discovery**
- **involvement in activities or projects**
- **discussion and debate**
- **simulation, role playing, and games that explore complex issues and processes**

Assessment and Evaluation

When we develop education programs we should always think about how to measure (1) the amount of knowledge the participants are gaining (i.e., **assessment**) and (2) the success of the program over the short- and long-term (i.e., **evaluation**). It's important to understand the difference between the two. Assessment is used to determine whether the measurable objectives were met, how successful the program was for students. Because these objectives were measurable, it is possible (and preferred) to use quantifiable measures in assessment. For instance, an easy way to measure participant learning includes using pre- and post-testing. Scores can be compared and percent change (i.e., knowledge gained) can be calculated. There are also other ways to assess learning, such as whether or not participants can answer questions or complete an activity related to a lesson that was taught earlier. All of this can be quantified!

Evaluation, on the other hand, is a little more difficult to quantify. Remember the program goals that we set were broad and intangible. However, there are ways to obtain quantifiable data through evaluation. For instance, we can list statements, such as "This program helped me better understand concepts related to bird migration," and then have the participants rank the degree to which they agree with the statement on a scale of 1-5. Then, results can be averaged for the entire group of participants. These kinds of data are especially helpful in monitoring program success if the program will be offered multiple times. Participant assessment results can also be used to support program evaluation; if the participants are gaining knowledge, then clearly the program is, at least by that measure, successful.

When evaluating a program, collect only data that will be used. For instance, we should not ask participants if the cost of a program was too high if we aren't willing to possibly lower it. Collect only the data that would assist you in improving the program.

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Physical Characteristics

In this session, we'll take a journey through the watershed, exploring the formation and dynamic physical characteristics of the main components of Utah watersheds. We'll begin at the top of the watershed, looking at how rivers and streams are formed and then, we'll investigate the role of freshwater lakes in storing water. Next we'll discuss the multiple types and functions of wetlands in Utah and, lastly, we'll examine the largest saltwater lake in North America: Great Salt Lake. After we journey through this watershed, we'll spend some time discussing both human and non-human factors that affect water quantity and quality throughout a watershed.

What is a Watershed?

A **watershed** is defined as a geographic area in which all water drains to a common point. It may be easier to observe in mountainous areas but, all lands and water bodies are part of a watershed. Watersheds refer primarily to surface water because groundwater may follow a different flow pattern between watersheds, but they still represent a vital part of measuring water movement. Watersheds vary in shape and size as well as cross numerous political boundaries.

Example of a watershed that begins in the mountains, includes agricultural and urban land uses, and ends in a lake. (*Image from Minister of Public Works & Government Services, Canada*)

Watershed Functions

The most obvious function of a watershed is that it **collects** water from all points draining into it. When a storm occurs in any portion of the watershed there is runoff into rivers and streams. There is also some collection through the soil, which often results in groundwater storage. The size and location of the precipitation event has a significant effect on the amount of water collected as well as the level of runoff. For instance, if a small storm occurs near a stream within a large watershed, the amount of collection, in proportion to the size of the watershed, will be minimal. If a large storm, which covers the majority of a watershed occurs, then the amount of collection will be significant, possibly resulting in a flooding event. Due to the natural acidity of precipitation, as well as the force of the storm event, and its resulting weathering of parent material, the draining water will also include natural additives such as various sediments and soils, dissolved minerals, metals, nutrients, and biological materials. These additives have been part of the natural systems for eons and have a direct impact upon water quality as the water progresses downhill through a watershed.

Another function is that of **storing** the water as it moves. The storage aspect seems obvious when one considers surface waters, such as lakes and wetlands, but there are significant amounts also stored in groundwater, plants, animals, humans, and even in the atmosphere. Soils can retain more than 300,000 gallons of water per acre following a precipitation event, most of which remains in the soil or percolates into groundwater.

The **discharge** of water is the final step for water within watersheds. Water is transported through a watershed via rivers and streams, and lakes, as well as runoff. Eventually, all watersheds empty into a larger watershed, or a terminal lake, or even the ocean. As water moves across the landscape, it can come in contact with pollutants. Along with the natural additives mentioned above, humans have largely inadvertently contributed vast amounts of waste materials into water systems to be discharged. Some of these include sediments, pesticides, fertilizers, animal/human waste, and trash.

Watershed Scales and Nesting

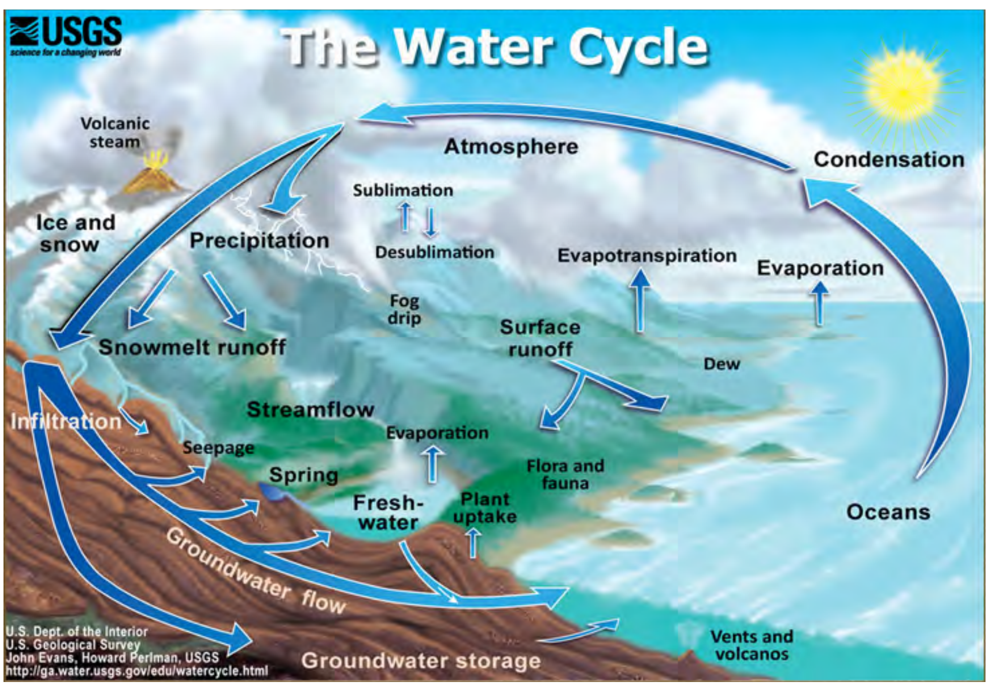
Depending on which scale we are considering, watersheds can have different sizes and names. Every large watershed can be made up of several small watersheds. Each small watershed can be made up of several small drainages, each of which is also considered a watershed. This concept of grouping watersheds within each other is called **nesting**. For example, someone who lives in Salt Lake City may be in the Mill Creek watershed, which is part of the Jordan River Watershed, which is part of the larger Great Salt Lake/Great Basin Watershed.

Major watersheds of Utah.
(*Image from USU Water Quality Extension*)

Major watersheds of the United States.
(*Image from U.S. Geological Survey*)

Water Cycle

Light and heat generated by the sun powers the water cycle. Should the sun suddenly stop shining, within 8 minutes the water cycle (and all other natural life-support systems) would begin shutting down. The light energy of the sun converts to heat as it enters earth's atmosphere. The heat causes surface waters to expand, convert to vapor, become less dense, and rise upward. The speed of this process, known as **evaporation**, is determined by many factors, including: the volume of surface area, temperature of the water and surrounding air mass, clouds, plant cover, and water movement. Water also vaporizes and escapes from plants (**transpiration**) and animals (**respiration** and **perspiration**). The rising water vapor soon ascends high enough where the thinner atmosphere results in much cooler temperatures, **condensing** the vapor into droplets and forming clouds. As the droplets increase in volume, and weight, they eventually will fall back to the ground as **precipitation**. Depending upon the season, amount of moisture, and geographical location, precipitation can be drizzles of rain or cloudbursts, sleet, snow, or hail. As the precipitation reaches the earth, its fate is determined by the surface it contacts and the volume of moisture in the storm. Pavement, highly compacted soils, or desert soils low in humus, absorb little water thereby leaving most of it on the surface. The resulting **runoff** can trickle, or roar, downhill where it eventually collects in surface waters such as rivers and streams, ponds, marshes, lakes, or the ocean. These surface waters are then susceptible to evaporation where the cycle repeats itself. If the soil has a higher water-holding capacity, the precipitation **percolates** or **infiltrates** downward through soil particles and rocks where one of two things can happen: It can either evaporate from the soil and transpire from plants, or continue infiltrating downward until it reaches a layer of rock or clay impervious to water penetration and collects as **groundwater**.



The complex cycle that circulates water throughout the world. (*Image from U.S. Geological Survey*)

Water Availability

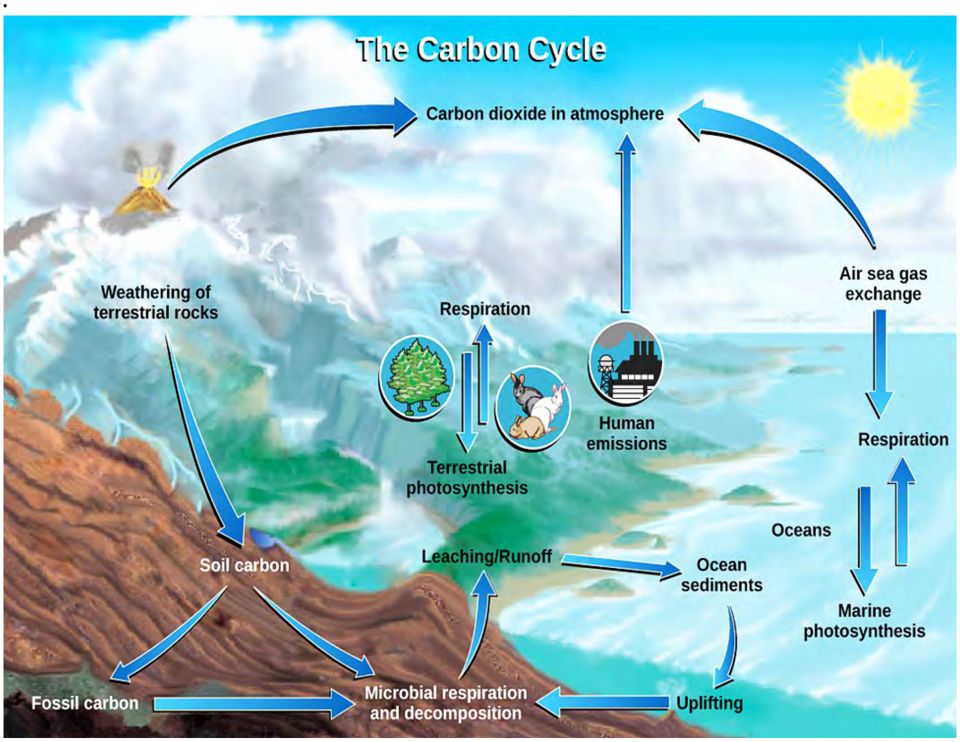
An enormous 97.2% of the water on Earth is in the oceans. Just 2.8% of the water on Earth is freshwater, and only a small fraction of the freshwater is available for our use. Much of the remaining freshwater is in the ground, only some of which is actually available for our use. A breakdown of the remaining water is below:

1. Glaciers & Icecaps - 2%
2. Groundwater – 0.6%
3. Freshwater Lakes – 0.009%
4. Inland Seas/Salt Lakes – 0.008%
5. Atmosphere – 0.001%
6. Rivers - 0.0001%

A rough calculation estimates that a maximum of approximately 0.8% of the water on Earth is available for use by humans. The other complicating factor is that not all of that water is suitable for use. Pollution, accessibility, and lack of infrastructure prevent much of the available water from being used.

The Carbon Cycle

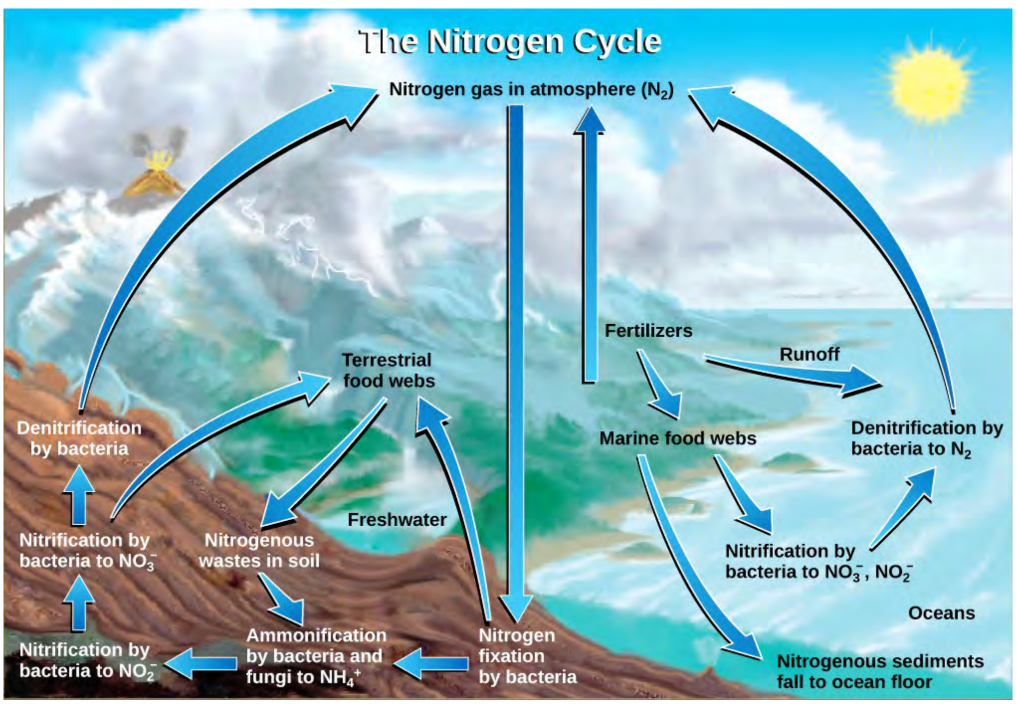
Carbon is an essential nutrient for plants, thus making it an essential nutrient for animals as well. Carbon occurs naturally in the atmosphere as carbon dioxide (CO_2), which is a by-product of plant and animal respiration, combustion of organic matter, and the burning of fossil fuels, and as methane (CH_4). Both carbon dioxide and methane are greenhouse gases that help maintain warmer atmospheric temperatures by trapping heat escaping the Earth's surface, allowing life on Earth. Atmospheric CO_2 is utilized by producers, such as plants, during photosynthesis where the carbon is used to create "food" for the plant and the remaining oxygen is released into the atmosphere. Herbivores consume plants and predators consume herbivores, incorporating carbon into their bodies and releasing any remaining carbon as CO_2 and waste. Plants and animals are both carbon-based organisms, and their deceased remains provide food for decomposers (e.g., earth worms) and microscopic organisms (e.g., bacteria) within the soil or water. Carbon stored in plant and animal tissues that is decomposed is either released through microbial respiration into the atmosphere as CO_2 or methane where it can once again be taken up by plants or it is stored in the soil**.** **Carbon sequestration** occurs in areas, such as peat bogs and rain forests, where prolific plant growth captures large amounts of carbon from the atmosphere. Deforestation and burning of fossil fuels over the past century have contributed to increasing atmospheric CO_2 levels and warmer atmospheric temperatures.



The complex cycle that circulates carbon throughout the world. (*Image from U.S. Geological Survey*)

The Nitrogen Cycle

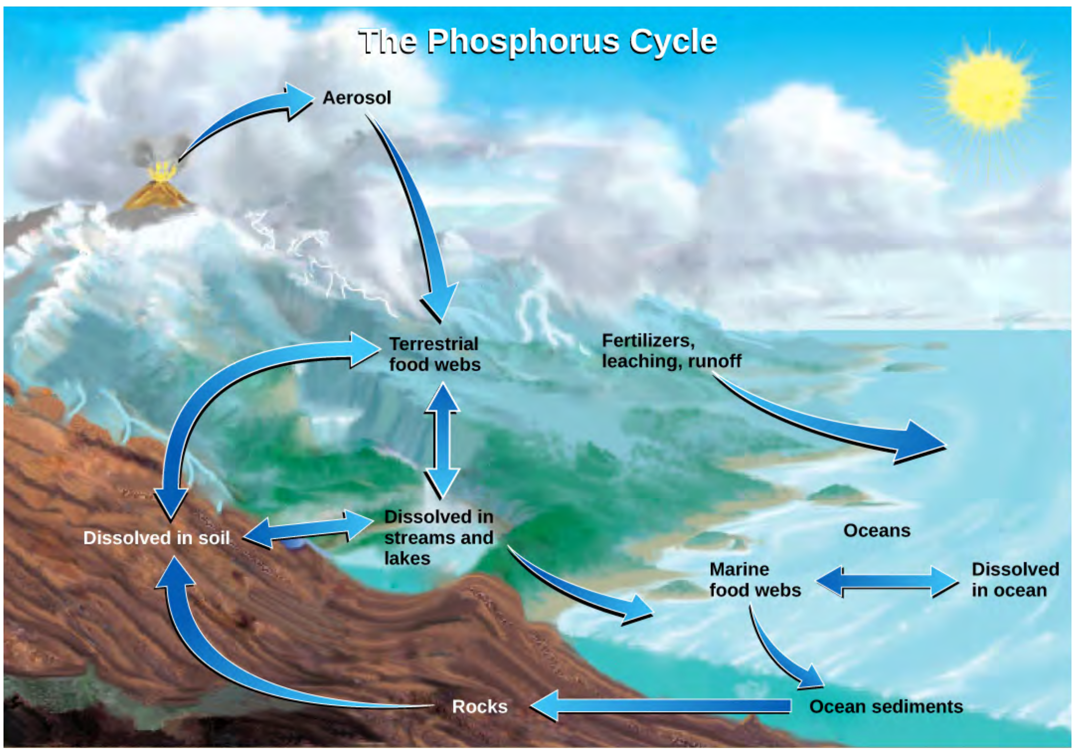
Nitrogen is another essential nutrient for all living organisms, and is a necessary component for many biomolecules like DNA. Although atmospheric nitrogen (N_2) is the most common element in the atmosphere, making up 78% of all gases, it is not readily utilized by plants and must go through **nitrogen fixation** in order to be converted to a usable form. The most common forms of N taken up by plants are nitrate (NO_2) and ammonium (NH_4^+). There are a number of ways whereby N_2 can be fixed, including lightning strikes, nitrogen fixing bacteria, and other microscopic organisms. For example *Azobacter* bacteria found free-living in soils utilize N_2 and release organic nitrogen into the soil where it can be absorbed by plants. Another example is *Rhizobium* bacteria, which live attached to the roots of plants where it creates a symbiotic relationship with the plant; the *Rhizobium* fix N_2 and provide organic nitrogen to the plant in exchange for organic carbon. In aquatic environments, cyanobacteria can fix nitrogen and release it into the water column to be used by aquatic plants. Once organic nitrogen is available, plants **assimilate** it into their tissues. **Ammonification** is the next step, which involves animals and microbes breaking down plant and animal matter and oxidizing nitrogen into ammonia (NH_4^+), which is released as waste. Decomposers break down the waste and release more organic nitrogen into the soil. The final step in the nitrogen cycle is **nitrification/denitrification**. Bacteria in the soil, specifically the *Nitrosomnas* species, oxidize ammonia (NH_3) into nitrite (NO_2^-) and then into nitrate (NO_3^-), where it can either remain in the soil, be taken up by plants, or percolate into groundwater. Other bacteria, primarily the *Pseudomonas* and *Clostridium* species, utilize the nitrate in the soil during respiration and release inorganic nitrogen back into the air where the cycle begins again. Burning of fossil fuels and the application of N-based fertilizers has drastically sped up the N cycle, doubling the rate of N-fixation.



The complex cycle that circulates nitrogen throughout the world. (*Image from U.S. Geological Survey*)

The Phosphorus Cycle

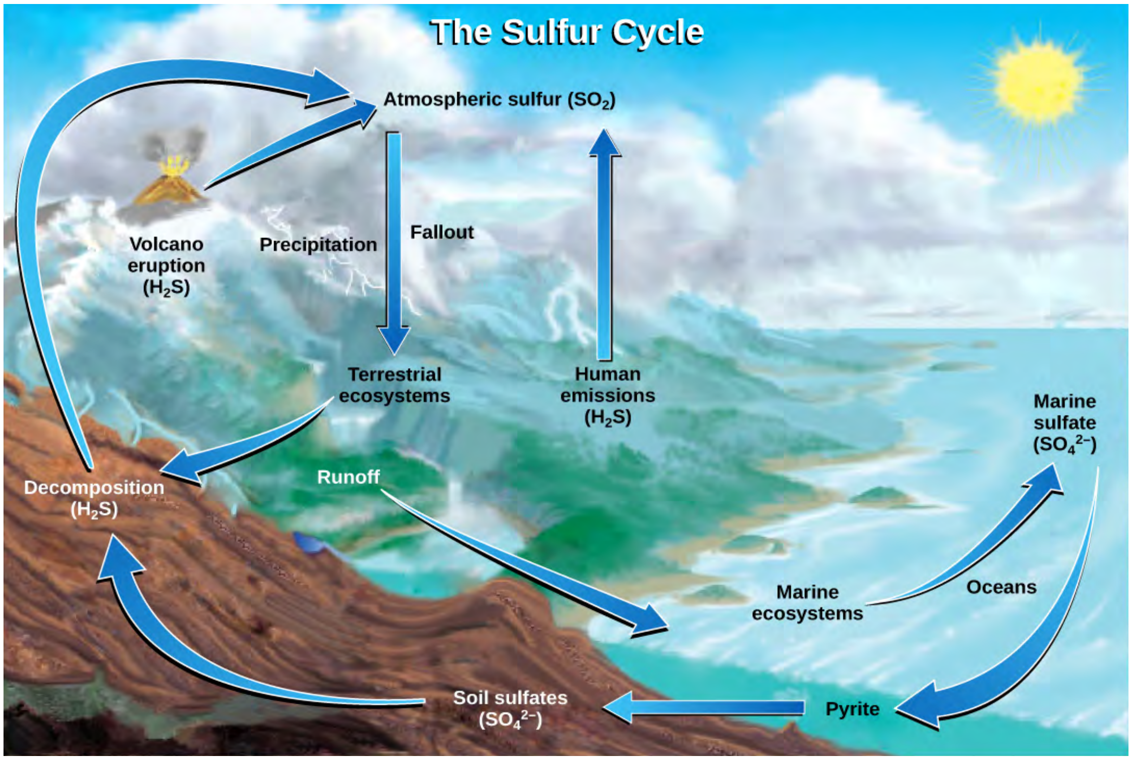
Phosphorus is also an essential nutrient for life on Earth. Unlike C and N, phosphorus has almost no atmospheric pool, with the exception of dust. The main reservoirs for phosphorus are soils, sediments, and rocks. Through **weathering**, or breakdown of rock via chemical or mechanical means, phosphorus can become available to producers in the soil or water. **Precipitation** can introduce inorganic phosphorus, which can then react with elements in the soil (i.e., iron, aluminum, manganese, or calcium) to create chemical compounds. **Mineralization** occurs when microorganisms convert organic phosphorus into orthophosphates ($H_2PO_4^-$ and HPO_4^{2-}) that are readily absorbed by plants. **Immobilization** is caused by microorganisms using the forms of P available to plants and converting them to inorganic P which is not readily absorbed by plants. Phosphorus molecules usable by plants bind to soil particles through **adsorption,** or fixing, and plant roots absorb the molecules. The opposite of adsorption is **desorption** where phosphorus is released from soil particles back into the soil profile. **Runoff** is the removal of soil-bound phosphorus through water-caused erosion commonly occurring on agricultural fields. Finally, **leaching**, occurs when phosphorus moves vertically through the soil profile with water movement. Fertilizers and, mostly in the past, detergents have been major contributors of phosphorus to aquatic and terrestrial ecosystems. In fact, mining of phosphorus for fertilizers liberates four times more phosphorus annually than natural weathering.



The complex cycle that circulates phosphorus throughout the world. (*Image from U.S. Geological Survey*)

<u>The Sulfur Cycle</u>

The sulfur cycle is both sedimentary and gaseous. In its sedimentary phase, organic and inorganic sulfur can be released via weathering and decomposition. **Mineralization and the oxidation** of organic sulfur, which is unavailable to plants, occur slowly through microbial processes and result in the creation of first hydrogen sulfides and then sulfate (SO_4^{2-}). Sulfate is the usable form of sulfur to plants. Bacteria can utilize sulfate, thus converting sulfur back to an unusable form; this process is called **immobilization. Leaching**, as with other nutrient cycles, moves sulfur vertically downward in the soil profile where it can enter the water cycle via groundwater. In its gaseous phase, sulfur enters the atmosphere from the combustion of fossil fuels, volcanic eruptions, and gases released during decomposition in a process called **volitalization**. Sulfur enters the atmosphere first as hydrogen sulfide, which then quickly binds to oxygen to form sulfur dioxide. Sulfur dioxide collects in atmospheric water droplets and is brought back to Earth's surface as a weak sulfuric acid in rainwater (i.e., acid rain).

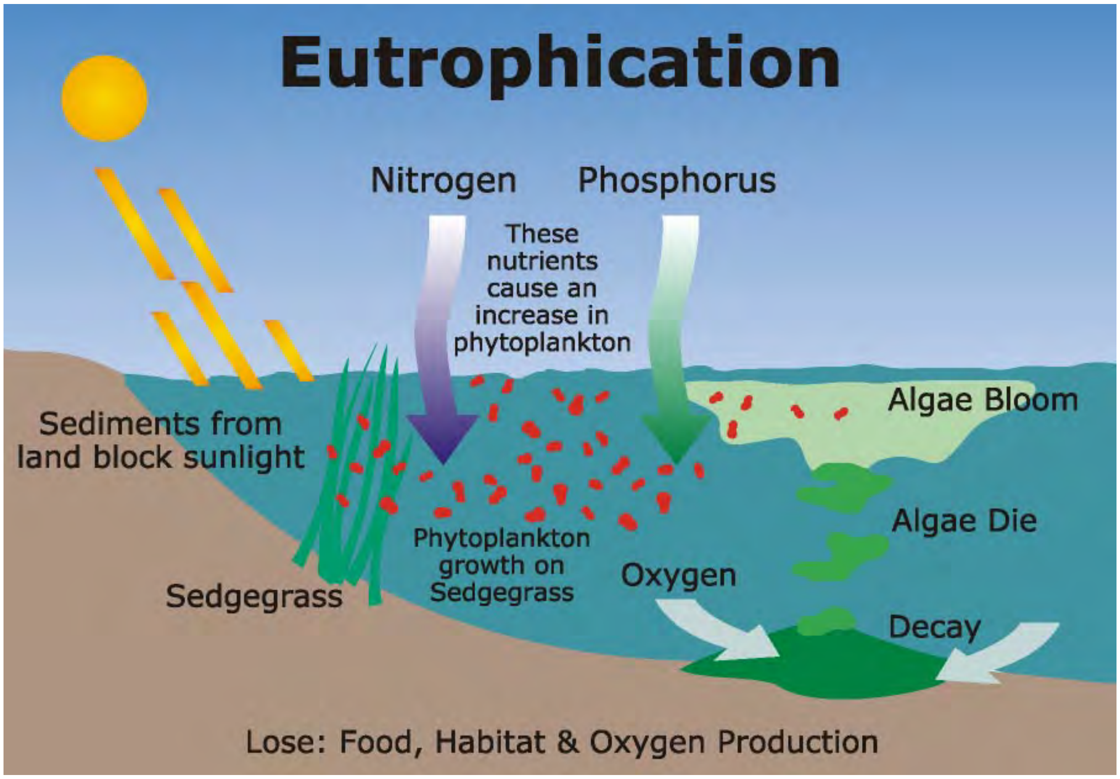


The complex cycle that circulates sulfur throughout the world. (*Image from U.S. Geological Survey*)

Eutrophication

Although the availability of nutrients is essential for the health of aquatic ecosystems, excessive amounts of nutrients (particularly nitrogen and phosphorus) can cause an imbalance, leading to **eutrophication**. This can happen naturally in some waterbodies over time, but human activities accelerate the process significantly through the depositing of human and animal waste, fertilizer, and other agricultural or industrial by-products. Excess nutrients fuel blooms of algae on the water surface, which can become so dense that they prevent sunlight from penetrating into the water. While prolific algae growth increases oxygen in the water during daytime photosynthesis, decomposition at night cause hypoxia, where oxygen levels are dangerously low. Eutrophication can cause large-scale animal die-offs and turn waterways into “dead zones.”

Algal blooms can also present a health hazard to humans and animals. Toxic cyanobacteria can grow in algal blooms, which can pollute drinking water and lead to sickness in humans, even after water treatments, and sickness or death in livestock and pets. Controlling levels of eutrophication is expensive and often ineffective. The most effective methods are manipulating the amount of nutrients being introduced into waterbodies and preventing introduction of harmful chemicals. Even though there has been some success in controlling and remediating human-caused eutrophication, it is still a significant problem in many watersheds, including in Utah. Farmington Bay in Great Salt Lake was determined to be “hypereutrophic with poor water quality” by the EPA in 2005. The EPA also determined that the amount of algae “exceeded levels considered to pose moderate or high probabilities of public health risk.” Essentially, the level of eutrophication in Farmington Bay is so high that it not only poses a risk to the organisms that utilized the area as habitat; it may also lead to pollution, or even poisoning, of public drinking water.



The process of eutrophication in an aquatic ecosystem. (*Image from Lincoln Nebraska Dept. of Public Works*)

Weather and Climate

Although the cartoon below might be amusing, what is inaccurate or misleading about it?

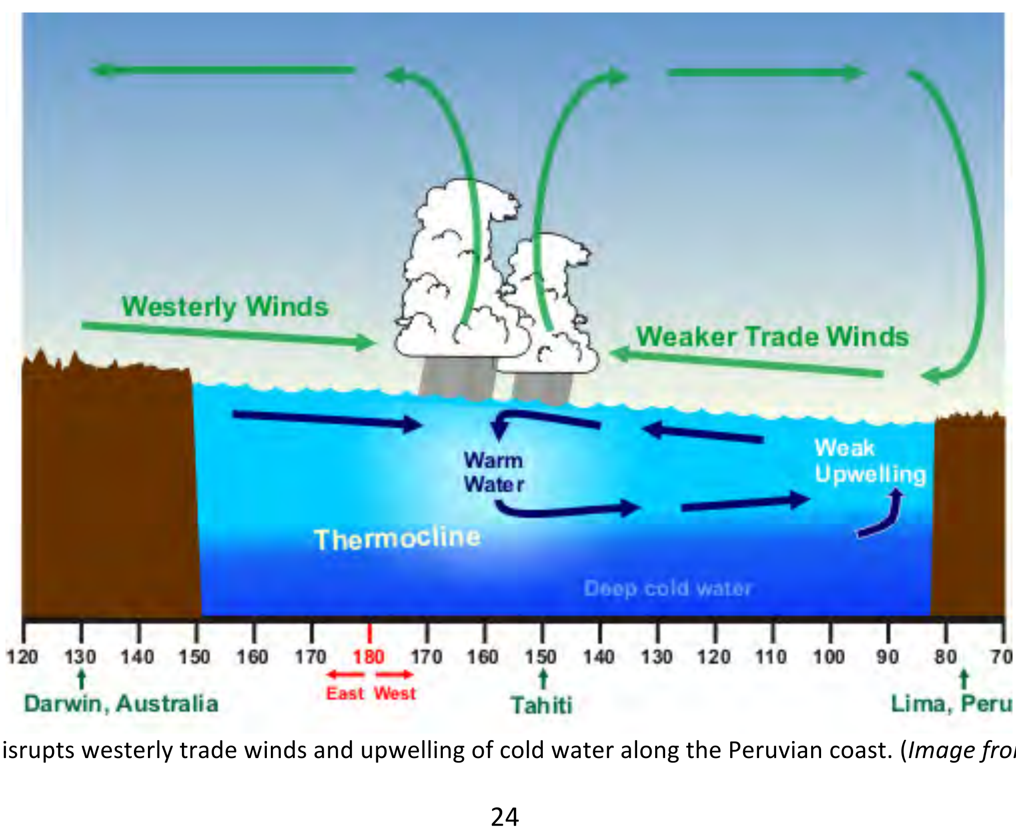
Weather and climate are actually two distinctly different processes. **Weather** is the combination of current atmospheric conditions, such as temperature, humidity, precipitation, cloud cover, visibility, and wind. Weather changes from day to day, sometimes from minute to minute. It affects the clothes that we wear each day, or whether we carry an umbrella. **Climate**, on the other hand, is about the long-term statistics of our environment, which include the statistics of weather, such as averages, extremes, and variability. As it relates to weather, then, Climate projections are about projecting what we expect to see in the statistics of our future weather — what will be average temperature and precipitation, what will we see in extremes, and how variable will the weather be.

Climate can change as well, but this occurs more slowly over greater time scales. Climate determines which plants we grow, how we build our homes (e.g., ventilation, insulation), and even where we live. So, the experts who state that global warming is real are not, in fact, predicting the weather, but rather the climate, 50 years from now. Climate is determined by solar activity, latitude, local geography, altitude, volcanic activity, atmospheric composition and patterns, and oceanic circulation patterns.

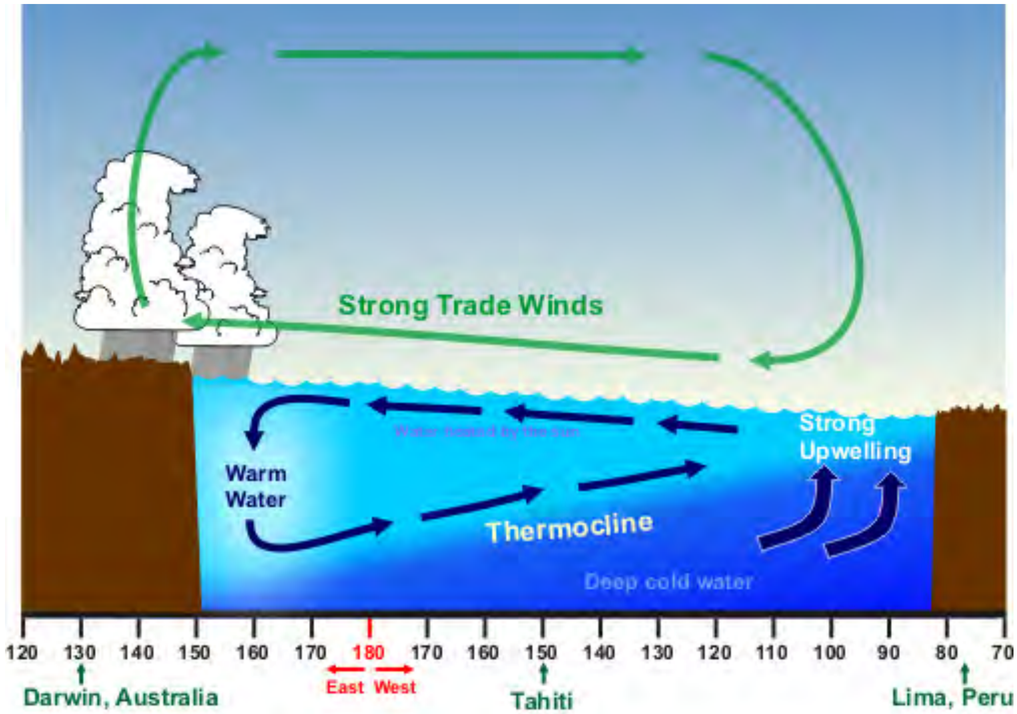
Climate Cycles

Climate cycles arise from the re-distribution of energy within the Earth system, principally between the oceans and the atmosphere. One such cycle is the El Niño / La Niña Southern Oscillation. In the El Niño part of the cycle, the ocean is dumping energy into the atmsophere; in the La Niña part, it's the other way around. The reason for this cycle is a little complicated, but basically has to do with ocean circulation and the trade winds.

The **El Niño** Southern Oscillation causes changes in climatic conditions throughout the world. El Niño causes shifts in winds and currents along the equator near the South Pacific region. El Niño events, also referred to as a "Pacific warm episodes," are climatic phenomena characterized by westward currents stopping or reversing in flow causing an "upwelling" of warm water on the Peruvian coast. The change in current is caused by the reversal of trade winds moving from a low-pressure area over Tahiti to a high-pressure area over Darwin, Australia. A La Niña event, or a "Pacific cold episode," is basically a reversed El Niño event with Tahiti representing the high-pressure area and Darwin, Australia, as the low-pressure area.



El Niño disrupts westerly trade winds and upwelling of cold water along the Peruvian coast. (*Image from NOAA*)



La Niña increases westerly trade winds and upwelling of cold water along the Peruvian coast. (*Image from NOAA*)

El Niño events cause a significant fluctuation in rainfall patterns worldwide. The areas most influenced by El Niño events are Indonesia and South America since these are the areas where warm water is directed from the changing currents. When El Niño events occur, precipitation levels in the central portion of the Pacific Ocean increase significantly, particularly along the equator, while rainfall in the western Pacific decreases. This pattern brings warmer winters and lower than average snowfall in Utah, which can have dramatic effects on water storage throughout the rest of the year. During La Niña events, rainfall patterns over the western equatorial Pacific increase in the area over Indonesia and the tropics, while precipitation over South America decreases. In general, La Niña years result in higher than average snowfall in Utah. But, these trends are difficult to predict, and the results can vary. El Niño events occur irregularly every 2-10 years.

Historic Climate Change

Scientists have determined that in prehistoric (or palaeoclimatic) eras, continents have shifted position and climates have changed over billions of years since the earth first developed an atmosphere. During the last 500 million years, the earth has experienced several periods of climate shifts from very warm periods to ice ages. These earlier climate shifts were all due to natural causes, and occurred slowly over hundreds to thousands of years.

The most recent **Ice Age**, or glacial period, ended approximately 10,000 years ago. During this time, 30% of the earth was covered by ice extending from the poles. Until 14,500 years ago when much of Utah was covered by Lake Bonneville, Utah was home to several now-extinct Pleistocene mammals, such as mammoths and mastodons, saber-toothed cats, bison, musk ox, camels, short-faced bears, and ground-sloths.

The modern era has also seen climatic changes, some natural, and, according to nearly all climate scientists, some caused by humans. Ocean sediments and polar ice core data show that from 900-1300A.D., the earth's climate was somewhat warmer than normal. However, between the 14th and 19th centuries, the earth experienced a little ice age. Scientists believe this was caused by a combination of three major, natural events:

1. **Less solar radiation** reaching earth. Although estimates guess this figure to be only one half of a percent, it was significant enough to lower global temperatures.
2. Although volcanic eruptions are rare, at least **five major eruptions** occurred each century during that period. The ash/sulfuric acid cloud shaded sunlight for years.
3. The **oceanic conveyor belt** was disrupted. Normally, warm water rises near the equator, then flows toward the poles, where cold water is sinking and traveling toward the equator. This circulation pattern is partially responsible for weather and climate patterns across the earth. The warming period which preceded 1300A.D., began melting the polar ice caps. The rush of additional fresh water, less dense than salt water, entered the oceans but did not sink. Climatologists believe that halted ocean circulation.

It's important to note, however, that the Little Ice Age was not a global event, but regional — mostly affecting the different parts of the northern hemisphere at different times.

Ice Age mammals that once roamed Utah. (Image from *USU Eastern Prehistoric Museum*)

Modern Climate Change

There is little, if any, disagreement as to the fact that the surface temperature of the Earth has increased. Although an increase in 1 degree Fahrenheit since the 1950s may seem subtle, it has contributed to 11 of the 12 hottest years on record occurring in the last 12 years. In February 2007, the Intergovernmental Panel on Climate Change (IPCC), a collection of climatologists from around the world, issued a report concluding that greenhouse gases have caused most of this change in our climate.

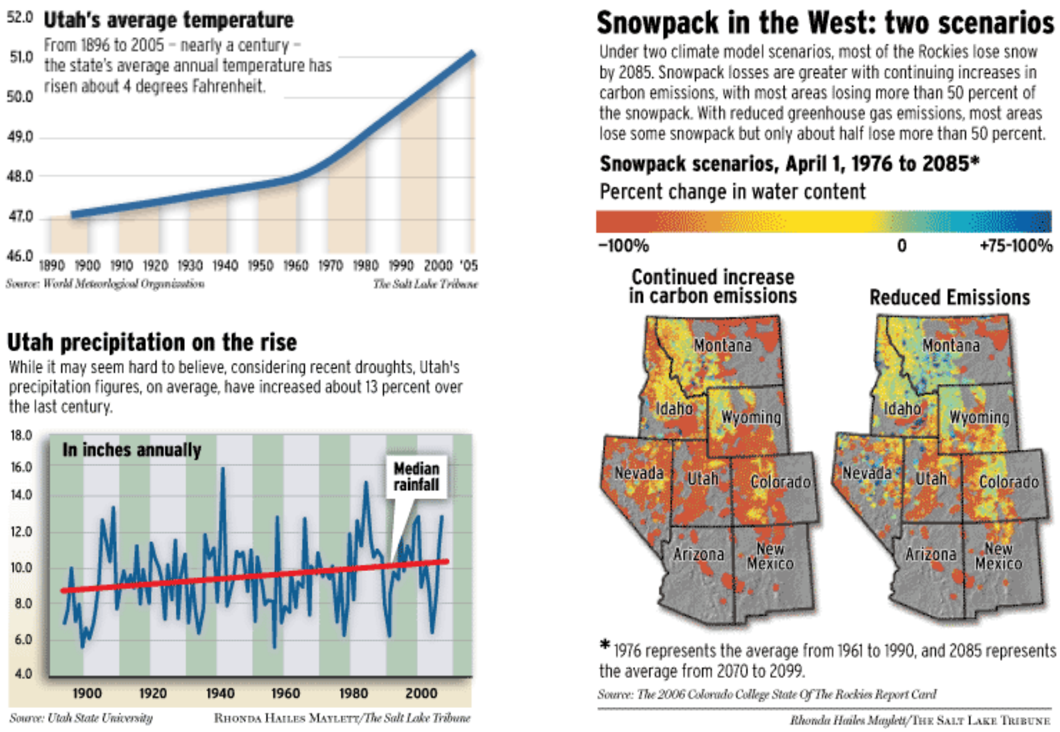
It is possible for climate to change based on any of these three basic causes:

1. Internal, natural variability (randomness in weather and climate),
2. Natural, external factors (increased heat from the sun or the Earth's core), and
3. Human-caused factors (increased greenhouse gases).

Internal, natural variability was, for the most part, ruled out because there was no similarity between the current warming trend and any of the paleoclimatic data. In addition, when natural cycles, such as (ENSO), cause warming in some areas, they also cause cooling in others, and the current increase has occurred globally. Solar output was discounted because, while the lower atmosphere (troposphere) has warmed, the upper atmosphere (stratosphere) has actually cooled. A hotter sun would have also warmed the stratosphere, and even then, only 0.2 degrees. In addition, increased heat from the Earth's core would have warmed the oceans from the bottom up instead of from the top down, which is what is currently happening.

Gabriele Hagerle, a professor at Duke University and coauthor of the IPCC report, said, "Without greenhouse gases and other [man-made] forcings, we cannot really explain the observed climate changes,". While carbon dioxide from automobiles, power plants, and airplanes account for much of the increased greenhouse gases in our atmosphere, there are several other factors that also contribute. Methane, from sources such as rice paddies and bovine flatulence, is also an effective greenhouse gas. Deforestation, primarily of rainforests, reduces the Earth's ability to store carbon. Along that same line, thawing of the permafrost makes vast amounts of stored carbon available. A warmer and denser atmosphere is predicted to cause diverse reactions, such as greater fluctuations in precipitation resulting in more extreme droughts, more intense hurricanes due to warmer ocean surface waters, floods, rising sea-level, or initiate a *new* little ice age as polar ice caps melt at abnormal rates.

Let's look at some effects of **climate change** on Utah. Since the late 1800s, Utah's average temperature has risen approximately 4 degrees Celsius. During this time, however, the average annual rainfall has actually increased by 13%. One would think that our water problems would be solved by this increased rainfall! Sadly, though, because of the warmer temperatures, more of Utah's precipitation is falling as rain rather than snow. Because water is released from snowpack at a slower rate, we are provided with water throughout the year. If more of this water comes from rain, it could result in increased stream flow in winter and spring, but decreased stream flow in summer and fall. Even with reduced greenhouse gas emissions, it is forecasted that Utah will be faced with snowpack shortages upward of 50% by 2085.



Climate trends for Utah. (*Images from The Salt Lake Tribune*)

Effects of climate change in Utah can be subtle, but even subtle effects can combine to result in considerable impacts. A study by Anthony Westerling of the University of California-Merced revealed that a warmer climate has caused an increase in wildfires in the western U.S. "What we saw very clearly was that most of the fires occurred in years with warm springs, sometimes drier winters, and early spring snow melts. And we had a much longer fire season in these years," stated Westerling. Most of the increased fire activity occurred in forests around 7,000 feet in elevation where forest management (e.g., fire suppression) has not been as much of a factor.

In areas where forest fires have occurred, the lack of vegetation to hold the soil together can result in increased runoff, sometimes causing flash floods. The runoff carries sediment with it, which is then deposited in streams and rivers. Siltation of the streams affects wildlife by destroying fish spawning habitat and even clogging the gills of fish, resulting in death. In addition, warmer rivers and streams would be less suitable habitat for cold water fish, such as trout.

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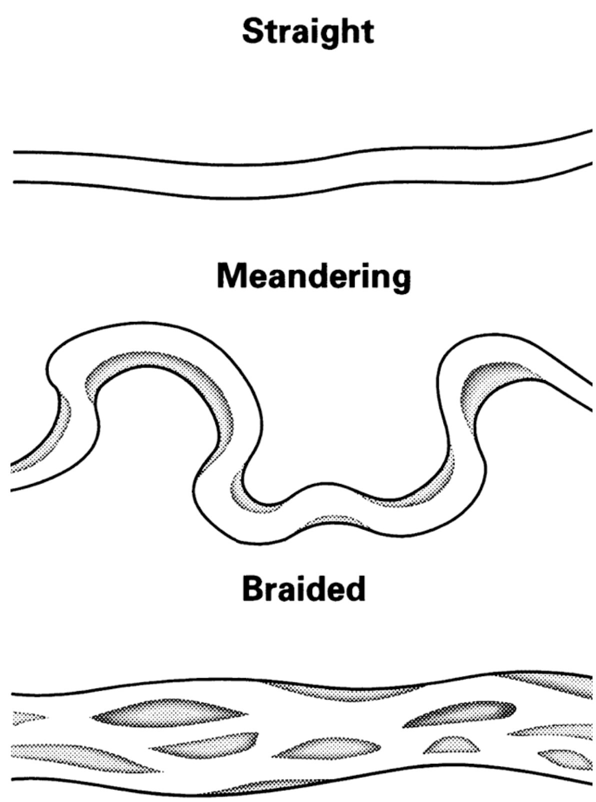
Watershed Ecosystems

Rivers and Streams

Perhaps the most important physical characteristic of rivers and streams is their **stream flow**. This is a measurement of the amount of water passing through a natural stream channel during a specific period of time. It is influenced by both the cross-sectional area of the channel, which influences the volume of water, and velocity (the speed that the water is moving). A key factor in a river or stream's flow is the area of the watershed that feeds into the point where flow is measured. The larger the area a river drains, the more water is likely to be present in the waterway. The size of the drainage, however, is not the only factor that impacts stream flow. In fact, stream flow is always changing, and many different factors can influence the amount of water moving through a stream channel. A primary influence on stream flow is precipitation across the watershed. As water falls into the watershed, or as snow melts, it seeks lower ground under the influence of gravity, and may eventually end up in a river or stream. Rainfall can increase stream flow, even if it is only raining high up in the watershed. Large watersheds usually collect more water, so the resulting stream flow is generally higher. However, the rise and fall of larger rivers usually occurs more slowly than smaller streams. A storm in a small watershed can increase the stream flow by many times over **base flow** (the "typical" stream flow for a specific stream or river) in a matter of minutes, while a storm in a big watershed can take days to rise, partly due to a longer travel time to reach the point where flow is measured.

There are other factors, both natural and human-caused, beyond rainfall and snowmelt that affect stream flow. Natural causes include evaporation from surface-water bodies and soil, transpiration (evaporation from leaf pores), groundwater discharge from aquifers and recharge from surface water bodies, sedimentation of lakes and wetlands, and the formation or dissipation of glaciers, snowfields, and permafrost. Human-induced mechanisms include surface water withdrawals and diversions, reservoirs, river flow regulation for hydropower and navigation, construction, or sedimentation of reservoirs and storm water detention ponds, stream channelization, levee construction, drainage or restoration of wetlands, land-use changes such as urbanization that alters erosion, infiltration, overland flow, and evapotranspiration rates, wastewater outfalls, and irrigation wastewater return flow.

Another physical characteristic of streams and rivers is the **stream shape**. This refers to the shape of the riverbed that the water has carved over time. Streams can be relatively straight and narrow, wide and meandering, or split into many different channels (braided). Rivers are dynamic systems, and the stream shape is always changing. These changes depend on the force of the water as it passes over land and the type of substrate that makes up the riverbed. These two variables determine the total amount of sediment that a stream can transport, which is referred to as **transport capacity**. Flood events have a big effect on stream shape. The increased volume of water has more force, and sediment bars deposited when the stream flow was lower are moved further downstream.



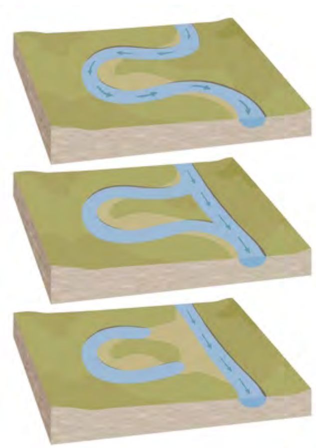
Basic stream shapes.

Straight streams are generally found on steep mountain slopes, where a smaller stream with high velocity has more energy to erode a channel. The path of least resistance is the straight line directly down a slope. Substrates, such as bedrock, boulders, and cobble, in mountain streams tend to be heavier and require more energy to erode, contributing to a straight stream shape. Since smaller substrates, such as gravel, sand, and silt, require little energy to move, they are readily washed downstream into the valleys.

A straight stream up in the mountains.

Large, slow flowing rivers on nearly flat land tend to take on a **meandering** shape. The water has little force, and finds the path of least resistance across the landscape. As a result, the river channel turns often, following the steepest gradients and loosest soils. Once these bends begin to form they are subject to a positive feedback loop: Faster moving, more energetic water is subject to centrifugal force and is drawn toward the outside of these bends, like passengers in a car being pushed to the side door while going around a curve. The higher energy water has a higher capacity to erode sediments, so the outer edge of these bends tends to be eroded further outward. Meanwhile, the lower energy water on the inside of a bend deposits sediment, resulting in sand, silt, or gravel bars that form on the inside shore. These two forces combine to increase the meandering nature of slower moving rivers. Sometimes the meandering becomes so extreme that it closes in on itself. The stream breaks through and bypasses a meander, resulting in an oxbow lake.

The meandering Green River in Utah.

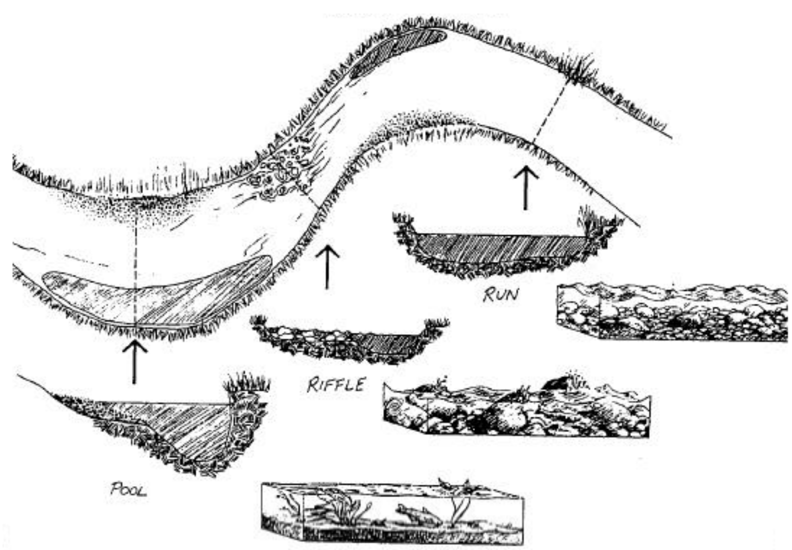


How an oxbow lake forms.

A **braided** stream is formed when the river has so little energy it is constantly depositing sediment in its channel. Braided streams are common at the mouth of a river, where it is emptying into an ocean or lake, on what is called an alluvial fan. The alluvial fan is caused by high amounts of sedimentation where the river channel comes nearly to a stop. The main channel does not have enough force to carve out one single channel and splits into many different channels that wind between the deposited sediment. Braided streams can also form when the riverbed is made up of large substrate, which the stream cannot erode into one main channel.

Notice the many channels of the braided river.

Natural stream channels have a lot of variation. The depth and speed of the water, as well as the substrate making up the channel's bottom change along the course of the channel. This leads to various types of habitat, which can be classified into several general groups. **Riffles** are characterized by turbulence at the surface, or white water. The slope of a riffle segment can vary widely, but it is always found in shallower parts of the stream where the water is moving quickly. Riffles are generally found flowing over areas of course substrate. **Runs** are similar, they are shallow and fast moving, but they occur over smaller substrate and more level channel bottoms. They are less turbulent and do not have white water. **Pools**, in contrast, are deeper and slower moving parts of the stream. Pool bottoms consist of finer substrate than is found in riffles. The boundaries between these classes of habitat are not always clear. They are, however, distinct ecological habitats. Different organisms have adaptations best suited for life in one of these habitat types.



Stream habitats. (*Image from EPA)*

Freshwater Lakes

Lakes are important components of watersheds, collecting and storing water and serving as habitat for wildlife. Lakes retain water within a watershed, providing more consistent water and downstream flow throughout the year. Lakes also provide important habitat for many different animal and plant species.

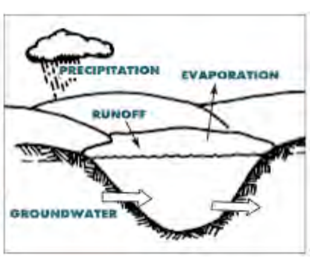
Lake water quality is tied to watershed size; typically, the larger the ratio of watershed size to lake size the poorer the water quality in the lake (e.g., small lakes with large watersheds have worse water quality). This is especially true in more urbanized areas. As water collects across a watershed, pollutants are transported and stored in lakes. Larger lakes have greater storage capacity, and pollutants will be less concentrated. The same amounts of pollutants are more concentrated in a small lake.

The physical characteristics in a lake play an important role in governing the kinds of organisms that can live there. Some important factors that influence species diversity are water temperature and nutrient load. Many other factors influence these, including climate, lake size, inflow and outflow, the amount of mixing, and the surrounding land use, and are generally interconnected. For instance, a shallow, turbid lake with high sediment and high algae won’t support the same species as a deep lake with high inflow and outflow.

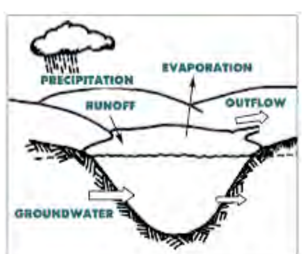
In contrast to ponds, which are generally shallow, lakes are classified as at least 6 feet, or 2 meters, deep. Since solar energy usually penetrates only a couple meters into the water column, the deeper sections of a lake do not receive any sunlight. As a result, production in these areas is much lower than elsewhere. In contrast, ponds usually receive solar energy throughout the entire water column. Contrary to popular perception, the depth of a lake is usually very small compared to its length. Most ordinary lakes appear like thin, straight lines when viewed from the side. Lake Baikal, the world’s deepest lake, is nearly 2 km deep. However, this is a small figure compared with the lake’s 750 km length. Conversely, Utah Lake is one of the largest freshwater lakes in the U.S., with an area of 384.4 km^2, but it is also a very shallow lake, with an average depth of 10.5 feet.

The surface area of a body of water influences the mechanisms for mixing water layers. Gentle thermally-induced mixing is characteristic of ponds, while more turbulent, wind-induced mixing is characteristic of lakes. Lake size also affects evaporation, disturbance, competition, and predation, all factors influencing species distribution.

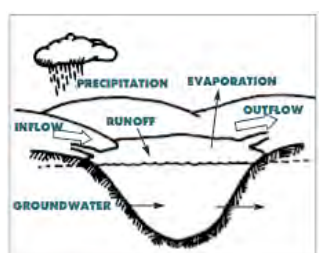
For a lake to remain fresh water there must be an outlet as well as an inlet. Lakes without outlets, like the Great Salt Lake, are collecting spots for minerals. The water is carried away by evaporation but the salts and minerals remain behind and increase in concentration. This is also why the oceans are salty. Outlets and inlets also affect the amount of water in a lake. For a lake’s volume to remain constant, inflow has to equal outflow (accounting for evaporation), otherwise lake volume changes.



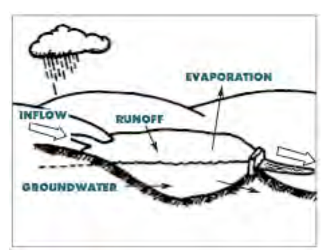
Seepage



Groundwater Drainage



Drainage



Impoundment

Lake types, as influenced by inflow and outflow. (*Images from University of Wisconsin- Stevens Point*)

There are many different ways that lakes can form. If a low-lying area, or basin, is surrounded by more elevated land and a river feeds into it, then a lake may form. There are several geologic processes that can lead to the formation of basins. Glacial lakes form in a few different ways. When ice sheets recede, they sometimes leave behind large blocks of ice. As the ice melts, it forms a basin that may retain water. This is called a **glacial or kettle lake**. The rough scouring of the ground beneath a glacier often creates basins that are left behind after the glacier has receded. If they retain water, the basin will become a lake called a **tarn**. Finally, a glacier pushes a lot of rocky debris ahead of it as it moves down a canyon. When a glacier's progress is terminated, this debris is deposited as a moraine that may form a natural dam. As this dam is filled with water, it creates a **moraine lake**. Another common type of lake is formed when a river bend closes in on itself and leaves behind a curved section of the river channel. These lakes are called fluvial lakes, or **oxbows**. Lastly, **tectonic lakes** are formed when a portion of the Earth's crust is uplifted, creating a natural impoundment.

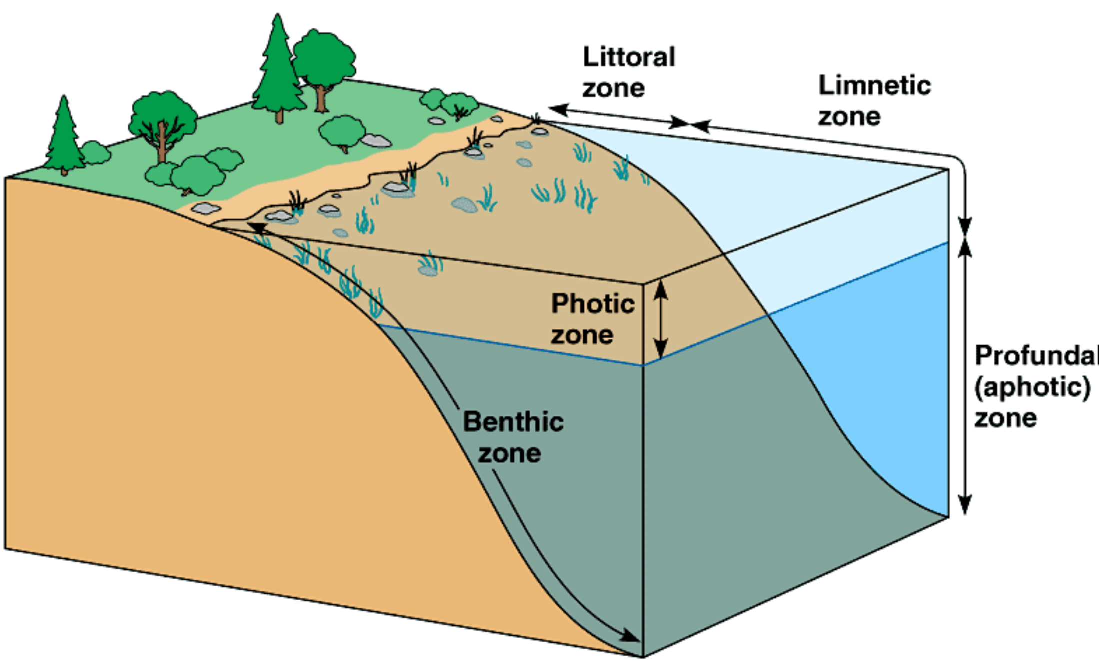
A tarn carved out by a glacier.

A moraine lake dammed by the debris deposited at the end of a glacier.

A tectonic lake formed by the subsidence of a mountain.

Lake Zones

Lakes are divided into separate zones, based on the presence of sunlight and type of primary production. The area close to shore where **macrophytes** can grow rooted to the bottom is called the **littoral zone**. Plants can only grow on the bottom if sufficient light reaches the sediment, or the plants are able to reach the water surface. Since light is absorbed and scattered as it travels through water, this generally occurs in relatively shallow water. It varies with the clarity of the lake, but is usually less than 6 feet (2 meters) deep. Emergent plants, like water lilies and cattails, are characteristic of the littoral zone, as well as submerged but rooted aquatic plants. This is the most productive and most diverse area of a lake. More types of organisms live in the sediment and water in the littoral zone than in other zones of the lake.



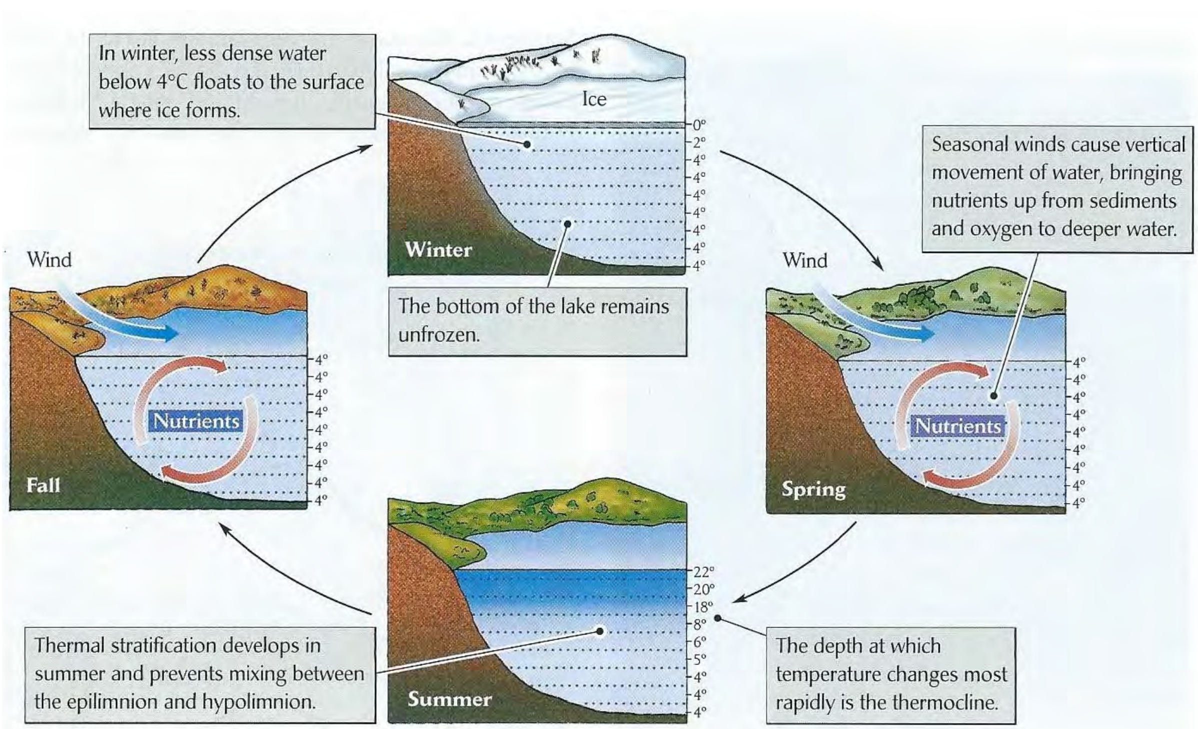
The zones of a freshwater lake. (*Image from Pearson Education*)

The open water of a lake, where plants cannot grow rooted to the bottom, is divided into two different zones. The dividing line is called the **compensation depth**. This is the depth where the amount of light (usually about 1% of the amount of light at the surface) allows enough photosynthesis to compensate for the energy consumed by heterotrophs (organisms that must take in other organic matter to survive). The volume of water above this dividing line, where there is positive net production, is called the **limnetic zone** or **pelagic zone**. The primary production in the limnetic zone is carried out by suspended **microphytes** , or **phytoplankton**, that drift in the current. These single-celled organisms use a greater variety of pigments to carry out photosynthesis than their macroscopic counterparts. Eukaryotic (cells containing a nucleus) phytoplankton use the same method as larger plants. They have organelles, called chloroplasts, where photosynthetic pigments are concentrated. Photosynthetic bacteria, like cyanobacteria, and other prokaryotes (cells with no nucleus) have pigments distributed throughout the cytoplasm. Larger organisms that are mobile in the current, or **nekton**, are also found in the limnetic zone. These include fish, crustaceans, insects, and other heterotrophs that actively seek out organic matter for consumption.

The volume of water beneath the compensation depth, where there is **negative net production**, is called the **profundal zone**. Since there is limited or no light, photosynthesis cannot directly support the ecosystem. This is not to say that there is no life in the profundal zone, though. Organisms, including free swimming, like river otters and fish, benthic (bottom-dwelling), like June suckers and mollusks, and microbes in the water column and sediment are dependent on organic matter drifting down from the limnetic zone.

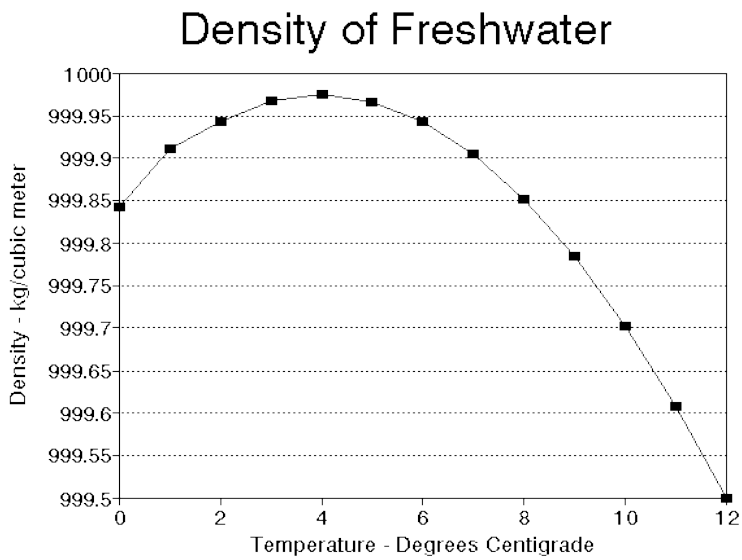
Lake Mixing

For temperate lakes in areas such as Utah, with four distinct seasons, temperature and wind combine to create an effect known as **seasonal overturning or mixing**, which is critical to maintaining the overall health of a lake. During fall, cooler winds begin to cool the surface waters of a lake. As the cooler surface water sinks and the warm water rises, the temperature in the lake eventually becomes homogeneous. The wind energy that is required to mix the entire lake volume is relatively low, since the entire lake is of a uniform density. This complete turnover of a lake keeps oxygen and nutrients evenly distributed from surface to bottom. As a result, nutrients support primary production in the limnetic zone and oxygen supports respiration in the profundal zone.



Seasonal lake mixing, as influenced by temperature and wind. (*Image from Ricklefs, 2007*)

Lake water mixes in a fairly predictable way over the course of a year due to temperature and density. Warmer water is less dense than colder water, but frozen water is less dense than liquid water. When water molecules freeze, they take on a crystalline structure, which increases the distance between molecules. When ice melts it loses its solid structure and the molecules can exist more closely to each other. As more heat is added, the molecules vibrate faster and push other molecules away, decreasing the density. As a result of these two competing processes, freshwater is densest at 4°C, not 0°C. Thus, warmer, less dense water sits on top of cold, dense water, creating a temperature gradient.



The density of freshwater is highest at 4°C, which is why ice floats.

During the winter, the surface of most lakes is frozen. Without any exposure to wind, and with minimal solar energy reaching the water, little or no mixing occurs. The densest, 4-degree water sits at the bottom and the less dense, colder water is just beneath the ice.

As the ice melts in the spring the surface water warms slightly. The water approaches 4°C and the temperature gradient that had been stable over the winter disappears. At the same time the protective layer of ice disappears, so wind turbulence begins mixing the water. Since the entire water column is once again the same temperature and density, it doesn't take much energy for the wind to mix the entire mass of water. This continues until warmer spring temperatures and more direct sunlight further warm the surface water and the cooler water sinks to the bottom.

The sun continues to warm the surface water into summer and another temperature gradient is established, this time with the cooler water on the bottom. The warm upper layer is called the **epilimnion** and the lower cooler layer is called the **hypolimnion**. The area where temperatures change quickly from the warmer surface water to the colder profundal zone is called the **thermocline** or **metalimnion**. Once this gradient has been established, it takes much more energy to mix the entire water column, and for the most part only the warm surface water is stirred by the wind in the summer.

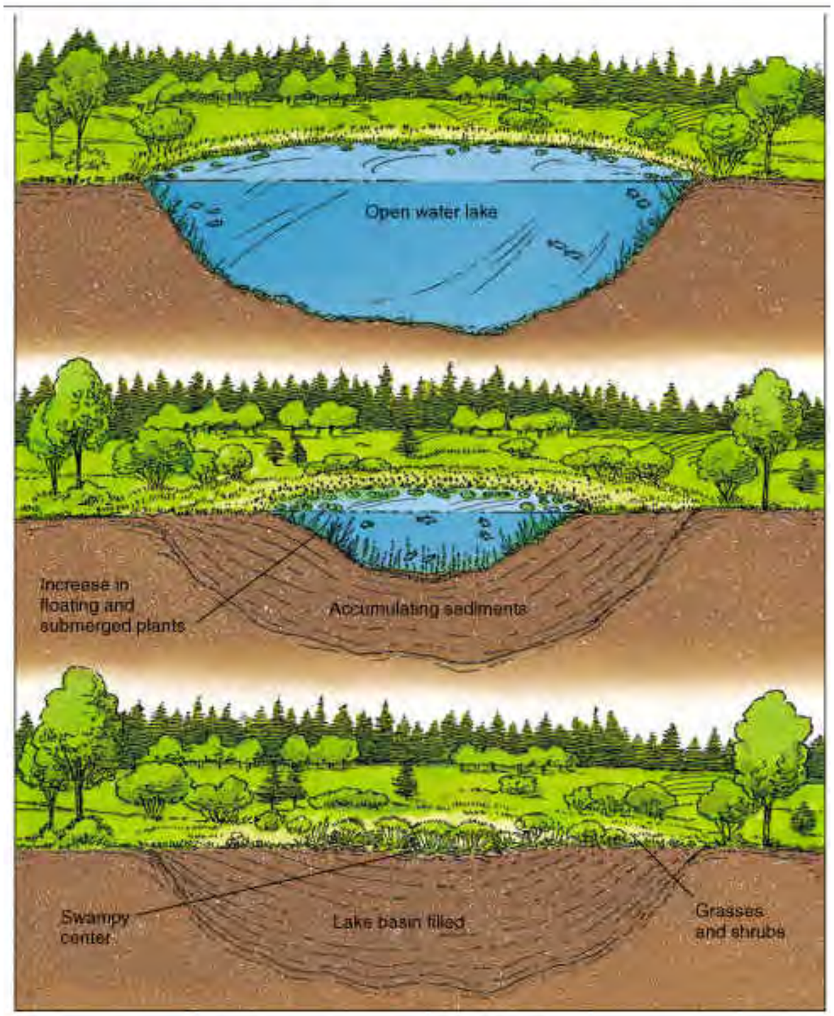
Increased primary production in the limnetic zone generally coincides with the warm summer surface water. The large amount of photosynthetic life that is found in this zone results in increasing oxygen levels. Turbulence on the surface also contributes some dissolved gas. Since the surface water does not mix with the rest of the water column, the oxygen accumulates only in the limnetic zone.

The aphotic (no light) profundul zone cannot support the production that occurs in the surface water. The organisms that live in the dark, cold water use oxygen that is not being replaced. These organisms include fish and other large animals (e.g., catfish, June/Utah sucker), benthic invertebrates (i.e., Northern crayfish), and decomposers (i.e., bacteria) that use oxygen to break down organic matter which sinks from the more productive surface water. Because there is no mixing, the profundal zone becomes stagnant and has relatively low oxygen levels. There is much less life found here than other parts of the lake, and the nutrients that sink down from surface waters are largely unused. This temperature gradient results in warm, oxygen rich water with low nutrient levels near the surface and cold, nutrient rich water with low oxygen concentration near the bottom. The seasonal overturning of lakes allows the oxygen and nutrients to support life throughout the entire lake, ensuring its survival as an ecosystem.

Then, in the autumn, the surface waters of the lake are cooled, and the lake overturns once again.

<u>Lake Succession</u>

Ecosystems, including freshwater lakes, are in a constant state of change. On a geologic time scale, lakes are actually short-lived systems. Lakes naturally fill in with sediment and detritus over time until there is no longer any standing water. The process starts with emergent vegetation growing around the shore. The dead remains of these plants fall into the water and sink to the bottom. New soil is formed near the shore, which becomes substrate for other emergent plants to grow. Hydrophytic (i.e., water-loving) shrubs and trees follow soon after. The process continues as nearly concentric rings of vegetative types are established around the lake, with aquatic species near the open water and wetland or upland species growing farther inland. In time, rings of vegetation extend toward the center of the lake depression. Eventually the lake becomes a swamp, which then succeeds to dry uplands.



The process of lake succession.

Wetlands

A wetland is a rare ecosystem in Utah. While wetlands comprise over half a million acres of land in Utah, that's only 1% of the entire state! At the time that the Mormon pioneers arrived in Utah, there were about 800,000 acres of wetlands across the state. Diversion, draining, filling and other impacts have contributed to the loss of 30% of our wetlands since then. Approximately 75% of Utah's wetlands are situated around the shores of Great Salt Lake. Since 80% of wildlife depend on wetlands for at least part of their life, the Great Salt Lake and its surrounding wetlands are an extremely important ecosystem.

Wetlands are generally found in low-lying areas and are fed by streams, rivers, lakes, precipitation, and groundwater. Defining a wetland can be difficult, because no two wetlands are exactly the same. There are four general characteristics that define a wetland. **All wetlands contain water for at least part of the growing season**. This is the variable that causes the most disagreement over wetland classification. Is a forest that is only flooded for a week every spring to be considered a wetland? Water levels are always fluctuating, so the boundaries of a wetland cannot be simply defined by where the water ends. Some wetlands do not have visible surface water, but the water table is so high that the root zone is constantly inundated. For these reasons, the presence of water alone cannot define a wetland.

Wetland soils, referred to as hydric soils, are often saturated with water, resulting in little or no oxygen present. The lack of available oxygen creates an anaerobic environment that restricts the types of plants and organisms that can grow there.

Hydrophytes ("water plants") have adapted to the anaerobic conditions found in wetland soils. While plants produce oxygen at the leaf via photosynthesis, they also need to take up oxygen in the roots for respiration. As a result, wetland plants include **aerenchyma**, or extra air spaces in the leaves and stem to allow oxygen to diffuse into the roots.

Lastly, wetlands are home to a vast array of organisms, from bacteria to moose, that derive food and shelter and contribute to the wetland ecosystem. Specially-adapted bacteria help decompose organic material and cycle nutrients through the ecosystem. Diverse wildlife rely on wetland ecosystems for survival, including feeding, mating, nesting, and protection.

Politics also make defining wetlands difficult. Since the late 1970s, when people began to realize the importance of intact wetlands, there has been a constant effort to define where wetlands are and which wetlands are in need of protection. The United States Environmental Protection Agency (EPA) and U.S. Department of Agriculture's Natural Resource Conservation Service define wetlands as "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas." Prior to the recognition of the importance of wetlands, they were usually drained to make room for agriculture, roads, or other developments important for the human economy. Now that the conflict between natural preservation and human development has been recognized, defining protected areas has become a political concern. Placing regulations, as was done under Section 404 of the Clean Water Act of 1977, on land use, particularly that on private land, has aided in protecting wetlands across the country. However, standards and regulations can vary between agency, state, or even from year to year, making wetland protection difficult.

<u>Wetland Functions</u>

Wetlands serve many vital roles within a larger watershed ecosystem. Wetlands are often described as the "kidneys of the watershed" because this is where the arteries (rivers and streams) bring water to be cleansed and purified. Wetlands are a source of life, water, and food for an entire watershed and beyond.

1. **Habitat -** While wetlands comprise only 1% of Utah, over 75% of all wildlife depend upon wetlands at some point of their life cycle. Wetlands are among the most productive ecosystems in the world. Nationwide, over 5,000 species of plants, 190 species of amphibians and 270 species of birds depend

on wetlands for food, shelter and space. Wetlands are important spawning and nursery areas for commercial and recreational fish and shellfish industries, as well as feeding, nesting and shelter zones for fish and migratory birds.

2. **Climate Control -** Many wetlands return over two-thirds of their annual water input to the atmosphere through evapotranspiration, which acts to moderate temperatures and humidity in adjacent uplands. Also, wetlands store carbon within dead plant matter and soil, reducing the release of carbon dioxide into the atmosphere. Carbon dioxide is a greenhouse gas that contributes to increased temperatures from climate change.
3. **Decontamination -** Wetland soils remove nutrients such as nitrogen and phosphorus found in residential and agricultural runoff from surface and groundwater. Wetland plants take up and use the nutrients and chemicals carried in collected sediments, which could otherwise contaminate rivers, lakes and groundwater supplies**.**
4. **Flood Control and Water Storage** - Wetlands control flooding by slowing down and spreading out fast moving water. They also absorb water like giant sponges and slowly release it into downstream habitats and groundwater. When walking through a wetland during times of soil saturation, one can hear the water squishing through the soil underfoot. During dry periods, wetland soils might not feel any different from upland soils.
5. **Nutrient Cycling -** An abundance of decomposers, such as bacteria, in wetlands continuously break down dead plant and animal material into nutrients and make them available to plants and other producers. Wetland processes play an important role in the cycling of carbon, nitrogen, phosphorus, and sulfur, constantly transforming and releasing them back into the ecosystem. The abundance of aquatic and terrestrial plants in the world's wetlands contributes significantly to oxygen in the atmosphere**.**
6. **Soil Conservation -** Water flowing into wetlands loses speed, causing sediment eroded upstream to accumulate for use by plants and animals. Plant roots bind soil to help it stay in place. Wetlands capture sediments and debris that could otherwise threaten life downstream by filling in deep pools, covering eggs, or clogging animals' gills. Some wetlands remove up to 90% of sediments**.**
7. **Human Enrichment -** Wetlands provide beauty, recreation, and solitude. From hunters to birdwatchers, to canoers, many people appreciate wetlands simply for their beauty.

<u>Ponds</u>

Standing water generally less than 6 ft (2 m) deep is a defining characteristic of **ponds**. The shallow depth permits light to penetrate through the entire water column, which allows aquatic plants to root on the bottom and still have emergent leaves. Because none of the pond is light-restricted, ponds are generally highly productive ecosystems. Ponds often form through erosion or from sinkholes.

A freshwater pond along the Wasatch Front. (*Image by M. Larese-Casanova*)

Marshes

The name "**marsh**" is widely used to describe most wetland ecosystems. This is partly because the most common idea of a wetland can be classified as a marsh; a large, flat area with little standing water and abundant emergent vegetation. Marshes are particularly important habitat for wildlife in Utah, particularly migratory waterfowl. Marshes spread across the state in many different watersheds. The Bear River Migratory Bird Refuge is a good example of a large marsh interspersed with segments of open water. Plants common in Utah marshes include cattails, bulrush, milkweed, and Phragmites.

A marsh at The Nature Conservancy's Great Salt Lake Shorelands Preserve. (*Image by M. Larese-Casanova*)

Wet Meadows

Wet meadows often seem dry but are covered in many different types of wetland plants. While there is no standing water, the high water table still inundates the soil and creates the hydric soil typical of wetlands. Wet meadows are often found on a gentle slope, usually angled toward a river, or on the outside edge of a depressional wetland, such as a pond or marsh. Plants often found in wet meadows include Russian olive trees, milkweed, Baltic rush, and numerous wildflowers. The diversity of plants and availability of water make excellent habitat for butterflies and other insects.

Wet Lake Margins/Lacustrine Fringe

The water levels in lakes are never constant. These changing water levels lead to an area around the fringe of the lake that is sometimes submerged and sometimes dry. This varying habitat is occupied by wetland plants that can survive with both environments. These include spikerush, bulrushes, cattails, and salt grass. It might be a little confusing to separate wet lake margins from marshes, because they look very similar. However, the proximity of deep water, and sometimes forest, to **wet lake margins** results in different hydrology and species composition. Water is usually more constant adjacent to lakes, and species such as the American beaver inhabit lakes and streams with a nearby source of trees and shrubs, and are not found in marshes.

A seemingly dry wet meadow in Utah. (*Image from Utah Ledpidoptera Society*)

A lacustrine fringe wetland along the shore of a montane lake.

Playas

Wetlands have different characteristics depending on their inflow and outflow. Depressions in which water collects that have no outlet are very different from wetlands with outlets. Like the Great Salt Lake, when a water body has no outlet except for evaporation, salts and other minerals begin to accumulate. In large scales, this leads to salt lakes, on a smaller scale this leads to **playas**. Playas are closed wetland systems that are fed by precipitation and runoff. During high runoff times, playas collect water in their shallow basins. During the hot and dry summer, water begins to evaporate and playas become drier and saltier. Hydric soils with high salinity create very difficult growing conditions for most plants. Playas generally have little vegetation. Plants adapted to high salt environments that live in and near playas include iodine bush, pickleweed, salt grass, and greasewood. In Utah, playas are common around the Great Salt Lake and Great Basin.

A shallow playa along the shore of Great Salt Lake.

Mudflats and Salt Flats

Mudflats and **salt flats** are very similar to playas, except that they have outlets to other water bodies. Like playas, mudflats and salt flats often have very little or no vegetation, they occur on large, dry lake bottoms, and are fed only by precipitation. There are vast expanses of salt flats in the Central Basin and Range where Lake Bonneville once occurred.

An arid mudflat in the middle of summer doesn't look like much of a wetland! (*Image by M. Larese-Casanova*)

Riparian Wetlands

Riparian areas are transition areas between uplands and rivers, lakes, and other sources of freshwater. Because of the abundant water they have much higher biodiversity than adjacent drier land. Not all riparian areas are wetlands, though, but some are flooded on a regular basis and maintain hydric soils, which allow them to be classified as wetlands. There are many different types of riparian wetlands; some are low-lying marshy areas directly adjacent to a river, some are cutoff meanders or oxbow ponds separated from a river, and some riparian wetlands look like forests with large cottonwoods and willows.

Riparian wetland along the edge of a river.

Potholes and Plungepools

Pothole wetlands found in the southern part of the state are important sources of water in arid desert regions. Water collects in depressions formed by erosion between two rocks during high water flows in the spring. **Plungepools** are similar, but are formed underneath waterfalls that flow during rainstorms. Both have hydric soils, although sometimes very minimally, and provide habitat for macroinvertebrates. Insects and amphibians breed in the pools, and the water source can support hydrophytic plants. Birds, mammals, and reptiles rely on potholes and plungepools as a vital source of water.

A desert pothole (left) and plungepool (right) provide water in an arid climate. (*Images by M. Larese-Casanova*)

Hanging Gardens

Hanging gardens form on the side of cliffs where groundwater seeps out of the rock. The water has traveled down through the rock for hundreds, even thousands, of years until it reaches a less permeable layer, at which point it flows outward. Water flows out of cliff faces continuously at times, even in the middle of a hot summer. Sediment collects on the moist rock and in alcoves formed by the water seepage, creating a unique wetland ecosystem called a **hanging garden**. Plants that take hold in these isolated wet soils have a high level of protection from large grazers that cannot reach them. Hanging gardens are home to various lilies, orchids, and ferns. In fact, about 35 species of plants endemic to the Colorado Plateau live in hanging gardens. Birds, flying insects, and other organisms that can reach these isolated wetlands are rewarded with many valuable resources in the desert habitat.


Hanging gardens cling to the cliff face in Zion National Park. (*Images by M. Larese-Casanova*)

Glacial Potholes

Glacial potholes are ponds found in montane areas of Utah. They are formed when receding glaciers leave large blocks of ice behind. Soil fills around the ice chunks so that when the ice finally melts, a small but deep pool is left behind. Rainwater and snowmelt continue to fill the pothole, sustaining the wetland. In Utah glacial potholes provide habitat for many different types of aquatic plants. Submerged and floating plants grow in the deepest parts, while emergent vegetation grows near the shore. Saturated soils are often found beyond the shoreline, creating marshes surrounding the pond. Glacial potholes provide wetland habitat at high elevations, which are very important for many different organisms. Moose, elk, deer, waterfowl, frogs, salamanders, and many kinds of insects use potholes as sources of food, water, shelter, and places to mate and raise young.

Glacial potholes high in the Uinta Mountains.

Fens

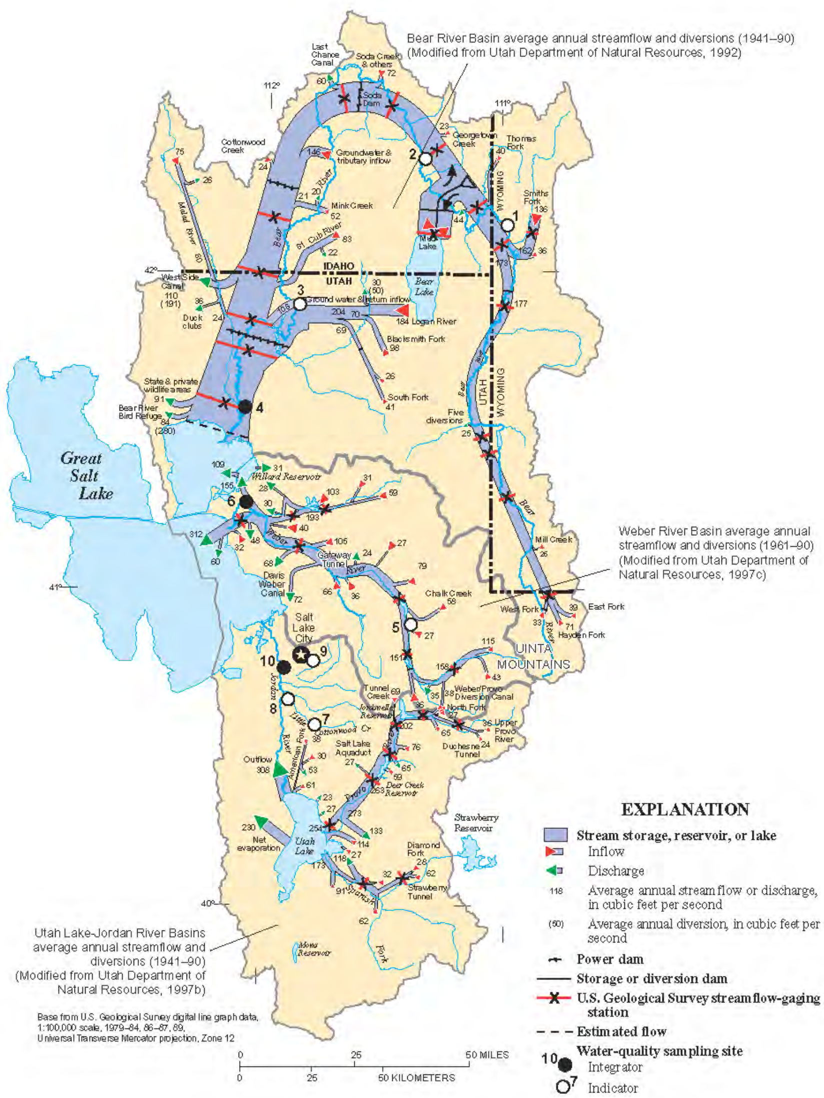
Fens are wetlands found in high elevations of Utah, and are very similar to bogs found in the eastern U.S. Fens are more alkaline (basic) pH, whereas bogs are typically more acidic. Unlike bogs, which are predominantly fed by rainwater, fens receive their water from groundwater that seeps into the wetland. Minerals in the soil and rocks, particularly calcium and magnesium, reduce the acidity of the water (raise the pH). The plants, such as grasses, sedges, rushes, and wildflowers, that grow in fens die and sink to the bottom, creating peat. Over time peat buildup may separate the fen from its groundwater source. When this happens fewer nutrients are delivered, rainwater increases the acidity, and the area may become a bog. Fens often have greater nutrient levels than more acidic wetlands like bogs, and therefore have a greater amount of biodiversity. Fens provide food for grazers and pollinating insects as well as habitat for diverse montane wildlife.

A fen above the Weber River. (*Image from Utah Geological Survey*)

Great Salt Lake

Great Salt Lake is a terminal lake, which means it has no outlets other than evaporation. It is the fourth largest terminal lake in the world, and the sixth largest lake in the US, just behind the five Great Lakes. Terminal lakes define their respective watersheds completely; in other words, since there is no outlet the watershed is not contained in any larger watershed. Since there is no way for water to leave other than evaporation, salts and other minerals accumulate giving the lake its characteristic high salinity level. The salinity of Great Salt Lake ranges from as low as 5% to full saturation at 27%, with an average of about 10-11%. By comparison, the salinity of seawater is about 3.5%! The salinity of Great Salt Lake varies wildly with time of year (as influenced by spring runoff, precipitation, and evaporation) and location.

The Great Salt Lake drains the Great Salt Lake watershed, which covers 21,500 square miles in Utah, Wyoming, and Idaho. Utah Lake and Bear Lake are two large fresh-water lakes that drain into the Great Salt Lake, and the major rivers that flow into the lake are the Bear River from the north, the Ogden and Weber Rivers from the east, and the Jordan River from the south. These rivers, along with smaller tributaries, account for 66% of the lakes inflow each year. The other 34% is made up of direct precipitation (31%) and a small amount of groundwater (3%).



The major rivers within the Great Salt Lake watershed. (*Image from Utah Department of Natural Resources*)

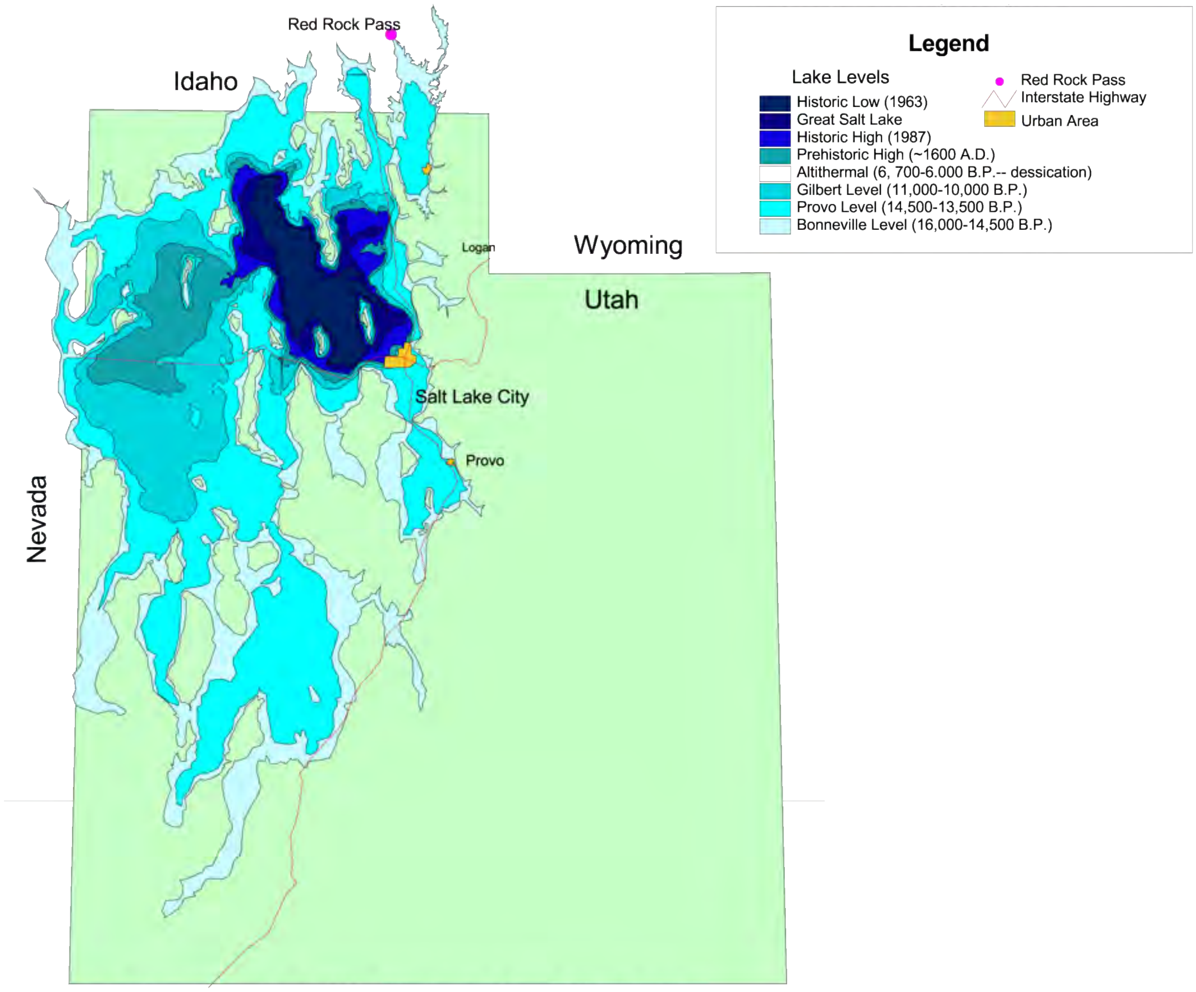
Because it is such a harsh, salty environment, Great Salt Lake supports a community of plants and wildlife that are low in diversity, but high in abundance. The high salt content of the soils surrounding the lake also make it difficult for all but a few plants to survive. There are **salt tolerant** plant species, including pickleweed, iodinebush, saltgrass, and greasewood, that do survive and provide shelter and food for wildlife. Due to the high salt content, the water of Great Salt Lake can't support fish populations. The only exception is Willard Bay, which has been impounded to prevent salt water from mixing with freshwater flowing in from the Bear River. The largest aquatic organisms found in Great Salt Lake are **brine shrimp** and **brine fly** larvae. These salt tolerant invertebrates help support the rest of the lake ecosystem as they are a major source of food for the migratory birds that frequent the lake.

Great Salt Lake is often referred to as an "avian oasis." Some of the largest concentrations of breeding and migrating birds in the West can be found at Great Salt Lake, depending on the time of year. Over 7.5 million birds from 260 species inhabit the lake in an average year. Large concentrations of even a single species can be found at the lake. Gunnison Island in the northwest part of the lake is home to over 20,000 breeding pelicans, which is either the first or second largest population in the U.S., depending on the year. Over half of the North American population, or approximately 2.5 million, eared grebes make their home at Great Salt Lake each year. Perhaps the biggest avian superstar at Great Salt Lake is the Wilson's phalarope, which doubles its weight during its migration layover at Great Salt Lake. While only 500,000 phalaropes can be found at the lake, it is one-third of the world's population!

Great Salt Lake, as well as several other Utah lakes, is a remnant of the ancient **Lake Bonneville**. Lake Bonneville was a huge freshwater lake that existed between 32 and 14 thousand years ago, and covered over 21,500 square miles in present-day western Utah, Nevada, and Idaho. Traces of Lake Bonneville can still be seen today. The shoreline of Lake Bonneville left benches, or narrow strips of level land, along the Wasatch Range. At different lake levels different benches formed, creating the terraced formation that is familiar in Utah geology. The four major shorelines left by Lake Bonneville and the early Great Salt Lake are:

1. **Stansbury shoreline**, at 4,445 feet above sea level, left between 24,000 and 23,000 years ago when a lava flow diverted the Bear River south to Lake Bonneville.
2. **Bonneville shoreline**, at 5,220 feet, formed between 18,000 and 16,800 years ago when Lake Bonneville broke through the natural dam at Red Rock Pass in Idaho, diverting the Bear River to the north again. Once water began flowing over the top of the pass, the erosion carved away greater amounts of earth, eventually leading to a catastrophic flood that followed the path of the Snake and Columbia Rivers to the Pacific Ocean.
3. **Provo shoreline**, at 4,840 feet, left between 16,800 and 16,000 years ago after another lava flow diverted the Bear River to Lake Bonneville again.
4. **Gilbert shoreline** of the early Great Salt Lake, 4,275 feet above sea level, left between 13,000 and 11,500 thousand years ago during a time of increased evaporation related to the warming climate.

These shorelines help to track the size of Lake Bonneville over the geologic time-scale. After the Gilbert shoreline was formed, the climate in the Great Basin began to change. The weather became warmer and drier, and evaporation from the lake increased, leading to the Great Salt Lake that we are familiar with today. Other remnants of Lake Bonneville are Utah Lake, Sevier Lake, and the Bonneville Salt Flats to the west of the Great Salt Lake.

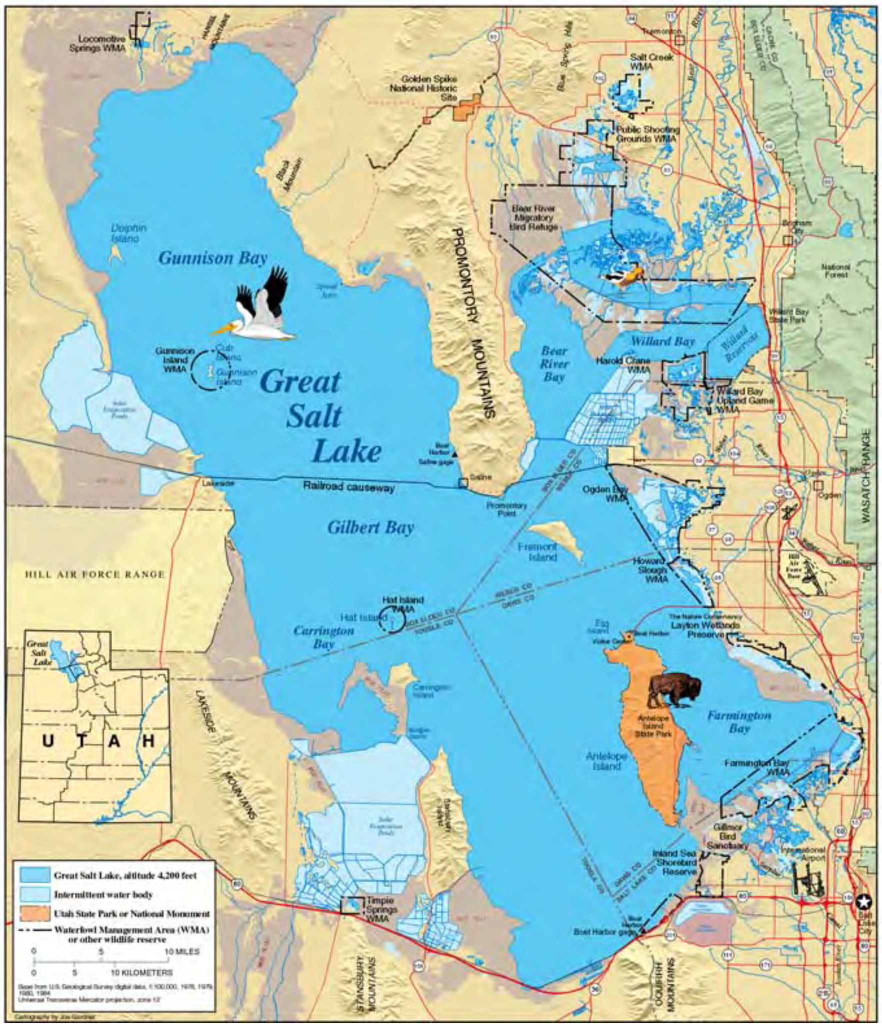


The major levels of Lake Bonneville and Great Salt Lake. (*Image from Utah Geological Survey*)

Even the present-day Great Salt Lake varies wildly in depth and area depending on factors such as precipitation, temperature and evaporation, and diversion of water from its tributaries. It is a shallow lake with an average water level at 4,202 feet above sea level and deepest point at 33 feet. Because of the shallow slopes that surround the lake, small changes in lake depth can greatly alter the area of the lake. On average, over the last 160 years, the lake has covered 2,300 square miles, with a volume of over 15 million acre-feet. The historic high point for the lake, during the flooding in 1986-87, raised the lake level 10 feet. This seemingly small rise increased the lake area to 133% of the average and doubled the volume of water in the lake. The historic low point for the lake level, occurring in 1963, was 11 feet below average, which reduced surface area of the lake to half the average size. The lake levels also change seasonally. The highest lake levels of the year are generally after the snowmelt has drained into the lake in May through July. The lowest levels are in October through November after the hot and dry summer months have increased the evaporation rate of the lake. On average, these seasonal fluctuations are between 1-2 feet per year.

Since the Great Salt Lake is a terminal lake system, its water levels are heavily dictated by evaporation rates. On average, about 2.9 million acre-feet of water evaporate from the lake surface every year. Evaporation compared to lake volume is fairly high for the Great Salt Lake because the lake is large and shallow. This creates a high ratio of surface area to water volume, and evaporation rates are tied directly to surface area. The evaporation rate also changes in relation to the temperature and humidity over the course of the year. If the inflow, mostly from mountain snowpack, is less than the amount of evaporation there will be a drop in lake level. If the inflow is greater than evaporation the lake level will rise. Climate has a huge impact on the lake level, affecting both precipitation rates and evaporation rates.

The **brine**, or salt water, of Great Salt Lake has unique chemical properties. As mentioned earlier, the salinity of Great Salt Lake varies between 5 and 27%. There are approximately 4.5 to 4.9 billion tons of salt in Great Salt Lake, and approximately 2.2 million tons of salt enter the lake each year. The typical concentrations of minerals in Great Salt Lake brine are: sodium 33%, chloride 54%, sulfate 7%, magnesium 3%, potassium 2%, and calcium <1%. Typical salinity levels are 8-10% in Gilbert Bay and 27% in Gunnison Bay.

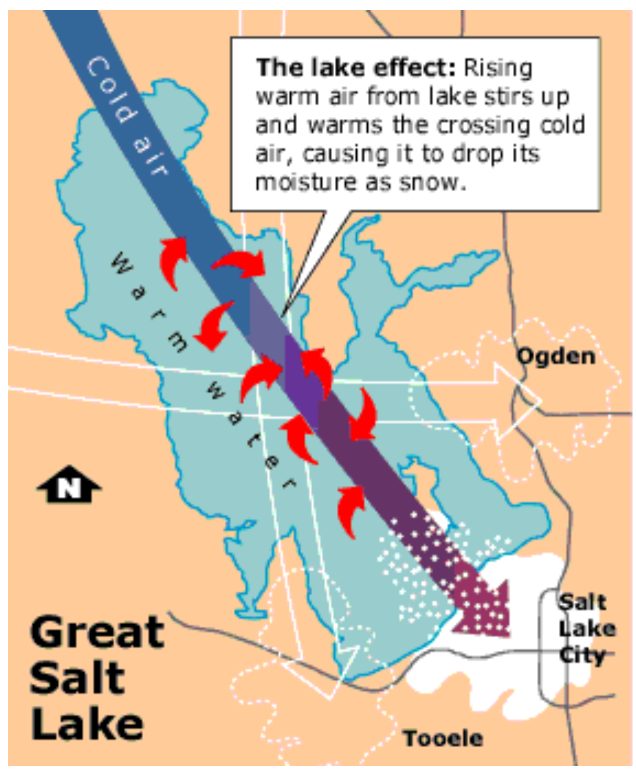


A map of the major bays and surrounding area of Great Salt Lake. (*Image from U.S. Geological Survey*)

There are three major salinity zones found in Great Salt Lake, one in Gunnison Bay to the northwest, the second in Gilbert Bay to the south, and the third in Willard and Bear River Bays to the northeast. The lake was split by the construction of the Southern Pacific Railroad's causeway in 1959. All four of the major rivers that feed the lake eventually flow into Gilbert Bay. The only sources of water for Gunnison Bay are salt water flowing through the causeway's few culverts, and through direct precipitation. The causeway was breached during the 1980s flooding, and the dissolved minerals recirculated. However, Gunnison Bay is usually saturated with salt, creating an environment where even brine shrimp cannot live. Willard and Bear River Bays contain freshwater, which was achieved by constructing dikes that control the inflow and outflow from the bay. The dikes raise the water level of the bay, allowing the inflow from the Bear River to contribute the vast majority of the water to the bay. The controlled outflow from Willard Bay keeps salts and minerals from accumulating. Willard Bay is fresh enough to support fish, and is a recreational asset for the state.

Satellite imagery of Great Salt Lake shows the lighter, saltier Gunnison Bay. (*Image from NASA*)

The Great Salt Lake has a direct effect on the climate in the Great Basin, just as the climate in the Great Basin affects the lake. Utah's latitude (distance north of the equator) lies in a general climate pattern characterized by westerly winds. Most of our weather comes from the Pacific Coast. These dry, westerly winds blow across the Great Basin, eventually encountering Great Salt Lake. As the dry air blows across the warm lake, it picks up large quantities of moisture through evaporation. Differences between lake and air temperature cause turbulence in the atmosphere, which also increases evaporation. The moist air comes off the lake and runs into and over the Wasatch Front, precipitating the water as the air rises, cools, and condenses. Since most of northern Utah's precipitation falls in the winter, this **lake-effect precipitation** results in tremendous snowfalls. Alta ski resort, up Little Cottonwood Canyon just on the east side of Great Salt Lake, has an average annual snowfall of 508 inches, and holds the state record of 811 inches of snow that fell during the 1983-1984 winter! It's no wonder our license plates say "*Greatest Snow on Earth*."



Lake effect snow in the Salt Lake area.
(*Image from Salt Lake Tribune*)

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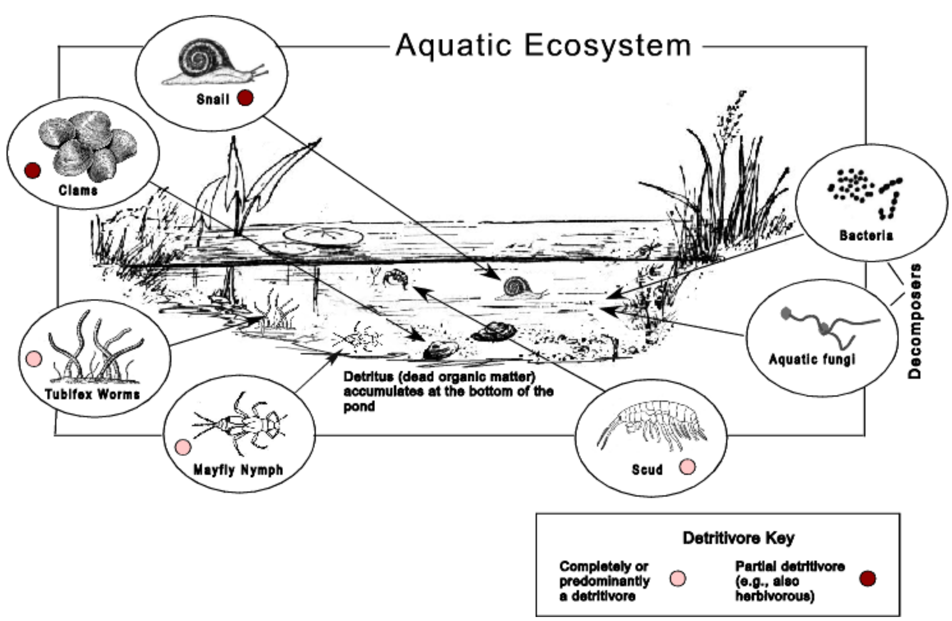
Watershed Ecology

Water is critical to all forms of life and is necessary for elementary life functions. It is processed and temporarily stored by green plants during photosynthesis and is used by animals to sustain life and conduct biological functions, such as digestion, blood transport, and muscle energy. Water exists in many forms throughout a watershed, from saturated soils in wetland habitat for plants and birds, to deep water lakes and springs that provide critical habitat for endemic fishes. Even the temporary desert potholes are essential water sources for a vast array of organisms. In a dry state like Utah, water attracts a great diversity of flora and fauna.

Food Webs

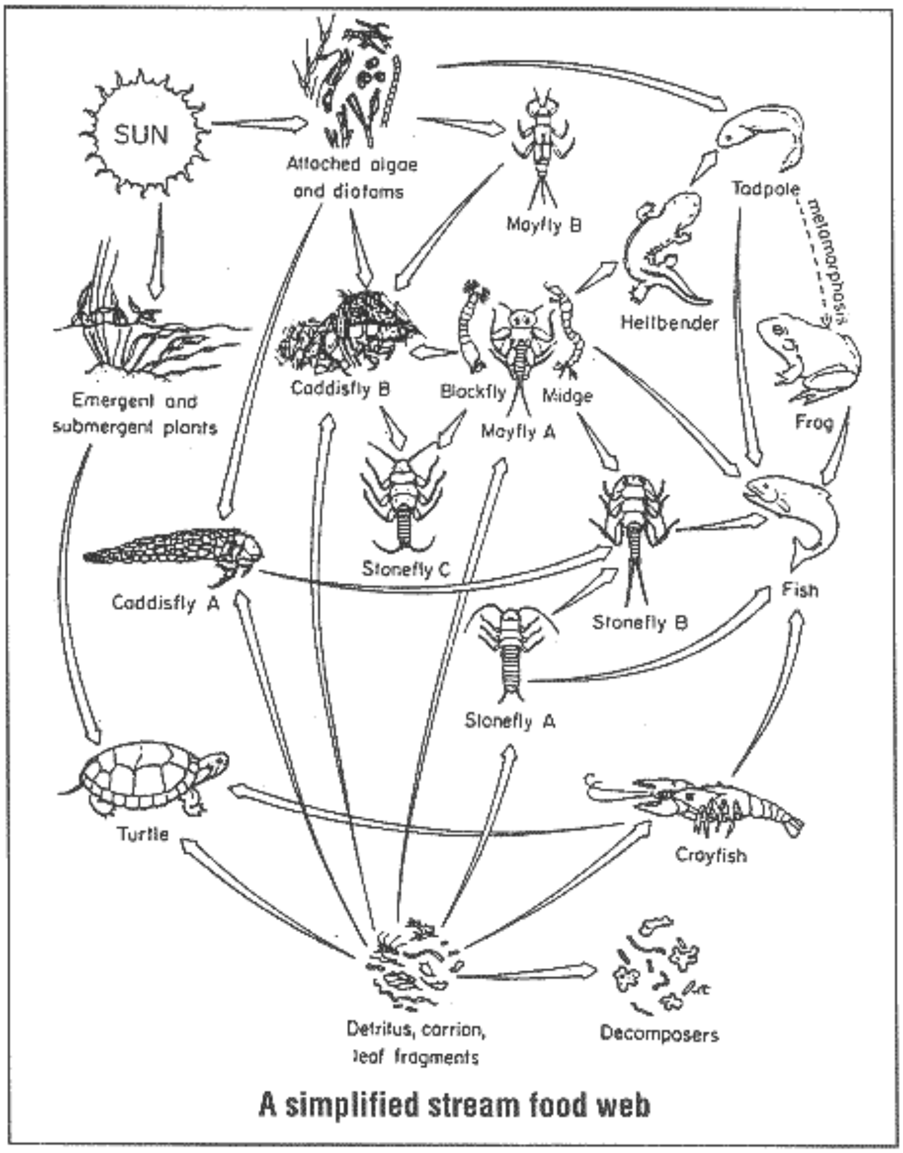
Food webs show the flow of energy through an ecosystem and the links between **producers** (e.g., plants, lichens, bacteria, etc.) that convert the sun's energy into chemical energy through photosynthesis, **consumers** that eat producers and other consumers, and **detritivores** that consume detritus (e.g., litter). Within a food web, there may be primary consumers, which feed on producers, secondary consumers that feed on primary consumers, tertiary consumers that feed on secondary consumers, and so on. As organisms excrete waste or die, **decomposers**, such as bacteria, break down organic matter into essential nutrients that are released back into the ecosystem.

Food webs are usually complex interactions among many species at each level. In nearly all aquatic ecosystems, invertebrates play a major role in ecosystem diversity and sustainability. They most often function as primary, secondary, and tertiary consumers, and even as the top predator as is the case of predaceous diving beetle larvae. Aquatic invertebrates also play a major role in nutrient cycling through aquatic systems as detritivores. In reality, though, many aquatic invertebrates are opportunistic omnivores, eating the most nutritious foods that are available at a given time.



The roles of detritivores in an aquatic ecosystem. (*Image from Ecological & Environmental Learning Services*)

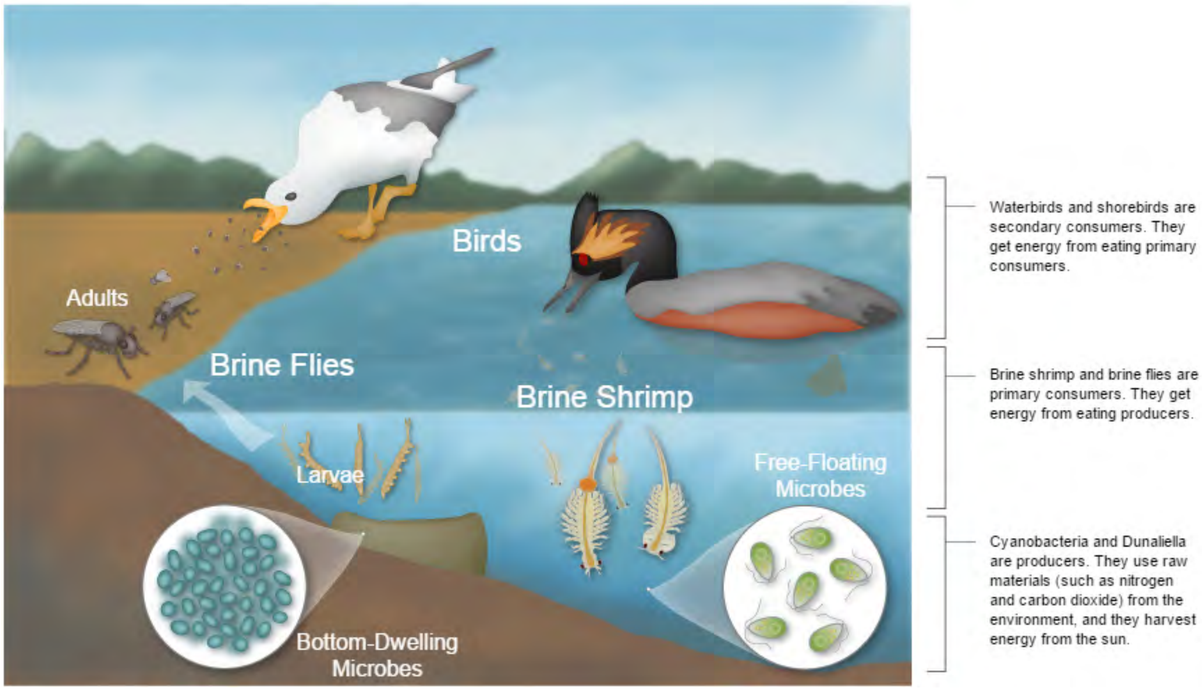
Aquatic invertebrates may feed as detritivores in a number of ways. **Shredders**, such as stonefly nymphs, 50% of which are also carnivores, feed by chewing and ingesting plant material that has fallen into a stream. **Collectors**, such as caddisfly or blackfly larvae, feed on particles of detritus that are collected, or filtered, out of the water. **Scrapers** (e.g., snails, several caddisflies, and some mayfly larvae), which primarily feed on algae growing on rocks and other substrates, do not generally contribute to the process of decomposition other than by producing waste products during consumption.



A simple stream food web shows the importance of aquatic invertebrates as both consumers and detritivores. (*Image from Boquet River Association*)

The Great Salt Lake is a unique, yet simple, food web. Because of the high salinity within Great Salt Lake, very few organisms are able to survive. Cyanobacteria are the primary producers within the Lake with primary consumers being brine shrimp and brine fly larvae, which also consume some organic material that is produced elsewhere and washed or blown into the lake. Migratory waterfowl, such as grebes and seagulls, represent the secondary consumers that forage on the flies and shrimp. Tertiary consumers, although not always present, can be foxes, coyotes, and other carnivores found on the banks of Great Salt

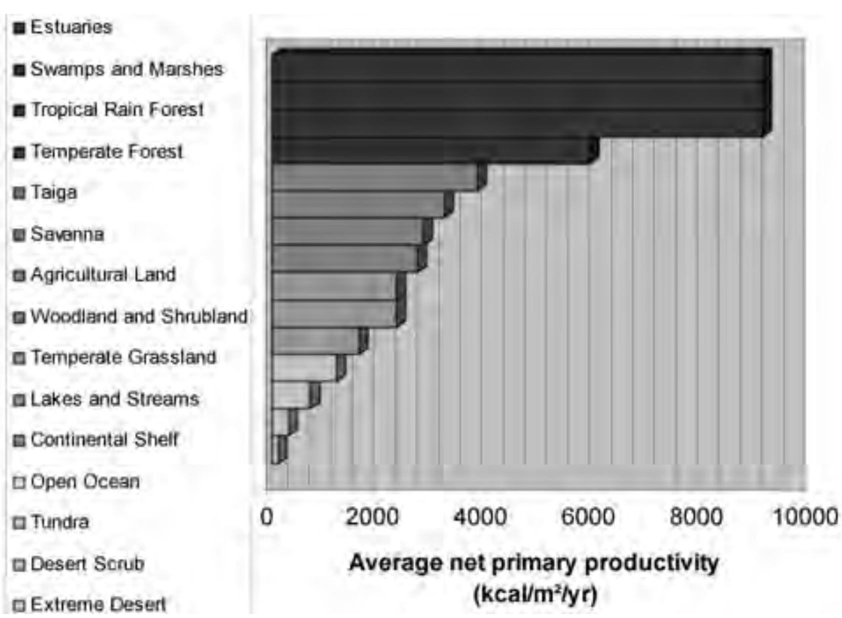
Lake. Finally, bacteria represent the decomposers that break down animal/plant waste and dead organisms.



The simple Great Salt Lake food web. (*Image from Great Salt Lake Institute at Westminster College*)

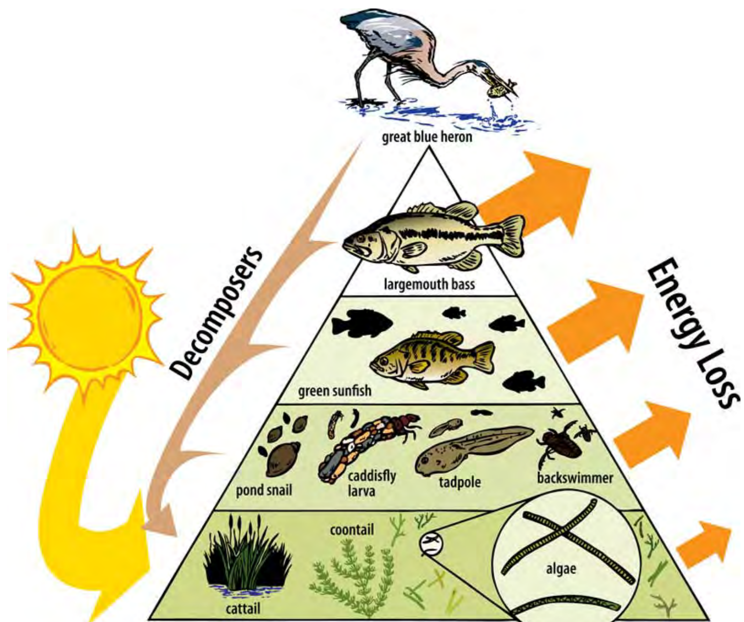
Trophic Levels

For ecosystems to function, there must be a flow of energy. Food webs, as discussed above, not only display the different types of organisms within an ecosystem; they also show the flow of energy from producers, which get their energy from the sun, to consumers that prey upon the producers. Energy availability in an ecosystem, as a simple concept, moves up a food web in a step-wise fashion with each step called a **trophic level**. The amount of energy produced, which is available to consumers and decomposers, is called **Net Primary Production** (NPP). NPP is the amount of solar energy converted to biomass by the producers, minus the energy used in respiration and the energy lost in death. Wetlands (e.g., swamps and marshes) have higher NPP in comparison with other aquatic ecosystems due to the extensive amount of producers, such as plants, that photosynthesize.



NPP for major ecosystems. (*Image from Algebra LAB*)

As energy progresses through each trophic level, between 2-40%, but usually around 10%, of the energy that is consumed is stored by the next trophic level, with the remaining energy used for metabolic processes, such as producing heat and fueling activity, or lost as waste. This loss of energy at higher trophic levels limits the number of organisms that can survive by consuming lower trophic levels. In a simple food web like Great Salt Lake, the interactions at each trophic level are critical in maintaining the functionality of the ecosystem. If a species, such as brine flies, is removed due to habitat loss, pollution, or some other reason, the effects can be detrimental to the entire ecosystem. However, in a more complex ecosystem, a species that disappears will often be replaced by other species that fill a similar **niche** (i.e., role) within the ecosystem. It may be that complex ecosystems can function with minimal species loss until entire niches or trophic levels disappear.



Energy flow through an aquatic ecosystem. (*Image from Texas Aquatic Science*)

Impacts to Food Webs

Abiotic factors directly affect the biotic components of and energy flow within an ecosystem. Natural, and gradual, changes to systems can often be managed without severe consequences. But rapid changes can produce drastic impacts on living things by exceeding an organism's **range of tolerance,** which is the spectrum of habitat conditions, both biotic and abiotic, that they can withstand. This is often apparent in areas that have experienced significant disturbance, usually, but not always, human-caused. The creation of Lake Powell through the construction of Glen Canyon Dam permanently altered the lower Colorado River ecosystem. For instance, the Colorado pikeminnow, only found in the Colorado River, is now endangered due to alteration of the physical habitat and flow regime on the Arizona side of the dam, which has led to its near extinction.

In aquatic ecosystems, oxygen, sunlight, temperature, acidity, nutrients, habitat availability, and hydrologic regime (e.g., water levels, and seasonal changes) are the most important limiting factors. That is, the reduction or alteration of these factors limit the growth or abundance of organisms within the ecosystem. Sometimes human actions can significantly change the amounts of limiting factors. Over-fertilizing agricultural lands or lawns can increase the amounts of nutrients, such as nitrogen and phosphorus, that eventually enter aquatic ecosystems. An increase in the amount of nutrients encourages a bloom of aquatic plants and algae. Decomposition and plant respiration require significant amounts of oxygen, which can lead to anoxic conditions that result in fish and invertebrate death. Loss of fish may remove a food source for animals that depend upon those fish for survival. An excess of nutrients that stimulate extensive algae growth in an aquatic system is known as **eutrophication**.

Atmospheric deposition (e.g., acid rain) and acidic mine drainage into aquatic ecosystems can quickly change the **pH balance** of the ecosystem. pH is measured in values ranging from 0 (acidic) to 14 (alkaline), with 7 being neutral. Most living organisms prefer pH within the range of 6.5 to 8.5. As air pollution contacts water vapor high in the atmosphere, it often returns as acid rain or snow. Sometimes, quick snowmelts or heavy rains can produce acid surges/shock into waterways, negatively affecting young fish and amphibians, as well as the supply of drinking water. **Turbidity**, or the amount of suspended sediments, of water bodies can increase after activities such as development or heavy grazing, resulting in heavily silted streams that reduce visibility, clog fish gills, or smother amphibian eggs. Quick runoff, which often occurs after wildfires or large-vegetation loss, can result in large amounts of silt being eroded into streams, reducing sunlight and oxygen in the entire ecosystem.

Biodiversity

Biologists will often calculate the **biodiversity** of an ecosystem, or the total number of species, to assist in determining the health of an ecosystem. Generally, the higher the diversity, the healthier the ecosystem. But, this does not always hold true. For example, a wetland with a high density of cattails, insects, and birds may be very productive, but may have low numbers of other plants and animals thus giving the wetland low overall biodiversity.

Areas with particularly high biodiversity are considered **biodiversity hotspots**. There are a number of biological hotspots in Utah, many of which are wetlands. The Pariette wetlands in the Uintah Basin are considered an “oasis” in the desert. The wetlands were created by digging 25 ponds along the Pariette draw, which created a substantial wetland/riparian area of 2,529 acres. Even though the Pariette wetlands are man-made they still represent one of the most biodiverse areas in Utah, particularly because of the high number of waterfowl terrestrial and aquatic mammals that utilize it. Another hotspot is the Farmington Bay Wildlife Management Area. Due to its proximity to the Great Salt Lake, Farmington Bay hosts a variety of freshwater and saltwater environments, which leads to a diversity of saltwater and freshwater plant and animal species. It is not only diverse by aquatic standards, though; the area is also frequented by many terrestrial bird and mammal species. These areas, along with many others, make Utah a highly biodiverse state.

Accurately determining the biodiversity of an ecosystem not only requires counting the number of species, or **species diversity**; it also requires calculating the ecological diversity and genetic diversity of an ecosystem. **Ecological diversity** refers to the differences between ecological processes, habitats, and communities between and within ecosystems. Grassland ecosystems of America are similar, but not identical to, the pampas of South American, because of the different organisms and climate in both areas. Ecological diversity may also exist within an ecoregion, like Zion National Park, because it contains forest, meadow, desert, river, and wetland habitats.

Genetic diversity represents the different genes within all the members of a population of a particular organism. Diversity in gene pools is important because the loss of genes can result in poor reproductive rates and susceptibility to diseases. Genetic diversity can be lost through random environmental changes or specific events. Sometimes a number of individuals will occupy a new area and become isolated from the larger population. This is called a **founder event**, much like the pioneers settling in Utah. Founder events can result in a significant loss in genetic diversity over time if no new genetic material (i.e., immigrating individuals) is introduced. If a founding population remains small and genetically isolated, it can result in a **genetic bottleneck** where genetic diversity continues to be lost through the lack of immigrating individuals and increased population size.

In Utah, founder events have begun to occur in waterways due to poor connections between aquatic habitats. One example is the Lahontan cutthroat trout, which has been experiencing a period of low population size and low genetic diversity. Biologists have determined that the reason the trout is doing poorly is the relative isolation of small populations from each other. Lahontan cutthroat trout stream and lake habitat throughout the Intermountain West was historically connected to by Lake Lahontan (i.e., a large lake similar in size and location to Lake Bonneville). However, the species currently exists in only 11% of its historic habitat. Another similar example of founder event occurs in western Utah among a genus of endemic mussels, *Anodonta*. The mussels were believed to have established in wetlands following excessively wet years. Once drought conditions occurred, however, the connections between the wetlands were lost, resulting in founder events for many mussel populations. *Anodonta* populations have been experience a loss in genetic diversity as a result.

Invasive Species

From a purely anthropocentric perspective, a species is considered **invasive** when its "introduction does or is likely to cause economic or environmental harm to human health." Generally speaking, though, an exotic species is a species that is introduced to an area that it doesn't naturally occur. When an exotic species becomes established in an ecosystem and proliferates easily due to a lack of competition, it is considered to be an invasive species. Without direct human intervention, or a significant abiotic event (i.e., fire, flood, etc.), invasive species can reduce biodiversity by outcompeting naturally occurring species, and changing the species composition of an ecosystem. They can also affect native species through predation, disease, or habitat degradation. Invasive species can be introduced through natural means, like being carried by an animal, and through artificial means, like releasing an aquarium fish into a lake. The introduction of invasive species has far-reaching environmental and economic impacts and management of invasive species is costly and often ineffective.

In Utah, invasive species are a significant problem, especially in wetlands. Mismanagement of wetlands, exotic species introductions, overgrazing, and natural flooding events weakened many ecosystems paving the way for invasive species introduction. For example, in the late 19^{th} century common carp were introduced into Utah Lake to supplement the depleted native fishery. Through the degradation of water quality, overfishing, and a long period of drought, carp populations outcompeted the native fish populations and became the dominant species in Utah Lake. A similar situation occurred along Great Salt Lake following flooding in 1983, which resulted in depressed plant populations along the shore. There was an explosion of invasive reeds (*Phragmites spp*) within the Great Salt Lake watershed after the flooding, and reed populations continued to spread throughout Utah.

Due to the significance of the aquatic invasive species (AIS) problem, the Utah Division of Wildlife Resources, along with other state, federal, tribal, and local organizations, has established the Utah Aquatic Invasive Species Task Force to evaluate, monitor, and manage AIS throughout Utah's watersheds. Even though the AIS program encompasses any species considered invasive or exotic, the primary goal of the Task Force's management plan is to address the growing *Dressenid* mussel problem within Utah's waters. *Dressenids*, which include quagga mussel (*Dreissena bugensis*), zebra mussel (*Dreissena polymorpha*), and the dark falsemussel (*Mytilopsis leucophaeta*), are invasive throughout the U.S. and have only recently been introduced into Utah waters. Managing waterways for *Dressenids* is extremely expensive, especially when they infiltrate water delivery systems (e.g., pipes and dams). Billions of dollars have been spent fighting *Dressenid* invasions nationwide but the problem still continues. The AIS management plan addresses a wide range of AIS within Utah as well as the different management actions that are being taken. You can read the full AIS Management Plan at http://www.anstaskforce.gov/State%20Plans/UT/AIS_mgt_plan_full.pdf.

Plant Adaptations to Watershed Ecosystems

Surviving in saturated soils, standing water, or saline environments present challenges to plants, which require essential ingredients, such as water, carbon dioxide, and even oxygen to survive. There are a few key **adaptations** that help wetland and aquatic plants survive these conditions.

Aerenchyma

Saturated soils in wetlands often have little or no oxygen, which is required by plant roots during respiration. **Aerenchyma**, or hollow cells in the leaf and stem of a plant, allow oxygen to diffuse from the leaves to the roots. In low-oxygen environments, plants are stimulated to produce ethylene, which slows root growth. So, it is essential that plant roots continue to receive oxygen through aerenchyma.

Floating Leaves

Submerged aquatic plants, such as water lilies, have air spaces and float at the water surface. The air spaces on the surface of their leaves take in oxygen, which is transported throughout the plant. Pressure created by temperature and water vapor pushes this oxygen down into the roots of the plant.

Flexible Stems and Leaves

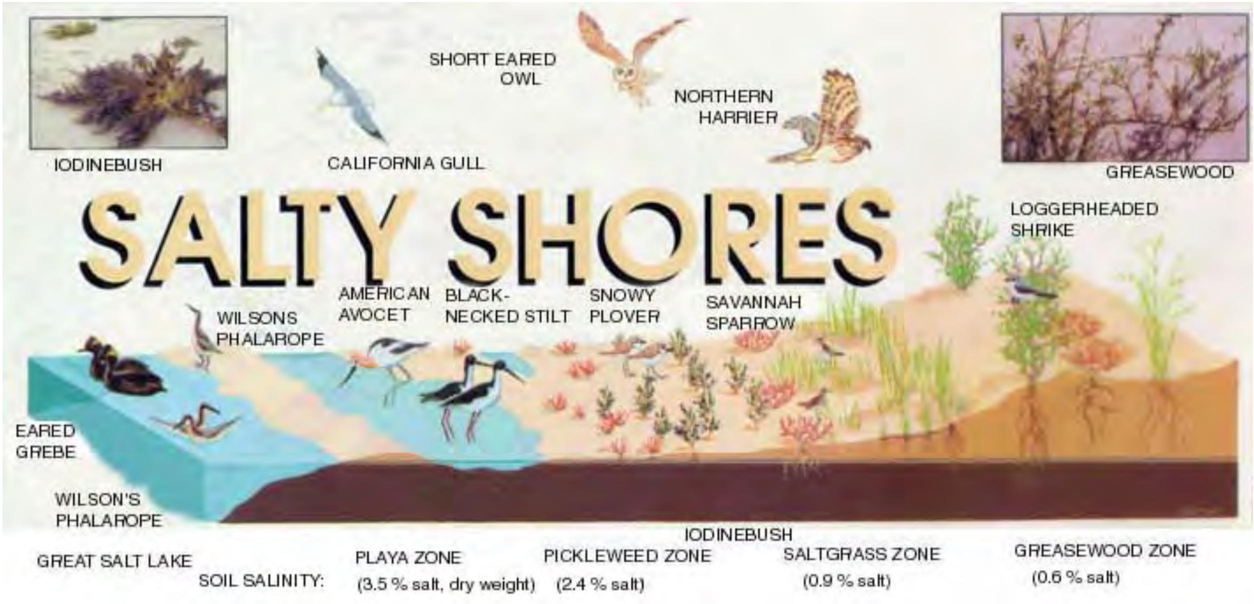
Many plants that grow in wetland and aquatic ecosystems are adapted to have flexible stems and leaves. Whether it is cattails blowing in the wind, or water lilies floating in a lake, flexible stems and leaves allow plants to survive in a constantly changing ecosystem.

Excluding Salts

Survival in a salty environment like a playa or along the shores of Great Salt Lake can be challenging for a plant. Typically, saline soils draw water out of a plant through **osmosis**, resulting in cell, or even plant, death. Halophytes, or plants that grow in saline soils, require special adaptations for survival.

Pickleweed (*Salicornia spp*.) grows in the most saline soils (i.e., around 2.4%, but up to 6%, salt), or closest to the water's edge or to the center of a playa. It is a succulent plant with no obvious leaves, but rather fleshy stems. As salt enters the roots of a pickleweed plant, some of the salt is excluded by sodium-potassium pumps in the root cell membrane, but large amounts of salt still enter the plant during water uptake. Each cell of a pickleweed plant contains a large, empty compartment, called a vacuole, to which salt is transported and stored. Pumping salt in the plant cell to the vacuole requires a considerable amount of energy, which limits the growth of pickleweed to a relatively small stature. While well-adapted for surviving in saline soils, pickleweed is often outcompeted by other plants in less saline soils.

Saltgrass (*Distichlis spicata*) grows in less saline soils (i.e., 1-1.5% and up to 3% salt) and has a slightly different way of dealing with salt uptake. As salt is transported through a saltgrass plant, it is excreted by special glands on the surface of the leaves. Close examination of a saltgrass leaf reveals a sparkling leaf surface covered in tiny salt crystals. While adept at surviving in saline soils, saltgrass is also a relatively small plant, usually less than 6-8 inches, but up to 16 inches, tall.



Great Salt Lake vegetation zones as defined by soil salinity. (*Image from Salt Lake Tribune*)

Varied Reproductive Strategies

Life in a continually changing environment, such as a wetland or pond, can result in unpredictable resources for plants. Sometimes, in years of low precipitation, a wetland might dry up. Or, the presence of saturated soil in a playa may be unpredictable. Many wetland and aquatic plants have multiple reproductive strategies to ensure survival and continued propagation.

Several wetland plants exhibit both sexual and asexual reproduction. For instance, grasses such as saltgrass and *Phragmites* establish new stands through seeds, and stands increase in size via **stolons** (above-ground lateral roots) and **rhizomes** (below-ground lateral roots). Some submerged aquatic plants can reproduce not only by producing flowers and seeds above water, but also through **fragmentation**. As a piece of a plant breaks off and floats away, it will eventually settle to the bottom where it will take root and grow into a new plant.

Pickleweed seeds are peculiar in that, from each node on a stem, six flowers bloom, and six seeds are produced. One of the seeds is larger than the others, and germinates early in the spring, while the smaller seeds lay dormant for another 2-3 months, or even several years. Pickleweed's hardy seeds and great ability to manage salt make it a true champion.

Animal Adaptations to Watershed Ecosystems

Living in an aquatic or wetland ecosystem presents some challenges for animals, largely in terms of mobility, breathing, and obtaining food. However, a continual or constant supply of water can be a fair tradeoff. As such, many animals possess unique adaptations for taking advantage of these habitats.

Webbed Feet

Several birds and mammals have **webbing** in between their toes to act like flippers, propelling them through the water. The most obvious example are ducks and geese that glide along the surface of the water. Diving birds, such as mergansers and cormorants, have webbed feet that allow them to swim great distances underwater. Aquatic mammals, like beaver and otters, have webbed feet as well, allowing them to be adept swimmers. All frogs have webbed feet on their powerful hind legs, allowing them to swim quickly to avoid predators.

Oily Feathers or Fur

Many of the birds and mammals with webbed feet also have oily feathers or fur. As oil repels water, it not only keeps the interior feathers or fur from from getting wet, but also keeps the animal warm in cold water. Maintaining an interior space of dry feathers or fur aids in buoyancy, allowing the bird or mammal to easily float. Peculiarly, the double-crested cormorant has little oil in its feathers, which allows it to dive to great depths in search of fish. As a result, cormorants must periodically perch out of the water with their wings outstretched to dry their feathers. Otherwise, they wouldn't float at all!

Gills

Just as terrestrial animals breathe air to obtain oxygen, fully aquatic animals must be adapted to obtain oxygen from the water. Many insect larvae, such as mayflies and stoneflies, fish, and amphibians have morphologically different **gills** that all function in the same way. A mayfly larva has small, feather-shaped gills that flutter along the sides of its abdomen. Fish gills, just behind the eyes, open and close, pumping water across thin membranes that allow oxygen to diffuse into the blood stream. Tiger salamander gills are large, frilly, external gills on either side of the head.

Flattened Tails

An obvious example of a flattened tail that aids in swimming is that of a fish. Its streamlined body is propelled through the water by its powerful tail. However, several mammals also have flattened tails that aid in swimming. Beavers' horizontally-flattened tail serves as a rudder when swimming. The strong, vertically-flattened tails of muskrats and otters are actually used to propel the animals through, and under, the water.

Long Legs

For animals that walk through water, long, skinny legs are essential. From shorebirds, like American avocets and great blue herons, to moose, their long legs are the best method for moving through water on foot.

Specialized Eyes, Nose, and Ears

For air-breathing animals that primarily live out of the water, specialized adaptations to see or hold their breath underwater are particularly useful. Most diving birds and aquatic mammals have **nictitating membranes**, which are essentially clear inner eyelids, that protect the eye while underwater, but still allow the animal to see. Beavers and otters can close their ears and noses completely to prevent water from entering while diving underwater.

Permeable Skin

The **permeable skin** of fish and amphibians is helpful in maintaining osmotic balance as well as for absorbing oxygen directly from the water. However, permeable skin can result in dramatic water loss if, say, a frog or salamander's habitat has dried up. It also allows the transfer of pollutants to easily pass through the skin, making amphibians particularly sensitive.

Unique Reproductive Strategies

Many aquatic organisms have highly adapted life cycles to take advantage of the benefits of living in aquatic environments. Several insects that are terrestrial as adults, including mayflies, stoneflies, caddisflies, dragonflies, and damselflies, have **larvae** or **nymphs** that are fully aquatic. Amphibians are similar in that the larvae, including tadpoles, essentially live like a fish while the adults are capable of surviving on land.

Some aquatic or semi-aquatic animals that live in extreme environments have adaptable or greatly accelerated life cycles. Female brine shrimp in Great Salt Lake produce free-swimming larvae when conditions are beneficial. But as soon as salinity increases in the heat of summer, or when the water cools in winter, the females switch to producing hard-shelled eggs, or **cysts**, that are capable of lying dormant for decades before hatching. Spadefoot toads breed in ephemeral pools in the desert. Due to the uncertainty of water persistence in these pools, spadefoot toads have adapted to have particularly fast metamorphosis from egg to adult. Eggs can hatch within 2 days of being laid, and tadpoles can metamorphose into adults in as little as 14 days! If water persists in a pothole, and conditions are optimal, a spadefoot toad will continue to grow and metamorphose at a later date.

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Management

Non-Human Factors Affecting Water Quantity and Quality

Location

Location, or the characteristics of the land uses in the vicinity of a river or stream, has a large impact on the characteristics of the water itself. These characteristics, and their impacts on a stream, change in predictable ways as the water progresses downstream. In the headwaters, where slopes are generally steeper and channels narrower, riparian vegetation has a great effect on the stream. Shading keeps algal growth levels low, so most of the organic input comes from terrestrial plant matter (i.e., coarse particulate organic material, or CPOM) that falls into the stream. Aquatic insects and other organisms consume the terrestrial plant detritus, which fuels the food web. The root systems of vegetation reduce erosion and increase soil stability, and the substrate is generally made up of larger rocks and gravel. Headwaters tend to flow faster and clearer than other parts of the river.

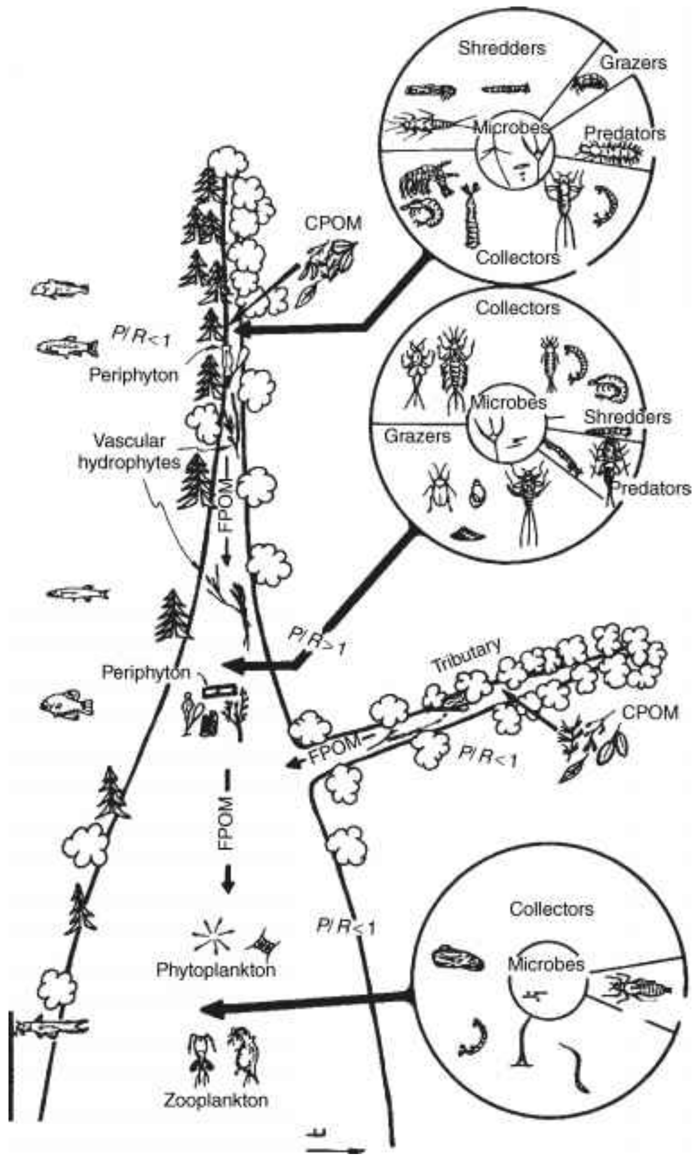
As water continues downstream, slope becomes less steep, tributaries feed into the stream, and the channel widens. Greater surface area correlates to increased solar energy entering the water, and algal production increases. As the channel widens, stream flow decreases and the substrate is finer than in the headwaters, though many larger rocks are still present. The increased diversity on the stream bottom results in more available niches and greater biodiversity. Varying amounts of sunlight on the surface cause thermal gradients, which also increase habitat diversity. More suspended sediment is present, plant matter size is reduced (i.e., fine particulate organic material, or FPOM), and more nutrients are available. This is the most productive and biodiverse stage in the linear progression from headwater to outlet.

As a river approaches the outlet, and slope gradients become less extreme, the channel slows and widens even further. The sediment load also increases and begins to block sunlight entering the water. This decreases algal production, and the river ecosystem relies more on organic matter carried in the current more than on photosynthetic production. As stream flow increases, a river's reliance on land-based production lessens. The substrate becomes finer and more uniform, reducing habitat diversity. Biodiversity is generally less here than farther upstream.

This occurrence is known as the **Stream Continuum Theory (River Continuum Concept)**. It is based on the idea that rivers are in a constant state of transition. Upstream conditions, tributaries, and the entire watershed must be considered to understand any one piece of the stream.

Climate

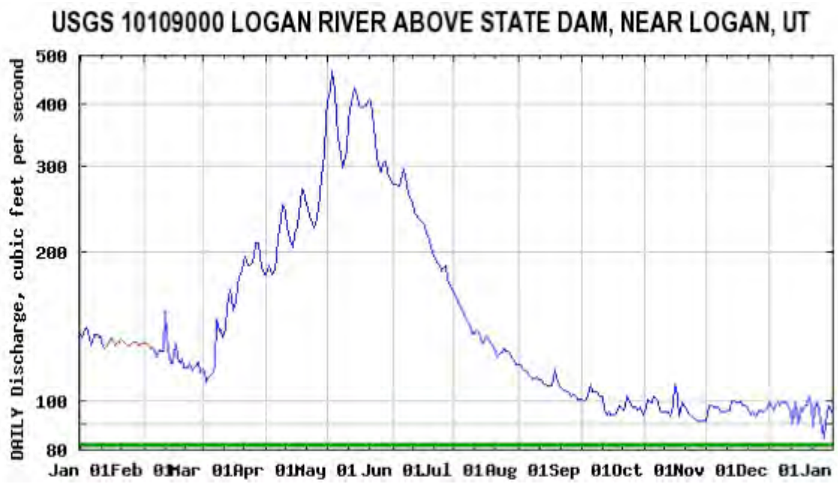
Stream flow and water volume in lakes and wetlands are always changing, and many different aspects can influence the amount of water within a watershed. The main influence is precipitation across the watershed, particularly since higher precipitation results in higher average stream flow and stored volume. As water falls into the watershed, it seeks lower ground under the influence of gravity, and may eventually end up in a river, as well as other downstream systems. Rainfall increases the stream flow, even if it is only raining high up in the watershed, or if it is no longer raining but has been recently somewhere in the drainage. Snowfall collects in mountain valleys over the winter as snowpack. The snowpack melts as the weather warms and increases stream flow. Other climate characteristics that influence water levels are heat and humidity, which have an effect on evaporation and transpiration (evaporation from leaf surface) rates.



Stream Continuum Theory postulates the relationship between stream order and biotic community.

<u>Season</u>

Climate changes from season to season, so stream flows have a lot of variation over the course of the year. The graphic representations of seasonal stream flow is referred to as an **annual hydrograph**. In northern Utah, the season with the highest average stream flow is the spring. This is when the winter's snowpack begins to melt, and the water that had been stored at high altitudes is released into the watershed. Floods are not uncommon in the spring after high snow winters; however, in southern Utah, snowpack has much less of an impact on seasonal stream flow. The highest average flows occur in the fall, when fall monsoons (seasonal storms) are typical. Flash floods often occur when precipitation drains quickly into the streams and rivers at the bottom of a watershed and stream flow increases very rapidly. They are more common in southern Utah, where less vegetation and less absorbent soils do little to slow the collection from across the drainage.



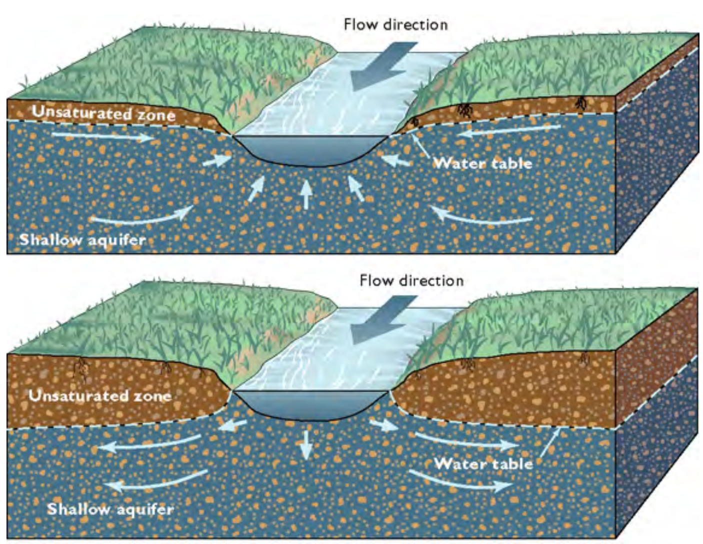
A typical annual hydrograph for the Logan River. (*Image from U.S. Geological Survey*)

Watershed Size

Watershed size is a major influence on stream flow as well as the volume of water in lakes and wetlands. The larger the area a river drains, the more water is likely to be present in the streams, lakes, and wetlands throughout the year. The amount of water collected during a precipitation event is directly linked to the size of the watershed. Larger watersheds also have larger amounts of snowpack and more groundwater volume, which can influence water quantity in the future. In addition, larger watersheds usually have higher stream orders (e.g., larger streams).

Groundwater

Surface water and **groundwater** are constantly interacting. Water from the surface seeps into the soil and replenishes the water table (the depth of the local aquifer). If the water table is at the surface, then groundwater emerges from springs and feeds back into surface waterways. If the water table is at the level of a stream bottom, then groundwater feeds directly into the stream, otherwise stream water is lost into the ground. This is one way that water can be stored in a watershed and replenish stream flow later on. The same process applies to lakes and especially wetlands.



Stream discharge to or recharge from groundwater. (*Image from Colorado Geological Survey*)

Vegetation

Vegetation in the watershed also has an impact on the water. In relation to rivers and streams, plants are often considered to be in one of two classifications, upland or riparian. Upland vegetation does not grow directly on the river's shore, but is somewhere in the drainage area. Water draining through upland vegetation can be intercepted for use by the plant. Plants also act as barriers that slow the runoff of water along the surface, and reduce erosion on steep slopes. Riparian vegetation is vegetation growing along the banks of a river or stream. It has all the same properties that lessen flows as upland plants, but also provide support for the banks of the stream channel, preventing erosion during storm events and high flows. Riparian vegetation also improves water quality by filtering water in the stream or river. Drought conditions are detrimental to wetland vegetation. Hydrophytes can die during dry conditions, creating a suitable environment for invasive species to take hold.

Wildfire

Suppression of fires within Utah has led to high densities of mesic forests, which has greatly altered watersheds. It has also created an environment for hotter, more intense wildfires leading to greater loss of standing vegetation and seed banks. Increased runoff is often seen in areas affected by moderate to severe wildfires due to the lack of vegetation, which can lead to flooding and mudslides. Streams and rivers can become clogged with debris transported by flooding and accompanying mudslides, which also fill waterways with sediment. Stream temperatures can also increase from the loss of shade trees along banks making the streams unfavorable to aquatic organisms.

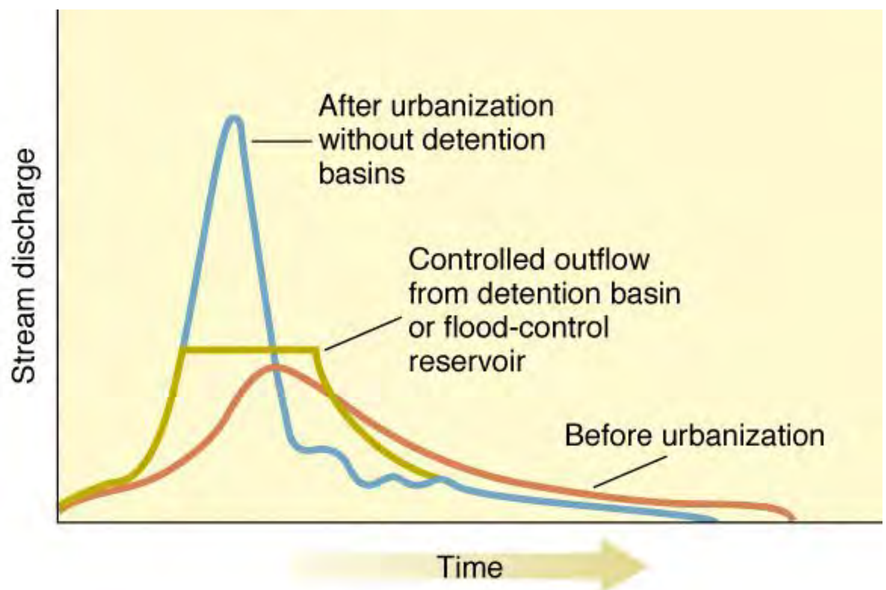
The effects of wildfire are not always negative, however. Fire is a necessary element of a healthy ecosystem and natural fire regimes promote plant regeneration. Moderate fires often only increase soil temperatures in the first 5 cm, thus saving much of the roots, seeds, and nutrients from being destroyed. In fact, ecosystems, post-fire, experience a boom in primary production due to the high levels of nitrogen left over from the burned material. In the end, fire has a positive effect on watersheds by removing decadent and dying vegetation, increasing soil moisture, and even controlling invasive plant species. For example, aspen forests depend on fire for removing older, dying trees and thinning out conifers that can compete with aspen for resources. Aspen trees also depend on fire for the generation of new trees. Fire is a crucial ecosystem function that is necessary for watershed health. Fire suppression, however, leads to unnatural fire regimes, which result in hotter burns that destroy seed banks and increase erosion.

Human Factors Affecting Water Quantity and Quality

Dams

Dams are very important for human communities in many different ways: they save water for use in dry times of the year, produce electricity, and provide recreational activities. Without dams, many arid parts of the world would be uninhabitable for humans.

However, the construction of dams has major impacts on a watershed. Most notably, dams interfere with the natural flow cycle of a river. The increased flow from the flood season is held in the reservoir and released at a slow and relatively constant rate, which means downstream portions of the river usually don't see the naturally high, fluctuating spring flows when a dam is present. Since flood cycles have a considerable effect on a river's shape, a dammed river will often lose natural channel characteristics, nutrient levels, or even plant and animal species. Reservoirs also increase the surface area of the water, which increases the amount lost to evaporation.



The effects of urbanization and dams on annual stream hydrographs. (*Image from Science Education Research Center at Carleton College*)

The Glen Canyon Dam has been surrounded by controversy since its completion in the 1960s. The flooding of Glen Canyon not only permanently altered the structure of the watershed; it also drastically changed habitats for many organisms unable to adapt to the sudden change. Many plant species, like the Kachina daisy, became endangered following the creation of Lake Powell due to habitat loss. Downstream of the dam, four fish species disappeared due to the lack of sediments coming through the dam, which they depended on for their reproduction. There was also a significant decrease in the biodiversity of insects leading to a lack of forage options for animals in the area. The Glen Canyon Dam certainly has its direct benefits to human populations in southern Utah and northern Arizona, but it also had serious implications to the natural ecosystem of the region.

Stream Bank Modification

Human development along a riverbank usually results in drastic changes to the river. Natural, meandering channels are often straightened and retained to increase the amount of useful land and to create a predictable river course. This is called **channelization**. It is an expensive process, and requires significant maintenance to keep the river from reassuming a more natural channel. Straightened rivers flow faster than unaltered ones. This stresses the walls and buffers that have been built to control the flow, especially at high flows. Development on a riverbank often results in decreased riparian vegetation. On natural riverbanks, the roots of riparian plants stabilize the bank and keeps erosion at a minimum. Once they are removed, erosion increases and more drastic measures have to be taken to keep riverside development on stable ground. These changes have a large impact on the type of habitat found in and surrounding a river. Organisms that once thrived in slow-moving water and riparian areas can no longer survive in the developed area.

Stream channelization dramatically alters flow, substrate, and riparian areas.

<u>Surrounding Land Use</u>

There are many other ways that human activities impact water quality. Development of land in a watershed will almost always have some effect on the area's water. Development often increases impermeable surfaces, resulting in a transition from open space – where water can permeate or soak into the soil – to asphalt, cement, and rooftops that collect water into surface drainage systems. Impermeable surfaces lead to more rapid changes in stream flow during a storm event, because the runoff finds its way to the waterways much faster. It also increases the amount of non-point source pollution, which is pollution that does not enter a river or stream from a specific source, such as an industrial plant, but is carried in runoff from a variety of unknown sources. Examples of non-point source pollution are antifreeze in someone's driveway or fertilizer from a lawn that are carried into a water body during a storm. Development also often results in reduced vegetation, which increases erosion and stream temperature, as discussed earlier. Road building has the same effects as other development. It also increases vehicle access into more parts of the watershed. This increased use of an area often results in even greater alteration to riparian areas and in litter and pollution in a river or stream. Development can also result in the filling or alteration of wetlands. Wetlands serve many functions within a watershed, and alteration impacts a key part of the watershed system. Wetlands provide unique habitat for many different organisms. They also filter out pollution and sediment from the water. When a wetland is filled and developed, these important contributions are lost. Grazing has a similar impact on streams. When cattle, sheep, and sometimes wild horses, are allowed access to a stream, banks and shorelines are often damaged. The plants that stabilize the banks are eaten and trampled, and the livestock contribute to erosion as well. Animal waste introduces many different chemicals to the water. It has a fertilizing effect on aquatic plant life, which triggers eutrophication. It can also contaminate the waterway with many different types of pathogens. Livestock, especially cattle and wild horses, can also exclude wildlife from utilizing wetlands. Livestock use of wetlands can be sustainable with good management practices; in fact, grazing can reduce invasive plant species to improve biodiversity. However, minimal or no livestock utilization of wetlands is best.

Artificial canals are important for irrigation, but they also impact habitat for many different species. Diverting water from streams and rivers decreases water flow that ties the watershed together, since canals are generally dead ends in terms of drainage.

Mineral Extraction

Along with the harvesting of brine shrimp, mineral extraction is a major industry on Great Salt Lake. Leases are managed by the Utah Division of Forestry, Fire, and State Lands, which issues them to six mining companies. Approximately 2.5 million tons of minerals flow into Great Salt Lake each year, and approximately 2 million tons of minerals are removed from Great Salt Lake each year. Extracted minerals include potassium sulfate used in fertilizers, sodium chloride used in water softeners and road salt, magnesium chloride used in road salt and industry, magnesium metal, chlorine gas used in bleach, sodium sulfate used in paper and detergents, and calcium sulfate (gypsum). Of these minerals, potassium sulfate is the most profitable.

Minerals are removed using shallow evaporation ponds, of which there are over 85,000 acres in Great Salt Lake. Evaporation from these ponds occurs at a rate of approximately 200 tons (i.e., 50,000 gallons) of water per minute. Once the water has evaporated, the minerals are removed using heavy machinery, and refined off-site.


Evaporation ponds where minerals are harvested from Great Salt Lake.

Southern Pacific Railroad Causeway

The Southern Pacific Railroad causeway was constructed in 1959 as a shortcut across Great Salt Lake for trains traveling west of Salt Lake City. During its construction, only two culverts were built to allow for the exchange of water between Gunnison Bay, the north arm, and Gilbert Bay, the south arm, of Great Salt Lake. Unfortunately, this was not enough to allow for a free exchange of water and nutrients between the two sides of the lake. As a result, there is typically a different elevation between the two bays (0.5-2 ft), as well as vast differences in salinity. While the **salinity** of Gilbert Bay is often 8-11%, Bear River and Farmington Bays fluctuate between 3-6% due to freshwater inflow. In contrast, salinity in Gunnison Bay is typically about 27 or 28%, because it does not receive much inflow of freshwater, with the exception of rainfall. Since the physical characteristics are so different, the biotic communities, from algae and brine shrimp to birdlife, can vary greatly between the two bays.

Variations between Gunnison Bay (lighter in color) and Gilbert Bay (darker in color) on either side of the railroad causeway. (*Images from USGS*)

Disturbance in the Watershed

Remember, Great Salt Lake is a terminal lake. Therefore, disturbances, such as siltation or pollution, even as high as the Uinta Mountains or as far away as southern Idaho, have the potential to impact Great Salt Lake. Pollutants, such as nutrients or toxic metals, tend to accumulate in Great Salt Lake because there is no outflow. Much of the eastern shore of Great Salt Lake is occupied by the Wasatch Front, a major metropolitan area containing over 80% of Utah's population. Wastewater facilities are significant contributors of pollution to Great Salt Lake. Although the output from wastewater plants in the Great Salt Lake Watershed is closely monitored for environmental contaminants, highly toxic chemicals, such as heavy metals, petroleum-based products, and even by-products from the water filtration process, are still released into the watershed. Excess nutrients from wastewater exacerbate eutrophication in areas like Farmington Bay. There are some places, like Park City, that have gone above and beyond the basic guidelines for ensuring clean discharge from wastewater plants in order to prevent watershed contamination. Park City has the only plant in Utah that removes excess phosphorus from wastewater to prevent eutrophication downstream.

Beneficial Uses of Water in Utah

The Utah Department of Natural Resources has a mandate, in part, to manage Utah's aquatic ecosystems, which includes general objectives to protect and sustain the resources, and "to provide for reasonable **beneficial uses** of those resources, consistent with their long-term protection and conservation." In addition, the Utah Division of Water Quality regularly monitors and assesses Utah's streams and lakes to ensure their designated beneficial uses are supported.

Which beneficial use receives the highest level of protection? Most people think that water used for drinking has the highest amount of protection, but actually, it's habitat for aquatic organisms! Imagine that, fish require cleaner water to survive than we do to drink.

Drinking

Although human consumption is one of the less prevalent uses of water in Utah (approximately 4% of water use occurs in residential homes), it has some of the most stringent regulations. Much of Utah's drinking water comes from snowpack in the Wasatch Front and other mountain ranges. In spring, the snow melts and drains into rivers and streams and recharges groundwater. Public and private water supplies come from wells tapped into these aquifers, as well as surface reservoirs filled by rivers. Water quality in drinking water is very important, as public health can be negatively impacted by poor quality drinking water.

Pathogen contamination is one concern for drinking water. Coliform bacteria are microscopic organisms that live in the intestinal tract of many animals, and are also present in the soil and vegetation. These bacteria are generally harmless, there are hundreds of different species of bacteria living in every animal, and for the most part they cause no health concerns. Some, like coliform bacteria, can cause illness, and its presence in drinking water indicates the possibility that dangerous **pathogens** (e.g., other bacteria, viruses, and parasites) may also be present. Most coliform bacteria enter natural streams from direct contamination by animal waste or from runoff from areas with high concentrations of humans or animals, such as feedlots, pastures, sewage plants. Intestinal bacteria cannot survive for long outside of the host body, so ground water is generally free of contamination. Although, if the groundwater is close to the source of contamination, some bacterial pollution may still be present. Properly constructed wells draw their water from a depth where bacteria are not present, but damaged, shallow, or improperly constructed wells may become contaminated.

Diseases may result from drinking bacteria-infected water, including typhoid fever, cholera, hepatitis, dysentery, diarrhea, giardiasis, and hemolytic uremic syndrome. The U.S. Environmental Protection Agency (USEPA) mandates that there be no colonies of coliform bacteria in 100 milliliters (ml) of public drinking water. Public water supplies are treated with a variety of means, including filtering and chlorination, to remove bacterial colonies. Private drinking water supplies should be tested at least once a year.

Irrigation

The most prominent use for the water (approximately 82%) in Utah is irrigation. In order to sustain agriculture in an arid environment, water must be diverted to the croplands where it is needed. Most Utah communities have massive public works projects to provide this necessity for farmers and gardeners. Man-made **canals** divert water from natural water bodies and distribute it across an area. The major water quality concern for irrigation is salinity, or the amount of salt in the water. If water has a high concentration of salts, it will not nourish plants. Instead, the water already present in the plant cells will diffuse out of the plant across the cell wall and the plant will die.

Hydroelectricity

Rivers and streams provide a considerable amount of electricity for the state. Dams built on rivers collect and store water from the high-flow season for use later on during the drier parts of the year. These reservoirs provide irrigation and drinking water when it would otherwise be scarce. The outflow, controlled by openings in the dam, can also be utilized to make power. The force of the water leaving the reservoir is directed over turbines, which turn and generate electricity. Substantial stream flow, particularly during the spring high-flow season, is needed to fill the reservoirs. In drought years, the spring runoff can fall short and the reservoir level is not enough to supply needed water for the rest of the year. If this is the case, conservation efforts are taken to ensure that the water supply does not run dry.

Recreation

Utah's rivers, streams, and lakes provide many different opportunities for recreation. Thousands of people visit water bodies in the state every year for boating, rafting, fishing, swimming, and other outdoor activities. Good overall water quality is important, and some aspects are particularly pertinent to recreation. Water used for recreation cannot be contaminated by pathogens that will make people sick. If animal waste runoff feeds directly into a popular swimming area, users might contract diseases. Many diseases, including cholera, typhoid fever, and giardia can be spread this way. Another recreational concern for water quality is the sediment load. People are not as inclined to use murky, muddy water for recreational purposes. Construction and removal of vegetation can cause increased erosion into popularly used water bodies, resulting in highly turbid and less desirable water.

Outdoor activities are an intangible asset to the public's happiness and well-being. Recreational users also support the programs in place to protect the state's waterways by paying access fees and buying permits for different uses (e.g., fishing and hunting).

Habitat

The flora and fauna throughout a watershed rely on an adequate source of water for survival. Therefore, it is an integral part of any **habitat**. Many species can tolerate only a narrow range of habitat characteristics, and contamination within a watershed can have dire and far-reaching consequences.

Stream flow is an important habitat component for several reasons. If a stream runs dry, then the organisms that depend on the water are less likely to survive. Plant communities surrounding streams, known as riparian areas, will no longer flourish. Changing stream flows will also affect the shape and types of habitat in the channel. Floods will carve out new pools and deposit new sediment bars. Without this constant reworking of the stream channel, pools can fill with sediment, side pools protected from the main channel by sediment deposition can become exposed, and the general diversity of habitat will decrease.

Gilled animals, such as fish and amphibians, obtain oxygen they require for respiration from dissolved gas in the water. Many factors can deplete the level of **dissolved oxygen** in water, and if levels are too low the animals will die. Dissolved oxygen is temperature dependent; as the water becomes warmer, it holds less dissolved oxygen. Decomposers compete for oxygen with other organisms, so if there is a large amount of dead and decaying biomass, oxygen levels often decrease. After a large algal bloom, when the plant matter has died and is decomposing, it is not uncommon for a body of water to become completely anoxic (no oxygen). Oxygen is replenished by turbulent surface water mixing oxygen into the water, and by photosynthesis by aquatic plants. As water temperature decreases, the concentration of dissolved oxygen increases.

pH is a measure of the acidity of a liquid. Lower pH values correspond to higher acidity, and higher pH values indicate more basic or alkaline water. A pH of 7.0 is considered neutral. Utah's rivers and lakes generally have pH levels between 6.5 and 9.0. Most aquatic organisms have a low tolerance for pH values outside these levels. Even moderately acidic (low pH) water will reduce the viability of fish and amphibian eggs, as well as irritate the membranes and gills of aquatic animals. More extreme pH values are deadly, and few species can survive in an environment with pH below 4 or above 10. Amphibians are particularly sensitive to shifts in pH. Some scientists believe the worldwide decline in amphibian numbers is due to polluted, acidic environments. Change in pH also affects how other chemicals behave in the water. Minerals, such as calcium and magnesium, in the soil and water (hard water) can have a buffering effect on the pH. Factors that influence the pH of a body of water include polluted precipitation (acid rain), caused by sulfuric and nitric acid released into the atmosphere by coal plants and car engines; industrial pollutants dumped directly into the water; and acid runoff from mining drainage.

Temperature affects the rates of chemical processes, which affects concentrations of dissolved oxygen and other nutrients, as well as biological processes, such as metabolism and growth. Different species have different temperature tolerances, so a shift in water temperature can lead to changes in the species present in a habitat. Riparian vegetation has a significant impact on stream temperature; overhanging tree limbs shade the water surface. Other natural factors affecting temperature include tributaries and groundwater springs flowing into the river. Human behavior can also affect temperature. Deforestation removes the shading effect, and water heated and used in industrial plants is often dumped back into rivers and streams, resulting in thermal pollution.

Turbidity is a measure of the clarity of water. Suspended sediments from increased erosion make the water cloudy. Human activities like logging, road building, and urbanization often increase erosion rates. This can have a negative effect on the habitat. Cloudy water reduces visibility, which makes feeding more difficult for many species, including visual predators like trout. Fine sediments can also settle over egg beds and suffocate embryos and clog gills. High turbidity can also indicate the presence of other pollutants suspended with the sediment.

Metal pollutants, such as mercury and cadmium, are uncommon in natural streams, unless they are draining areas of high urbanization, mine tailings, or industrial and domestic discharges. More acidic, warmer streams are more likely to carry toxic metals. One concern from toxic metal in the water is bioaccumulation. Small invertebrates and fish are exposed to the metals in non-toxic levels, and it is stored in their tissue. As predators feed on these animals, the metal continues to accumulate until it is at toxic levels. This is dangerous to humans who fish or hunt, as they will be exposed to the metals by eating the tissue of the animal.

Utah Lake: A Case Study

Utah Lake played an important role in the settlement of the state by providing a reliable supply of water and food to early settlers. During food shortages in the middle of the 1800s, many towns organized fishing companies to harvest fish from Utah Lake. During these times, it seemed as though the supply of fish was limitless, and tens, possibly hundreds, of tons of fish were harvested. Toward the end of the 1800s, the fish populations in Utah Lake began to decline. In order to replenish the fish biomass in Utah Lake, carp were introduced in 1881.

As is often the case, the introduction of non-native fish species has dramatically disrupted the Utah Lake ecosystem. Invasive species, particularly carp and white bass, make up more than 99% of fish biomass in the lake. To make matters worse, Utah lake, a particularly shallow lake, is ideal spawning habitat for carp. Only two of the 13 native species that once were found in the lake are still present. These invasive species impact June sucker and Utah sucker numbers through predation on young fish, competition for resources, and habitat alteration.

The presence of carp in Utah Lake significantly degrades the ecosystem. Carp tend to stir up sediment while foraging on aquatic invertebrates. This results in water with relatively high turbidity levels, which, in turn, reduces the amount of light that penetrates the water, thereby reducing the amount of aquatic vegetation that can grow. The lack of aquatic vegetation not only reduces the amount of dissolved oxygen in the water, but it also eliminates habitat for young fish to hide from predators such as walleye and white bass.

Utah Lake is one of the largest freshwater lakes west of the Rocky Mountains. Unfortunately, human activities have greatly impacted this lake over the past 150 years. Wastewater treatment plants are responsible for dumping approximately 75% of the phosphorus in Utah Lake. This excess of phosphorus promotes rapid and excessive growth of algae and bacteria, which can have considerable consequences. The thick mats of algae tend to block the sunlight from penetrating the lake, thus reducing growth of beneficial aquatic plants that are an important foundation for the lake’s food web. The eventual decomposition of the algae removes dissolved oxygen from the water, which threatens other aquatic life, such as fish.

Laws and Regulations

Clean Water Act

The environmental movement of the 1970’s led to the passage of much-needed changes in the law regarding pollution. One of these pieces of legislation was the **Clean Water Act**, passed in 1972. The act began the regulation of pollutants dumped into the nation’s waterways, and gave the EPA more authority to implement pollution control programs. Water quality standards were established for all surface waters. Dumping chemicals into water became illegal. The act also funded the building of sewage treatment plants. Non-point source pollution (polluted runoff) was addressed in 1987 with the passage of Section 319. This amendment to the original act provides grant money for state, local, and tribal agencies to implement projects aimed at non-point source pollution, as well as to monitor the success of various programs.

Section 401 of the Clean Water Act gives States and Tribes the authority to review and approve, condition, or deny any federal permit or license that might result in a discharge into state or tribal waters. These include projects to build roads in wetland areas, hydroelectric dams, levees, mining, and other development. If there is a possibility it will impact a watershed, section 401 applies and the state has the power to deny the project. This is one of the main ways that states can protect their water resources.

Section 404 of the Act regulates the discharge of dredged and fill material in U.S. waterways. When a construction project is underway in an aquatic setting, sediment is often removed and filler sediment is brought in to stabilize the structures. This results in large amounts of sediment that could cause damage to the watershed. Section 404 states that no dredged material may be discarded or fill material may be used if there is a less damaging alternative or the nation's waters would be significantly degraded. When developers applied for a permit, they must show they have taken steps to avoid and minimize potential wetland impacts, and will provide compensation for degraded areas. Section 404 permits are subject to state power under section 401.

The Utah state legislature passed a bill in 2002 that supplements the Clean Water Act, **Title R317**. It created a Project Priority System to determine which water quality projects would provide the greatest beneficial use for the public. The rule weighs first the need for water quality improvement, then the potential for improvement, and finally the number of people that would be served.

Section 303(d) of the Clean Water Act mandates that each state compile a list of impaired waters; the Utah list for 2004 reports 141 impaired waters.

When an organization or individual introduces pollutants illegally, whether through the lack of a permit or exceeding pollution levels permitted to them, the EPA can initially require the responsible party to either clean up the effected site themselves or pay for a third party to do the cleanup. The EPA can also file civil and/or criminal charges if any Clean Water Act regulation is breached. Consequences of such lawsuits can lead to financial penalties, cleaning up additional polluted sites (other than the one polluted originally), as well as possible jail time depending on the scope of the damage done.

Prior Appropriation vs. Riparian Doctrine

In the United States, there are two approaches to granting water rights. **Riparian Doctrine** was originally implemented in the eastern U.S. following a series of disputes surrounding the use of a river to power mills, which eventually resulted in a lawsuit. The resulting court decision established the Riparian Doctrine, which provides water rights for any landowner with property bordering riparian land unless there is some extreme interference with another use. Although the Riparian Doctrine allows for full utilization of water resources, there are limitations to what can be done with water: 1) water cannot be diverted for personal use, 2) water must return to its original source, 3) water can only be used in the watershed from where it was drawn, 4) water can't be stored seasonally. Even though water rights remain permanently associated with the land regardless of its utilization, water rights can be lost based on non-use.

The alternative approach to water rights is **Prior Appropriation**. This is a "first come, first served" approach also known as "first in time, first in right." In other words, earlier claims to water rights are considered superior to later requests, regardless of social benefit or drought conditions. Prior Appropriation was initiated during the early days of the expansion into the West where miners, ranchers, and settlers needed water in order to survive. Due to the arid nature of the western U.S. much of the land, especially the areas utilized for agriculture and mining, didn't border rivers, streams, or other waterbodies, thus requiring water to be diverted. Unlike the Riparian Doctrine, Prior Appropriation requires that any diverted water have a specific volume, a specific use, a specific destination, and a specific date of initiation. The regulations were instituted to reduce the amount of water waste. Water rights under Prior Appropriation allow for long-term storage of diverted water and the sale or transfer of water rights to other individuals or organizations, and water rights can be lost due to non-use.

Colorado River Compact

The **Colorado River Compact** was signed by seven U.S. states and Mexico in 1922, and outlines the use of water in the Colorado River watershed. The watershed is divided into an Upper Basin and a Lower Basin; the Upper Basin states are Colorado, Wyoming, most of Utah and New Mexico, and a small portion of Arizona and the Lower Basin states are Arizona, Nevada, California, and the remaining portions of Utah and New Mexico. The dividing point is Lee's Ferry, Arizona, which is on the Colorado River, 1 mile below the Paria River.

The Colorado River Compact grants the Upper and Lower Basins each 7.5 million acre-feet/year of water for beneficial consumptive use. Water was apportioned to Mexico from the surplus. Unfortunately, these figures were based on higher than average flows, and we now know that stream flow in the Colorado River can vary between 4.5 and 24 million acre-feet/year. To guard against water shortages, the Upper Basin built dams to store water to be delivered to the Lower Basins during years with lower stream flow, resulting in the creation of Lake Powell just upstream from Lee's Ferry. The creation of the Colorado River Compact sought to relieve these states from Prior Appropriation because California was settled and developed before the Great Basin states. Therefore, if Prior Appropriation held in this case, California would have been entitled to vast amounts of water from the Colorado River.

The Salt Lake Tribune

The future is unsure for the Compact states particularly with the growing concern over water shortages and drought. California and Nevada are facing record population sizes and their water needs are only growing. Nevada's Las Vegas area is struggling with the amount of water allotted under the Compact, leading to conflict with other states over water surpluses. The agreements within the Compact cast a potential concern if water shortages become prevalent in both the Lower and Upper Basin states. Under the Compact, each state is allotted 7.5 million acre/feet annually; however, if a state does not receive its allotted water, states can issue a "call," or a demand, for their total allowance. This means that every state upstream is required to cease their access to Colorado River until the allowance for that state, or states, is filled. There is hope that, in the event of a water shortage along the Colorado River, states will be willing to negotiate and compromise to ensure everyone is allowed access.

Bear River Compact

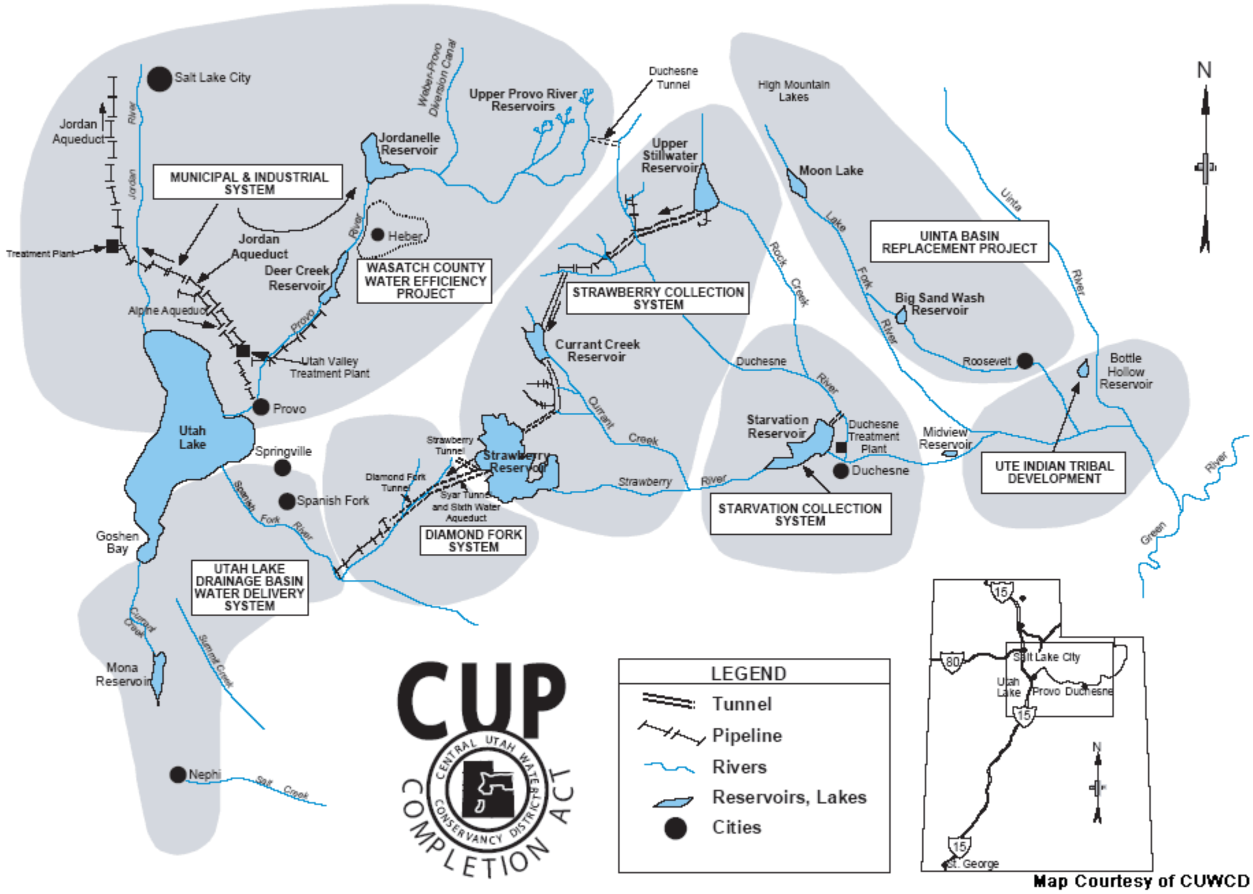
The **Bear River Compact** is an agreement between Utah, Idaho, and Wyoming regarding the partitioning of water resources from the Bear River. Beginning in 1958, the Compact laid down a set of regulations for water use from the Bear River and its tributaries above Bear Lake, as well as water storage in the lake itself. It limited the amount of water that could be withheld in Bear Lake, ensuring downriver communities got their share of the water. It also created the Bear River Commission, an interstate administrative agency composed of three commissioners from each state as well as a non-voting representative of the United States as a whole. During the 1970s, the states considered amendments regarding direct flow and storable water from the river below Bear Lake as well as from groundwater. In 1980, the Amended Bear River Compact went into effect. Water laws in each of the states are based on the decisions and limitations set forth in the Bear River Compact.

The Bear River Watershed flows through three states. (*Image from Utah Division of Water Rights*)

Central Utah Project

The **Central Utah Project** is a development project attempting to bring more water resources into areas of central and eastern central Utah, and represents the most extensive water development program initiated in the state. Water from Starvation Reservoir, Steinaker Reservoir, Red Fleet Reservoir, Soldier Creek, Current Creek, Upper Stillwater, and the Jordanelle River is diverted for use in the areas of high development on the Wasatch Front, as well as for irrigation and other uses in the Bonneville and Uintah Basins to the west and east of the Wasatch Range.

The Central Utah Project Completion Act of 1992 (CUPCA) legislated several changes to the CUP. It established the Utah Reclamation Mitigation and Conservation Commission. It also increased the amount of non-federal funds coming into the project, and encourages hydroelectric power development by non-federal parties. In addition, the CUPCA mandated more attention be paid to concerns related to water conservation.

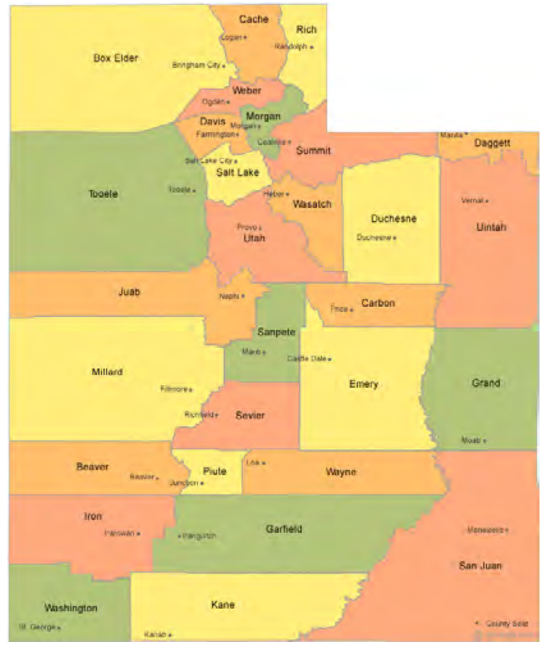


The extensive Central Utah Project provides water to the Wasatch Front. (*Image from CUWCD*)

Practical Methods for Management

Managing Using a Watershed Approach

Boundaries of watersheds do not usually align with county boundaries in Utah, making it difficult for watersheds to be managed on a county level. The Utah Division of Water Quality divides the state into 10 distinct watersheds. When making management decisions, the Utah Division of Water Quality thinks inclusively across the entire watershed. They make a watershed plan, taking into account the characteristics of the specific watershed as well as more direct water quality concerns for an immediate area. The plan prioritizes environmental concerns based on how the watershed system behaves, and what the likely effects of action will be. It is a long-term commitment to the improvement of the watershed's health and stability. For instance, the Duchesne Watershed Plan has the following goals: improve water quality throughout the watershed through reducing sediment loads, improve wildlife habitat, and educate the public about water quality and how they can improve it. Their plans to meet these goals are to maintain water quality in the headwaters of the Duchesne River and to improve fish habitat along the Duchesne River near Hanna, Utah.



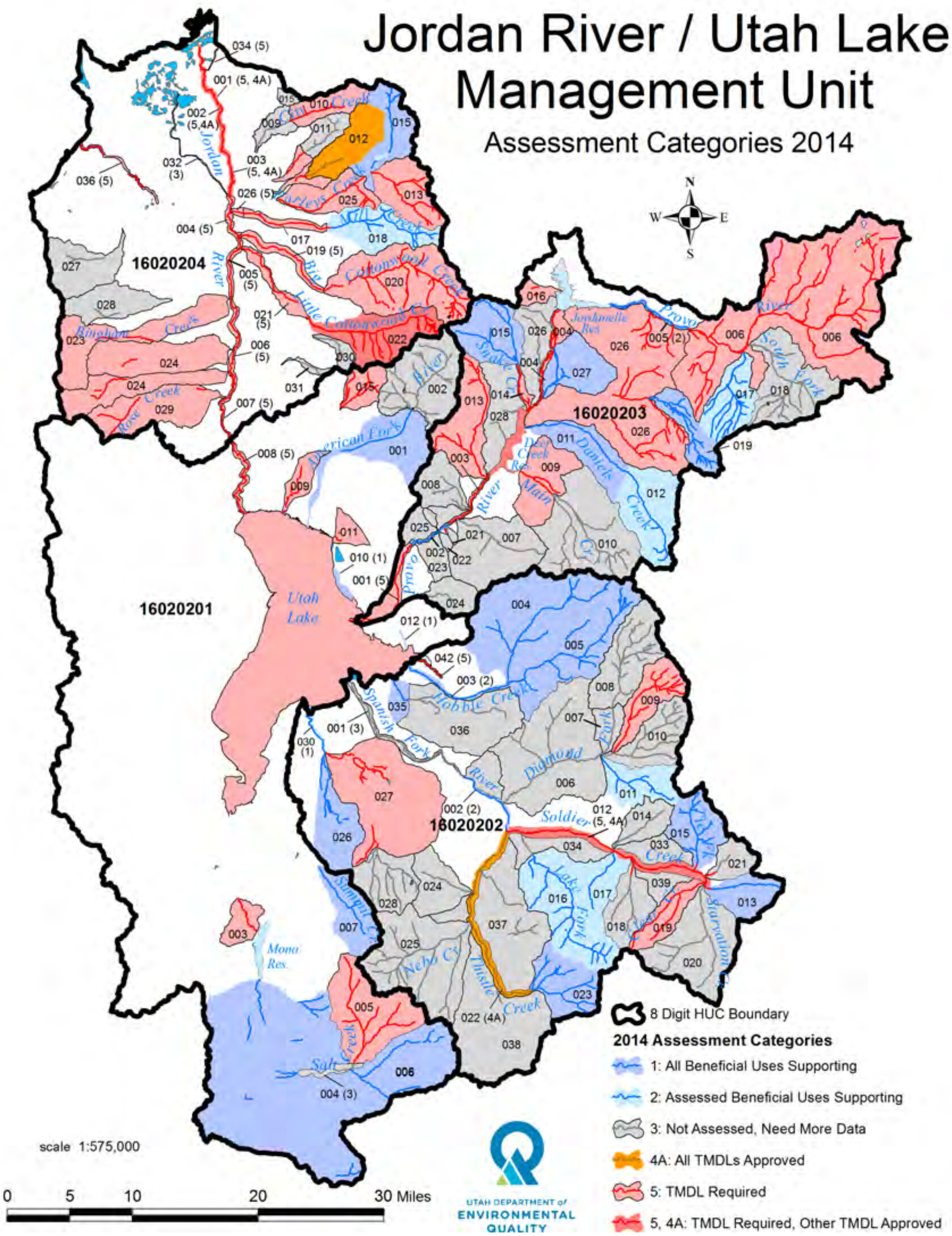
Watershed and county boundaries to not often align. (*Image on left from USU Water Quality Extension*)

Total Maximum Daily Load (TMDL)

The Clean Water Act requires all states to study and set a **total maximum daily load** (TMDL) for pollutants. A TMDL establishes the maximum concentration of pollutants allowed in the water while still maintaining all of its designated beneficial uses. Once TMDLs are established for pollutants, the DWQ continually monitors all of the state's waterways. If any water is found to have pollutants above the TMDL it is placed on the 303(d) impaired waters list, and actions to improve the water quality are undertaken.

Water Quality Monitoring

Monitoring **water quality** aids in determining the overall health of a watershed. The Utah Division of Water Quality rotates through each of the 10 state watersheds, intensively monitoring each over the course of 5 years. Water quality monitoring generally involves extensive time in the field collecting samples and time in the laboratory analyzing samples. Chemical tests measure concentrations of various chemicals, such as nitrates, phosphates, and dissolved oxygen, and physical measurements often include temperature and turbidity. Monitors also sample the organisms, including aquatic macroinvertebrates present in an ecosystem to aid in assessing its overall health. This is an effective way to determine the water quality over a longer period of time, since the organisms are sensitive to shifts in water quality. Different species have different levels of tolerance to pollution. The presence of a high diversity of sensitive invertebrates like caddisflies, mayflies, and stoneflies, indicates a healthy stream ecosystem with exceptional water quality. If only highly tolerant species, such as leeches, snails, and amphipods, are found, it is a good indication that the stream is or has been polluted. Observation of different stream characteristics (erosion, habitat, surrounding land use) also plays an important role.



Watershed assessment and TMDLs for a management unit. (*Image from Utah Dept. of Environmental Quality*)

Reservoirs and Stream Discharge

One method of managing the impacts of dams on the downstream ecosystem is by manipulating the discharge. Typically, negative impacts occur because of the lack of natural variability in stream flows, especially spring runoff. Without changing amounts of water, the geophysical processes that determine stream shape and habitats become stuck in a single trajectory. In other words, areas being eroded are continually eroded and areas with high sediment deposition have a constant accumulation of substrate. By fluctuating the discharge from a reservoir to more closely resemble natural flows, these consequences can be lessened, and the diverse natural habitat needed by many species is retained. In March, 2008, the U.S. Bureau of Reclamation opened the gates in Glen Canyon Dam to release 41,000 cubic feet of water per second for 60 hours in an effort to recreate a natural spring flood. This effort stirred up sediment in the river bottom, deposited new beaches, and restored fish spawning habitat in the riverbed. The challenge in performing this spring flood is to balance habitat restoration with the needs for producing hydroelectricity for approximately 400,000 homes and supplying irrigation water to arid areas.

Wetland Mitigation

Wetland mitigation is a method used to limit the cumulative amount of damage done to wetlands by human development. By law, developers who wish to complete a project that will degrade or destroy natural wetlands must compensate for the damage by either restoring or enhancing existing wetlands or creating artificial wetland of a greater area. This system both helps to maintain the benefits of wetlands for a watershed and to provide incentive to developers to minimize their impact on sensitive and important areas. While effective, this system does have some shortcomings. Created wetlands in a new location often do not function as well or have the same effect on a watershed that the original wetland did. While providing habitat for many species, the artificial wetlands usually have lower biodiversity than wetlands that arise naturally. For this reason, created wetlands are often required to be built at an area greater than the wetlands that were impacted, usually at a 2:1 ratio. Wetland restoration and enhancement are often required at a smaller ratio, usually between 1:1 and 1.5:1.

There are several examples of wetland mitigation in Utah including the Utah Lake Wetland Preserve, South Shore Ecological Preserve, Jordan River Wetlands, and Great Salt Lake Shorelands Preserve. Many of these projects involve acquiring lands and restoring existing wetland systems. Many of these sites are integral components of the Greater Great Salt Lake Ecosystem, and, as such, are important habitat for migratory birds and other wildlife.

Fisheries Management

Species that play a role in recreation have to be managed differently. Healthy fisheries provide a source of enjoyment and food for the Utah public, as well as a source of revenue for state wildlife management programs. For this reason, managing fisheries is a high priority for the Division of Wildlife Resources. Pollution has negative effects on the health of Utah fisheries, both by killing fish and by rendering the fish unsafe to eat. For this reason, and other environmental concerns, the DWR takes watershed pollution very seriously. In the early and mid-20th century Utah fisheries experienced significant losses due to toxic runoff, dams, overfishing, and introduction of non-native fish species. Utah Lake experienced significant native fish losses due to excessive water utilization for agriculture and a general disregard for preventing agricultural and residential wastes from entering the lake. With the diminished water quality, high fishing pressure, and the competition with introduced fish species, native fish populations crashed. Even after decades of conservation work to save one of the few native fish species in Utah Lake, the June sucker, there is still conservation efforts in place to undo the damage from the past.

Utah DWR also manages state fisheries by stocking them with sport fish like rainbow and brook trout. This involves raising fish in hatcheries and releasing them into heavily used fishing areas to supplement the populations in the reservoirs, lakes, and rivers. The DWR often stocks with fish species or subpopulations that do not reproduce in the wild, such as the rainbow trout stocked in Strawberry Reservoir, in an attempt to keep the impact on the natural ecosystem at a minimum.

Brine Shrimp Harvesting in Great Salt Lake

Brine shrimp have been harvested commercially from Great Salt Lake beginning in the 1950s when the adult shrimp were used as food in the aquarium trade. During the 1970s, however, the harvest switched from adults to cysts, which are still used in the **aquaculture** industry, mostly outside the United States. The cysts are hatched and used as food for shrimp, prawns, and some fish. The harvest of brine shrimp is focused in late fall and early winter, when female brine shrimp produce large amounts of cysts to survive the winter.

Because the production of cysts increases with salinity (optimally, above 10%), there is reduced production in years with high inflow of freshwater to Great Salt Lake. Brine shrimp cyst harvest levels reached around 15 million pounds per year in the mid-1990's. During the flooding periods of the late 1980s, harvests levels dropped to around 6 million pounds. As salinity levels drop to 5-6%, the cysts lose their buoyancy and sink, making them difficult to harvest.

Waterfowl Management

Waterfowl hunting is common along the shores of Great Salt Lake. In fact, there are 27 private duck hunting clubs and at least six Waterfowl Management Areas along the eastern shore of the lake. Even with the apparent popularity of waterfowl hunting, revenue from permits continues to decline in Utah. The money spent by hunters goes directly into conservation actions for waterfowl habitat. While the management of these areas is primarily for hunting waterfowl, other wildlife species common to the shores of Great Salt Lake also benefit. Waterfowl Management Areas, managed by the Utah Division of Wildlife Resources, are often popular areas to view non-game wildlife, such as migratory birds. They also offer valuable opportunities for citizens of Utah to learn about and appreciate wetlands in Utah.

Selected Management Issues

Rivers and Streams

The **Jordan River Restoration Project** has a goal to restore 274 acres of riparian habitat along the Jordan River. Historically these areas were an important refuge for migratory birds; however, due to years of development, pollution, channelization, dredging, and grazing, there are only a few viable riparian areas along the river's channel. The U.S. Fish and Wildlife Service has spearheaded the project, in cooperation with other local groups. Restoration includes removing exotic and invasive species from the riverbanks, establishing native plants, and recontouring the banks to restore the natural floodplain (A floodplain is the area just above the natural banks of the river; during a flood the water covers the floodplain and deposits sediment).

The **Provo River Restoration Project** is part of the mitigation for the Central Utah Project. The project has goals and objectives similar to the Jordan River Restoration Project, specifically through restoration of fish and wildlife habitat along the middle Provo River, mitigating damage from straightening the river in the mid-20th century, and creating and maintaining wetlands similar to the natural wetlands originally present. Fish habitat in the middle Provo River was severely degraded as the result of earlier actions taken to develop Provo River waters for agricultural, municipal, industrial and other purposes. In addition, angler access to the river and instream flows has been improved, and Jordanelle wetlands mitigation has occurred.

Wetlands

Increasing human populations creates increasing stress on the infrastructure and a need for more space, housing, businesses, and transportation. Communities near wetlands often encroach into the natural wetlands. Wetlands are often drained and filled to make way for homes, shopping centers, industrial plants, and the roads to connect them. One current example of this in Utah is the **Legacy Highway Project**. Increasing population on the Wasatch Front creates congestion on the roads, so alternate transportation options are required. The highway resulted in a loss or degradation of wetland systems. The **Legacy Nature Preserve** is a 2,225 acre wildlife preserve that was established as a mitigation bank to offset these impacts, but it is likely that the highway, which cuts across wetland habitat to the southeast of the Great Salt Lake, segments and degrades the natural area, as well as encourage further development in these important natural habitats.

Considering that wetlands function, in part, to improve water quality, several organizations and agencies are beginning to construct artificial wetlands specifically to treat wastewater. Addressing and improving water quality onsite help to reduce the demand on wastewater treatment facilities and also minimizes the risk of offsite contamination during transport.

Great Salt Lake

Eutrophication is a considerable problem in parts of the Great Salt Lake, Farmington Bay in particular. Due to receiving nutrient waste from the Wasatch Front for decades, Farmington Bay is one of the most polluted water bodies in the state. Total phosphorus in the bay is eight times the level that is considered eutrophic. Sewage treatment plants are the major contributor of excess nutrients to Farmington Bay. Dense algae on the surface waters block sunlight and create completely anoxic conditions in the water column, exacerbated by decomposition. In addition to the production of foul-smelling hydrogen sulfide, the conditions are not suitable for brine shrimp, which are a major component of the Great Salt Lake food web.

The expansion of Great Salt Lake Minerals' evaporation ponds on the northwestern shore of Great Salt Lake was approved by the State of Utah, but is currently being appealed. Although mineral extraction leases are issued by the Utah Division of Forestry, Fire, and State Lands, the U.S. Army Corps of Engineers must maintain all navigable waters for the "public trust," which typically includes commerce, navigation, and fishing. The argument in the appeal is that the expansion of the mineral extraction operation will not necessarily benefit the public trust. The main issue in the expansion of Great Salt Lake Minerals' evaporation ponds is the population of nesting American white pelicans, less than 2 miles away on Gunnison Island. Pelicans are usually relatively sensitive to human disturbance and may completely abandon nesting sites.

Because Great Salt Lake is a terminal lake, naturally-occurring levels of selenium have the potential to concentrate over time. Along with this potential, selenium enters Great Salt Lake via mine tailings and from refinery waste. Public concern over the potential of increasing selenium input to Great Salt Lake as the result of the South West Jordan Valley groundwater cleanup project brought a renewed focus on the need for developing numeric standards. Along with the Great Salt Lake Water Quality Steering Committee, the Utah Division of Water Quality has begun a process to establish numeric standards for selenium within the Great Salt Lake.

While studying selenium levels in Great Salt Lake, the U.S. Geological Survey and the U.S. Fish and Wildlife Service discovered some of the highest levels of methylmercury ever recorded. While concentrations of methylmercury exceeded 25 nanograms per liter of Great Salt Lake water, concentrations of 1 nanogram per liter are usually enough to result in fish consumption advisories. In addition, brine shrimp cysts are harvested and sent around the world to support the aquaculture industry, so methylmercury from Great Salt Lake is potentially spread around the world. Consumption advisory are periodically issued for certain duck species (e.g., cinnamon teal, northern shovelers, and common goldeneyes) due to levels of mercury that exceed U.S. Environmental Protection Agency screening values in ducks taken along the eastern shore of Great Salt Lake.

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Stewardship

What is Environmental Stewardship?

The literal definition of a steward is "one who manages property or affairs for someone else." How does this definition apply to **environmental stewardship**? When considering the effects of land use, it is important to include all components together as a whole: the land and the resources and people that occupy the land. Aldo Leopold believed that human benefit, economic benefit in particular, was the primary driving force behind land use. This can be summed up in the following quote:

> "We end, I think, at what might be called the standard paradox of the twentieth century; our tools are better than we are, and grow faster than we do. They suffice to crack the atom, to command the tides. But they do not suffice for the oldest task in history; to live on a piece of land without spoiling it... [Q]uit thinking about decent land use as solely an economic problem. Examine each question in terms of what is ethically and aesthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong otherwise."

One should accept the intrinsic value of all resources on the land:

> "A land ethic of course cannot prevent the alteration, management, and use of these 'resources,' but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state. In short, a land ethic changes the role of [humans] from conqueror of the land-community to a plain member and citizen of it."

Considering Our Own Resource Use

There are countless ways for us to think about, and be more efficient in, our use of natural resources. This refers not only to our direct use of water, but also to everything we do. You'd be surprised by how many aspects of our lives use and depend on water or affect water resources in some way.

Monitoring water use is fairly easy to do. Unfortunately, water is so inexpensive in Utah that we are unlikely to see dramatic results like from a lower electricity bill. However, by monitoring water use, and challenging ourselves to use less water, particularly in summer, will surely translate to not only water saved, but also money saved.

Let's start inside our homes and look at some things we can do to save water. Shorter showers and washing only full loads in the dishwasher is obvious savings; but what about that dripping faucet? Amazingly, a faucet leaking one drip per second wastes 200 gallons each year! A full glass jar in the toilet tank will save that volume of water every time a toilet is flushed. Contact your city or county to find out about local efforts to conserve water.

Living in Utah, we all know that scarce water and high evaporation are great reasons to conserve water in our landscapes. That doesn't mean a yard full of rocks and cow skulls, though! We can have yards with lawn and ornamental plantings and still conserve water, as long as we are putting some thought into it. There are several organizations, such as slowtheflow.org or the Center for Water-Efficient Landscaping, that can help you select beautiful, well-adapted plants and design a landscape that will not only look great, but also save water. By conserving water both in the home and landscape, we'll reduce the demand for more dams and reservoirs, thereby protecting rivers and streams in Utah.

There are many things that we take for granted that can affect the natural world. Our travel or transportation patterns can have a great impact on natural systems from harmful vehicle exhaust to sediment buildup next to roads. Exploring the ideas of carpooling or using mass transit will not only help to reduce air pollution, but could also save us money, gas, and possibly time. Do you like to travel to exotic locations when you vacation, or do you stay close to home? These are all things to think about if we are considering our own use of resources.

The goods that we buy often have a tremendous impact on water resources or on the environment as a whole. Remember that loaf of bread that went moldy in the cupboard? It took 150 gallons of water to produce it! So, it is important to not only think about the amount of goods that we buy, but also how we use them. There is a lot to think about when we begin to consider how we use natural resources, including water. The important thing is to address this issue at your own pace and start out with solutions that are easy to implement.

Being an Active Citizen

Activism can be defined as simply be "*doing something.*" It was Edward Abbey who said "sentiment without action is the ruin of the soul". There are many important ways in which we can "do something". Stewardship can be promoted by educating not only others, but also ourselves. It is great to be an educator, but we should all start with our personal lives. We cannot begin to promote stewardship to others unless we have a better understanding of our own resource use. We should always ask ourselves where our resources come from, how much we are using, and if there is a way to conserve resources more wisely. Once we have made the change within ourselves we can then begin to empower others to do the same.

Showing your support for sustainable natural resource management can include everything from planting a waterwise landscape with habitat for songbirds to participating in a local volunteer project to plant willows in a riparian area. There are also several agencies and organizations, such as the Utah Division of Wildlife Resources and Utah State University Water Quality Extension, that have developed citizen monitoring programs. These programs are excellent venues for applying knowledge and working with (and learning from) resource professionals. Monitoring can also include something as simple as recording seasonal observations of songbirds in your backyard. It is amazing what we can see in nature if only we take the time to look!

Volunteering is one of the most effective ways to promote stewardship. Our commitment of time to a person, project, or organization serves as an example of our unending desire to help others understand, appreciate, or manage Utah's natural world.

> "Never doubt that a small group of committed people can change the world. Indeed, it is the only thing that ever has." -Margaret Mead

Promoting Stewardship in Our Professional Lives

Many of us work as educators or land managers, so it is important to discuss some ideas to consider in our professional lives if we're going to be effective stewards. Balancing use and resource protection is critical for ensuring a sustainable operation, for protecting wildlife and habitats, and for ensuring a high-quality experience for our audience.

Essentially, this means we need to plan for what, how, and how much in regard to resource use. How these decisions are made will influence the impacts on the environment and the type of experience that we might provide to our audience, from school children to park visitors. As individuals, we can influence planning decisions by becoming involved on committees, planning boards, and as voters.

Site Planning

In terms of planning for or managing a site for visitors, our first priority is protecting our sites from degradation. Recognizing impacts to the natural areas we manage, such as changes in plant communities, erosion, and declines in wildlife sightings, is critical for planning how to reduce those impacts. This step is just as critical to a neighborhood park as it is to a preserve that is thousands of acres in size. If we notice negative impacts, let someone in charge know about it.

What about when your visitors leave our sites? Educating visitors to the potential impacts of offsite practices, such as nutrient loading from residential areas or the negative impacts of non-native plants and animals on natural communities, can help them recognize potentially damaging behaviors. An informed public is also better equipped to participate in decisions regarding land use strategies and ensuring development in Utah incorporates conserving natural areas as a high priority.

Remember that on a regional basis, we are all in this together. For that reason, we should promote other responsible nature-based opportunities - by doing so, we promote and reward good land stewardship and responsible behaviors to the benefit of the resource.

Limiting Inappropriate Behavior

Informing persons about appropriate behavior can be a delicate topic. There may be times, such as the beginning of a tour, when we need to inform people about behaviors we expect them to observe. (“Kids, we need to stay on the trail”). Likewise, there may be times when we need to explain to someone that his or her actions are not appropriate (“Ma’am, picking wildflowers within the park is prohibited.”) To reach our audience with messages regarding ethical behavior, we need to be tactful and respectful. It is our responsibility as naturalists to inform people of the potential consequences of inappropriate behaviors, and to provide explanations that place these behaviors in perspective. In other words, an explanation can go a long way to helping people understand and support appropriate behaviors.

More often than not, people don’t recognize their actions as harmful. For example, prohibiting the picking of a small bouquet of flowers in a park when those same flowers can be seen growing along any roadside ditch seems a bit absurd to most people. However, this seems less absurd when one considers the potential cumulative impact of dozens or hundreds of visitors picking flowers along the trail each day. The same argument can be made for cleaning up after a dog on the trail or in a neighborhood – the cumulative effect of dog feces on water quality in many of Utah’s lakes and rivers could be substantial, especially if they are used for drinking water. So, we should try to deliver our message in a straightforward and friendly manner and we will probably find that most people appreciate the information, rather than resent it.

Considering All Points of View

Living in a sustainable society that conserves biodiversity and wild places, that maintains important ecological functions and services, and that leaves a legacy of responsible environmental stewardship for future generations to enjoy is an appropriate ethical goal. How we accomplish this goal, however, is not easily resolved when decisions are being made that affect individuals and communities. Often these issues are described and argued in terms of "rights."

There are many perspectives on the issues of rights. Discussing these perspectives is often contentious because of their respective consequences. Discussions regarding issues that affect the rights of plants and animals, individuals, society, and of future generations are neither straightforward nor easily resolved, but need to be considered. Regardless of the position taken, an ethical approach will consider and attempt to balance the element of fairness for all stakeholders, including future generations.

The policies and philosophies we support at local, state, and national levels ultimately influence the outcome of these issues and their collective effects on the environment at scales that range from local parks, to regional strategies for maintaining wildlife corridors, to the debate on global warming. Ultimately, these decisions will weigh heavily not only on the type of world we live in, but in the world that future generations inherit and the manner in which that world will nourish those generations, both in terms of food and soul.

Stewardship in Our Personal Lives

Remember, every environmental educator is a role model to his or her students. Many students, especially children, learn by example. Because children are incredibly perceptive, we must be sure we truly believe in what we are teaching prior to teaching it to students. In leading by example, educators have the great opportunity, and responsibility, of making the connection between ideal and reality.

Sharing our knowledge with others can take one of many forms. Not all of us are trained or employed as educators. Our knowledge can be shared with colleagues via discussions, reports, or management plans. We can also share our knowledge with others while volunteering on a restoration project. We can even share our knowledge with friends and family while on a leisurely hike through the woods. Sharing knowledge and passion doesn't have to be planned and doesn't have to be a "lesson."

By serving as a role model and sharing our knowledge with others, we will promote environmental literacy and, ultimately, greater stewardship of Utah's natural world. One thing is for certain: by participating in the Utah Master Naturalist Program, we haven't learned all we need to know. Truly being a "master naturalist" requires a lifetime of exploring and learning! While our knowledge will always increase with effort, we will never know everything. It is also very important that we use our title of Utah Master Naturalist wisely. While we have all made a great achievement by completing a Utah Master Naturalist course, we are not necessarily experts. We are people whom others will know have not only gained a wealth of knowledge related to Utah's natural world, but have also made a commitment to taking steps in our lives toward being effective stewards.

There is no standard way that someone should "be a steward." There is a lot to think about, and it all takes time to sink in. But, it gets easier! As we think more and more about the impacts that we have, and can have, on Utah's natural world, it will eventually become part of the decisions we make in our everyday life. Most importantly, we should **have fun!** Being a Utah Master Naturalist should not feel like it is a chore. Promoting stewardship should be something that we *want* to do, something that we find a way to do even if in some small but personal way. This idea of promoting environmental stewardship through literacy is best summed up in another quote from Aldo Leopold:

> "When we see the land as a community to which we belong, we may begin to use it with love and respect."

Most people can say they love themselves, their family, their friends, and perhaps their community. Remember that environmental stewardship requires expanding the idea of one's community beyond the human component to include the soils, waters, plants, and animals, collectively known as the land. Before doing this, we must first understand the land where we live. We must become environmentally literate citizens, and education is the essential key to achieving this.

Thank you for participating in the Utah Master Naturalist Program! Congratulations on completing the course and may you continue to enjoy exploring, learning about, and conserving Utah's amazing natural world!