Adopt-a-SNOTEL Site

Teacher's Guide

United States Department of Agriculture

Natural Resources Conservation Service

Prepared for Idaho NRCS Snow Survey by

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How to Use This Booklet

We're glad you'd like to learn about SNOTEL (SNOw TELemetry).

We have attempted to compile adequate and helpful information in a convenient way, with *Adopt-a-SNOTEL Site Teacher's Guide*. It is divided into eight sections, including four lesson plans in Section E. While you may be motivated to use *Adopt-a-SNOTEL Site* in its entirety, it was designed also to be used section-by-section. We are pleased to have this educational project play a role in your place of learning.

Think snow!

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Introduction

Let It Snow, Let It Snow, Let It Snow

Welcome to *Adopt-A-SNOTEL Site Teacher's Guide*

An Educational Program about Snow, Snow Measurement, and Water Supply in the Western United States

This *Adopt-A-SNOTEL Site Teacher's Guide* will assist you and your students in exploring the white, watery world of snow and its impact on our water supply.

Snowpack—accumulated snow mostly at higher elevations—supplies 70 percent of the West's water. Forecasting water supply by measuring snow is the job of the Natural Resources Conservation Service (NRCS), an agency of the United State Department of Agriculture. The right tool for NRCS's snow measuring job is a system called SNOTEL—automated SNOw TELemetry stations. SNOTEL sites—768 in all—are located throughout 13 Western states (Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming).

This guide contains teaching ideas, lesson plans, resource listings, information on correlations to standards, background and reference materials, and a glossary. All these educational resources are meant to make incorporating the science-based study of snow, measuring snow, and water supply prediction into your place of learning easier.

Just as NRCS scientists do, you and your students can monitor snowpack using SNOTEL (SNOw TELemetry) data, which are freely available on the Internet. We encourage you to pick a nearby SNOTEL site to observe regularly throughout the year, while inviting you to watch other sites to broaden your understanding of variation across the country. With this near real-time data as a starting point, integrated lessons covering many areas of science, math, language arts, social studies, physical education and health, and environmental education are possible. We aim to help you develop an appreciation for and understanding of hydrology, water quality, environment, and conservation.

What is the NRCS?

Known until 1994 as the Soil Conservation Service, the Natural Resources Conservation Service (NRCS) is an agency within the United State Department of Agriculture concerned with conserving soil, water, and related resources. The agency's vision is one of "harmony between people and the land."

NRCS's mission is *"to provide leadership in a partnership effort to help people conserve, improve, and sustain our natural resources and environment."*

Since the mid-1930s, this agency has directed the Snow Survey and Water Supply Forecasting Program in the Western states. The main tool in measuring snowpack is called SNOTEL—short for SNOw TELemetry. SNOTEL is a sophisticated yet tough near-real-time hydrometeorological data collection network.

SNOTEL (say "snow-tell") provides a key to the cooperative snow survey and water supply forecasting program relied upon by irrigators, recreationists, municipal water managers, and many other water users in the West. Each day more than 700 remote data collection sites—mostly in the remote, rugged high mountains of the West—transmit snow, precipitation, and temperature data to a central computer facility in Portland, Oregon. There, the Centralized Forecasting System analyzes the data within a massive relational database, where various analyses, tables, and graphs can be generated. Current and historical data and analyses are available via the Internet.

Adopt-a-SNOTEL Site Teacher's Guide has been developed by NRCS to provide a glimpse inside this important process. SNOTEL data can be accessed by any computer equipped to access the Internet and a web browser. Linking to the World Wide Web allows you to view and gather data—from historical records many decades old to fresh readings from today.

NRCS conservationists have long supported the important role education plays in sustaining a conservation ethic. They are pleased that you have decided to bring their work into your classroom.

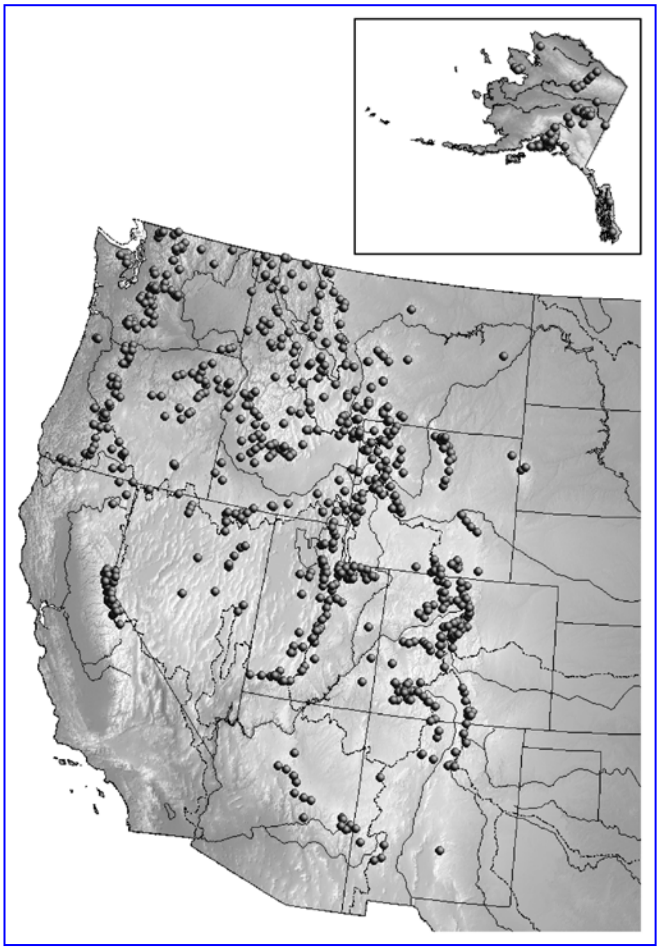
Goals of This Educational Program

The goals of *Adopt-A-SNOTEL Site Teacher's Guide* and the program it represents are to:

- Improve awareness, among teachers and students, of SNOTEL data collection and analysis by the NRCS;
- Encourage a strong conservation ethic with respect to soil, water, and other environmental resources;
- Inspire students to explore careers in natural resources conservation;
- Promote expanded use of data and information collected by NRCS.

How the Program Operates

Adopt-A-SNOTEL Site Teacher's Guide can be used by any educator. We've worked hard to make it capable of being used readily by skilled teachers regardless of location. NRCS support for the Adopt-A-SNOTEL Site Program is open to any class or school in the 13 western states where NRCS has a water supply forecasting program: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming.



SNOTEL's Site Locations

In the 1980s, Snow Survey and Water Supply Forecasting Program staff (within what was then still called the Soil Conservation Service) recognized the educational value of involving teachers and students in the excitement of their profession and the significance of their work. Various activities were started. One particularly popular one involved adoption of a SNOTEL site by teachers and their classes. The Adopt-a-SNOTEL Site concept was pilot tested at three National Science Teachers Association conventions with enthusiastic responses. It seemed like a West-wide Adopt-A-SNOTEL Site Program was in order, so the scientists of the Snow Survey wrote one, with significant input from teachers. They published the first edition of *Adopt-a-SNOTEL Site Teacher's Guide* was published in 1988-89.

In order to incorporate updates, especially with respect to computer access to SNOTEL data, *Adopt-a-SNOTEL Site Teacher's Guide* was revised and a second edition released in 2005. NRCS contracted with the Idaho Environmental Education Association to accomplish this revision. Several dozen educators and water supply professionals were consulted to improve the program and guide (see Acknowledgements). We hope this guide is useful, interesting, and—most of all—educational for you and your students.

You are free to adopt any site and to work with the data with as much vigor and intensity as you can muster. Because of free availability of SNOTEL readings on the Internet, you will have no shortage of data. In fact, you may find the sheer amount of SNOTEL data and information initially overwhelming. That's where this teacher's guide may assist, by showing ways of focusing your investigations and offering explanations to alleviate potential confusion.

Though we offer many suggestions, we trust in your abilities to adapt the materials to meet your specific needs. As questions arise about SNOTEL and NRCS's work, you are encouraged to contact either the nearest NRCS office or your state's NRCS Snow Survey staff.

A Guide for Teachers to Guide Their Students

For many students, relevant information means it has an observable and timely effect on their daily lives. Across the American West, snowpack and water supply forecasts meet these criteria. We hope you agree and incorporate materials and concepts contained in this guide into your lessons.

We've tried to make this guide easy to use and flexible, so you can pick and choose to meet your needs.

Comments Welcomed

Please let us know what you think. It is anticipated that additional activities, related topics, and materials will be identified by the participants. We encourage you to share those with us, so we can learn from you and pass your ideas along to other educators.

For more information, contact:

Ron Abramovich, Water Supply Specialist • 208-378-5741 • Ron.Abramovich@id.usda.gov
NRCS Idaho
9173 W. Barnes Dr., Suite C
Boise, ID 83709

Warning!!!

SNOTEL sites are located in remote areas. Casual visits to a site can be hazardous to those not familiar with the area and not properly equipped. The dangers can be intensified by sudden winter storms, avalanches, and other hazards. Teachers should be careful not to inadvertently suggest or condone a site visit without supervision for the students. Visits at any time of the year should only be undertaken after coordination with your local NRCS office.

Acknowledgements

In the process of revising the *Adopt-a-SNOTEL Site Teacher's Guide*, we've tried to model educational best practices. We've attempted to be learner-centered, by beginning with lesson plans and ideas from teachers already using snow-based data with their students and then repeatedly taking our ideas and drafts to teachers for review and comment. We've attempted to be alternately group- and individual-oriented, presenting our work at workshops and in classrooms at various stages before returning to our offices for further revision based on these formative evaluations. And, we've attempted to incorporate strands from various disciplines (though science is the most obvious).

To gauge the success of these attempts, we worked with many educators. We've listened to their suggestions and tried to incorporate every one which could improve this curriculum guide. We acknowledge their contributions, with gratitude.

Educators who provided extensive reviews of drafts of this guide: Kristen Clayton, East Side & West Side Soil & Water Conservation Districts, Idaho Falls, ID; Anna Lindstedt, Friends of the Teton River, Driggs, ID; and, Jody Fagan, NRCS Idaho, Boise, ID.

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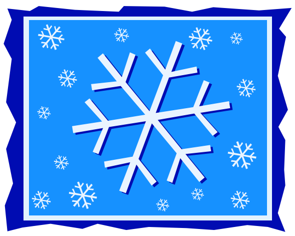
Section A

Selecting A SNOTEL Site to Adopt



Pull out the two maps from the pocket of *Adopt-a-SNOTEL Site Teacher's Guide*. Open them up and find your school's (or learning site's) location. Then look for the SNOTEL site nearest to you.

The activities and suggestions in this teacher's guide work best if you adopt a SNOTEL site that holds a lot of relevance to your students. So, the closest site may be a good choice. But, it might not be the best, as there are a few additional criteria to consider as you and your students make your selection of an adopted SNOTEL site.

Consider these factors about the SNOTEL sites under inspection:

- Proximity;
- Located within your watershed;
- Located in an area known to, at least, a few of your students;
- Serviced by NRCS staff members in your community.

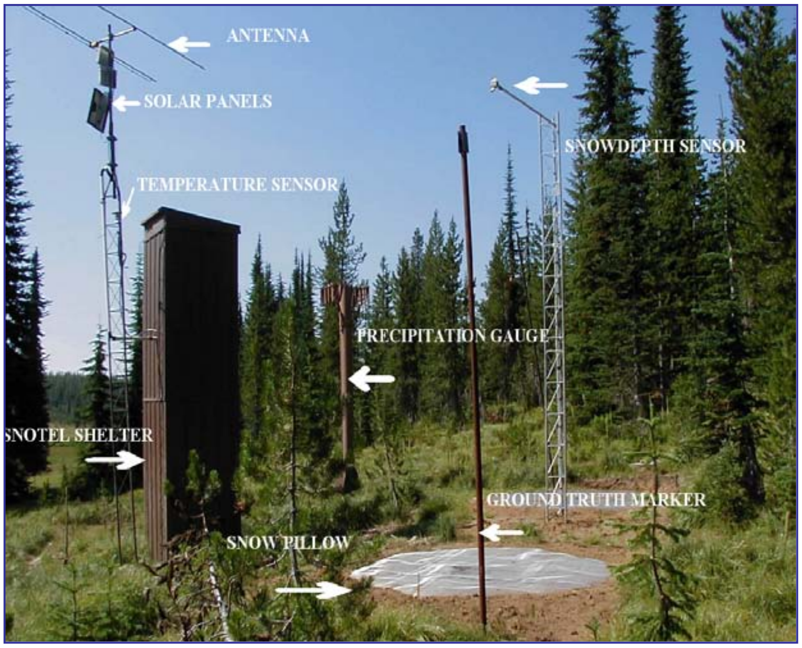
As you explore the possible SNOTEL sites that would be reasonable for you to adopt, consider including your students in this early decision-making. They can work on map-reading skills, as they gather, organize, analyze, interpret, evaluate, and report on site selection. Having them involved from the beginning of a project invests them in its development and outcomes, as well as increasing the likelihood of their buy-in throughout the course of your investigation.

Maps

Two maps are standard issue with your *Adopt-a-SNOTEL Site Teacher's Guide.* First, there's a small-scale map showing all SNOTEL sites throughout the West, including

Alaska. Second, a map of your state and/or region shows more details because it is larger in size and has a larger scale. Including both maps makes in possible to touch on the concepts of map scale, distance, latitude and longitude, etc.

A Typical SNOTEL Site



A typical SNOTEL Site, with its instruments labeled (Craters Meadow SNOTEL Site, North Fork of the Clearwater River Basin, Idaho)

When NRCS scientists decide where to place SNOTEL sites, they look for certain characteristics. While most SNOTEL sites are located at high elevations, they are almost never placed right on summits or ridgelines. Gusty conditions there mean windblown crusts on the windward side and drifting on the lee. Rather, SNOTEL sites are preferably placed on small flat spots or even in shallow swales, at a little lower elevation where there is less turbulence. When possible, they are placed at saddles, on or near watershed divides. Thus, one station can produce data helpful to building predictions for two different basins. Other factors include land ownership, geologic stability, vegetation cover, and not being too close to a body of water. The key is for the data collected to be representative of the snowpack in the broader area, and not just that particular spot.

Each SNOTEL site consists of measuring devices and sensors, a shelter housing the radio telemetry equipment, and an antenna that also supports the solar panels used to provide electric power. A standard sensor configuration includes snow pillows, a storage precipitation gauge, and a temperature sensor. Some sites are more sophisticated and have other sensors and additional pieces of equipment. At all SNOTEL sites, the snow pillow is the workhorse sensor upon which the system of automated snowpack measurement relies.

Standard Equipment for a SNOTEL Site:

- Snow Pillow—A heavy-duty bladder flush with the ground, the snow pillow is filled with an environmentally safe antifreeze solution. Weight of accumulating snow on the pillow increases the pressure on the fluid. Automatic measuring devices connected by hoses from the pillow to the inside of the shelterhouse convert the weight of the snow into a reading of the snow's water equivalent, the actual amount of water in a given volume of snow. NRCS uses pillows made from hypalon (like river rafts) and butyl (like inner tubes) synthetic rubbers or stainless steel. Some are fenced for protection from livestock and grazing wildlife.

- Precipitation Gauge—Stack-like storage gauges are used to capture all precipitation in any form that falls during the year, be it rain, snow, sleet, hail, or some combination thereof. These gauges are sized according to the average annual precipitation at each site. Around the opening at top of the gauge, a wind screen—a collar of baffles—reduces effects of swirling winds on an accurate measurement of precipitation. Fluid pressure, from both precipitation gauge and snow pillow, is measured with pressure transducers.
- Air Temperature Sensor—You might call it a thermometer. For these remote locations with extreme conditions, heavy duty models are used. They are able to read temperatures from about -40˚ F to 160˚ F.
- Solar Panels—SNOTEL sites are powered by the sun. Arrays of solar panels are mounted on masts attached to the antennas. They keep banks of batteries in the shelters charged.
- Antenna—For sending radio transmissions of data from the mountains to waiting NRCS scientists, water users, teachers, and students.
- Shelter—All sites have a small shelter that houses the electronics: transducers, datalogger, radio transmission, and power equipment. Yes, it looks like an outhouse!

Other Sensors Installed at Some SNOTEL Sites:

- Snow Depth—Remember that the snow pillow is really measuring only the weight of the snow. Not all snow has the same density, however. Powdery snow, with its gorgeous light individual flakes, is a lot less dense than slushy stuff with big, compound globs of many flakes stuck together. A snow depth sensor works much like an auto-focusing camera, bouncing a signal off a surface to read a distance.
- Wind Speed/Direction—An anemometer reads the wind's direction and speed. These are important additions to a SNOTEL site's data when an area is prone to wildfires.
- Solar Radiation—A measure of the intensity of the sun's rays can add to scientists' ability to predict how fast snow is melting, thereby adding flow to streams.
- Relative Humidity—Another important factor for improving predictions about melt-off.
- Soil Moisture/Soil Temperature—For adding considerations of the site's soil to the water supply equation. Keep in mind that as snow thaws some of the melt water makes its way into groundwater supplies.
- Tipping Bucket Rain Gauge—Another method for measuring precipitation.
- Barometric Pressure—Helps with short-term weather forecasting.
- Fuel Moisture/Fuel Temperature—Useful in fire-prone areas to show how much vegetation might burn if ignited.
- Ground Truth Markers—Ground truthing is a manual check to verify sensor accuracy. Ground truth markers surround a snow pillow to guide NRCS snow

survey workers when they are taking manual snow cores when visiting SNOTEL sites. Taking cores helps to verify both the snow depth readings and the snow water equivalency data. The markers are really important, because no one wants to puncture a snow pillow! That's an expensive mistake, because of lost data and the cost of repairing the pillow.

Warning!!!

SNOTEL sites are located in remote areas. Casual visits to a site can be hazardous to those not familiar with the area and not properly equipped. The dangers can be intensified by sudden winter storms, avalanches, and other hazards. Teachers should be careful not to inadvertently suggest or condone a site visit without supervision for the students. Visits at any time of the year should only be undertaken after coordination with your local NRCS office.

Example of a Class Report about Their Adopted SNOTEL Site

We have adopted Santiam Junction, Oregon, SNOTEL site (number 102). It is located in Linn County, about 47 miles east of Sweet Home at 44˚26' North latitude and 121˚56' West longitude at an elevation of 3,750 feet above sea level. This is in Township 13 South, Range 7 East, Section 14. The site is shown on the attached map. The drawing and description of a typical SNOTEL site are similar to Santiam Junction. A photograph of Santiam Junction is pasted below:

For comparison purposes, we will also study data for Hogg Pass SNOTEL site located about four miles east of Santiam Junction at elevation 4,760 feet.

The nearest NRCS Field Office is in Tangent at:
33935 Highway 99E
Tangent, OR 97389
(503) 967-5927

Santiam Junction was installed in 1975, and is located in the Willamette National Forest. A manual snow course has been measured in the same vicinity since 1940. Santiam Junction in the west slope of the Cascade Mountains is used to forecast streamflow on the South Santiam River at Waterloo and on the North Santiam River at Mehama. The Santiam River is a tributary of the Willamette River.

The climate at Santiam Junction is cold in the winter with temperatures as low as -15˚F. Temperatures dip even lower nearby at higher elevations. On summer days, the temperature may climb as high as 90˚-95˚F, but evening always brings significant cooling.

Santiam Junction receives 76.4" precipitation in an average year. A dry year such as 1987 received on 55.4" inches, while 1984, a wet year, was 86.2 inches. Typically, about 70 percent of the total annual precipitation falls as rain with only 30 percent as snow. At higher elevations, these percentages would change to as much as 70 percent snow.

As reported in a Soil Resource Inventory conducted by the Forest Service, the soils in this area are volcanic in origin with exposed lava beds within a mile west of the site. The soils are deep and very deep black and very dark grayish brown volcanic sands and cinders. The soils are excessively drained and have rapid permeability. The underlying bedrock is basalt and andesite, but some areas have a layer of glacial till about the bedrock.

This combination of climate and soils supports a variety of plants and trees. Some of the more common species include those found in the transition from mixed conifer forest to mountain fir forest. There are still some Douglas fir and western hemlock which are seen more frequently at lower elevations. Nobel fir, Pacific fir, and mountain hemlock are very common near the site. Some lodgepole pine is found in the vicinity but more frequently at high elevations and will invade any wildfires. The deciduous trees include vine maple and Pacific dogwood. Rhododendrons are common and bear grass covers much of the ground.

Animal visitors to Santiam Junction in the summer might include all the species common to lower elevation of the Cascades—black-tailed deer, Roosevelt elk, and occasionally black bear and coyotes. Blue and ruffed grouse are large birds that can be found, and frequently bald eagles can be seen. In the winter, you would probably see most of the same animals except for the black bear who has gone into hibernation.

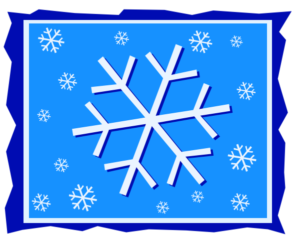
Some animals can cause problems for the Santiam Junction site. Bears sometimes damage the snow pillows while looking underneath them for grubs. This is a greater problem at sites that are more remote than Santiam Junction. A major pest for SNOTEL sites has been porcupines because they like to gnaw on wood; the plywood used in the SNOTEL shelters seems to be a favorite.

Section B

Backgrounder on Snow, Measuring Snow, and Forecasting Water Supply

"The importance of snowpack to life in and around the Rocky Mountains cannot be overemphasized."

—*Rocky Mountain/Great Basin Regional Climate-Change Assessment*, U.S. Global Change Research Project (2003, Utah State University)



This section contains a collection of background information intended to assist you when preparing lessons and activities for your particular setting and specific needs. We've divided this overview into three sections, organized around key subject areas. This trio of concepts—snow's physical properties and characteristics; techniques for accurately measuring snowpack; and the steep challenge of using the resulting data to build meaningful forecasts of water supply—build upon each other. Feel free to extract particulars from within this section as needed.

Snow

Frozen and crystallized precipitation falling all the way to the ground is called "snow." As a form of precipitation, snow is distinct from rain (visible droplets of water), sleet (freezing rain), hail (ice balls formed by updrafts), and drizzle (droplets of water to small to be visible one by one).

Except under very cold conditions (chillier than -40˚ F), snow formation requires tiny particles aloft in the atmosphere, which give water vapor, in air at 32˚ F or cooler, something on which to start freezing. An individual particle begins to attract water molecules far above the ground, while swirling in the clouds. A nucleus can be a fleck of volcanic ash, salt from ocean spray, windblown wood smoke, or even soot and other pollutants. Collectively, the particles serving as snow seeds are called "cloud condensation nuclei."

As a particle begins to attract water molecules, they freeze first to the particle, then to themselves. Water forms crystals when frozen because of the substance's molecular structure. This structure is hinted at by the chemical notation of water: H_2O. Two hydrogen atoms are each smaller than a single oxygen atom and attach toward one side of the oxygen. This tendency gives each molecule polarity. The positive end of one molecule shares a mild attraction with the negative end of up to four other water molecules. Known as hydrogen bonding, this ever-so-slight stickiness between molecules of water is responsible for many of the remarkable properties of this inorganic substance without which life cannot exist.

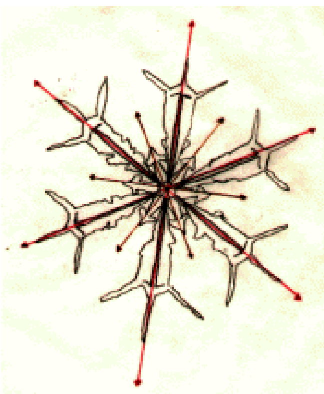


Image of a snowflake.

One of water's properties is the formation of crystals when frozen. As droplets solidify, they branch out in six evenly-angled directions, forming a hexagonal flake. From that classic snowflake shape, with its six sides, there are endless possibilities in exact size and details, so that no two snowflakes are exactly the same. The old saying really is true!

Key determinants to the size and shape of each unique flake include temperature, humidity, and amount of time spent circulating in clouds as the crystals form. As amalgamations of crystals, most snowflakes are ⅛" to ½" in diameter. Blown by winds, flakes often crash together, becoming broken and conjoined. The biggest flakes—up to almost two inches across—require near-freezing-point temperatures, light winds, and convective air conditions. Bigger flakes tend to be heavy, and fall from the sky more readily. Studies in the Rocky Mountains have shown that the fluffiest snow forms when winds are light and temperatures are around 15° F. This kind of snow is referred to as "powder." At even colder temperatures, flakes tend to be smaller and denser.

Meltwater cuts a streamlet in the snowpack.

As a rough rule of thumb, an inch of snow makes about 0.10 inches of melt water. It is worth keeping in mind that this approximation is quite coarse. Snow varies widely in its density, that is, its water content per volume. In reality, ratios as low as 100-to-one and as high as three-to-one have been found. So, whereas 10 inches of Rocky Mountain powder might contain 0.10 inches of water, 10 inches of heavy, wet slush might be equivalent to more than three inches of rain.

Compared to other forms of precipitation, snow poses difficulties to meteorologists as they work to predict the weather. They have a tough time detecting snow falling from a distance and even greater trouble in predicting timing and locations of snow showers. Ironically, snow is the most visible form of precipitation once on the ground as a cool white covering across a landscape.

Why is snow white anyway?

Because of snow's crystalline structure, it reflects most light falling on it, not absorbing any portion of the spectrum much more than any other. So, we see the reflected light as white, an even mixture of all portions of the visible spectrum. Most other natural materials absorb some segment of sunlight to produce their non-white color.

The lower elevational limit of a snowpack in central Idaho climbs in spring.

Once snowflakes hit the ground, they accumulate. They lose their individual nature and become part of the pack—the snowpack. Snowpack has a set of material characteristics different from falling snowflakes. NRCS hydrologists and other scientists have worked long and hard to understand the energetic and structural properties of snowpack. Snowpacks are composed of crystallized water, ice, and air. These elements come together and can be described in terms of depth, density, volume, area, porosity, and—of keen significance to water users in the West—snow water content.

For sources of more in-depth sources of information on snow's physical properties, see Section F, "Related Topics with Suggested Activities and Resources," especially the first subsection (p. 121). Terms that might be unfamiliar can be looked up in Section H, "Glossary for Adopt-a-SNOTEL Site" (p. 131).

Measuring Snow

To a casual observer, the process by which we get water from the mountain snowpack is simple: the weather cools as winter approaches and precipitation changes from raindrops to snowflakes. Snow accumulates in winter, and with warming of spring and early summer it melts, producing streamflow.

In reality, the relationship between snowpack and amount of snowmelt runoff is much more complex. It depends on many factors, such as moisture content of the soil, ground water contributions, precipitation patterns, fluctuation in air temperature, use of water by plants, and frequency of storm events. These factors change throughout the year and from year to year. Their relative importance varies depending on location.

Melting snow produces streamflow—a vital source of water for people living in the West.

The stage is set for the snow-water year even before the first snowflakes fall. The amount of moisture that accumulates in the soil early in winter, before the snowpack develops, will affect runoff the following spring. Dry soils tend to absorb more of the melt water than wet soils. The amount of moisture that is absorbed depends on soil characteristics as well as precipitation. Wind, air temperature, storm frequency, and amount of moisture in the atmosphere determine the accumulation of the snowpack. How the snowpack accumulates affects its density (amount of water per unit volume of snow) and texture (crystalline structure). Density increases as the snowpack becomes deeper and the lower layers are compressed. Wetness of the snow also affects density. Compression affects the crystalline structure of the snowpack. Density and crystalline structure affect how fast the snowpack melts and how much water it yields.

Air temperature and availability of atmospheric moisture determine how wet or dry the snow is. Typically, the west slope of the Cascade Range, in response to the Pacific Ocean's strong influence, receives heavy, wet snow. One foot of that snow, newly fallen, can produce up to 1.5 inches of water. In other areas, such as the Wasatch Mountains in central Utah, the snow is much drier. It is light and powdery—excellent for skiing—and one foot of fresh snowpack might contain only an inch of water.

Skiers may prefer light, powdery snow, but heavy, wet snow contributes more to the water supply. (Courtesy of Bogus Basin Mountain Resort)

Winds can redistribute the snow into drifts. Drifts differ from the surrounding snowpack in texture and density because of the weight of additional snow. On unsheltered snowpacks, high winds can evaporate the snow cover at temperatures lower than 32° F—a process called sublimation. Mountain snowpacks do not melt steadily. Melting varies according to weather, ground temperature, and exposure to the sun's rays. A snowpack begins to melt when its temperature from top to bottom equalizes at 32° F. Before reaching this isothermal state, the snowpack has different temperatures at different depths. Ground temperature, air temperature, and exposure to incoming solar radiation affect how quickly it becomes isothermal. South-facing slopes and open areas receive the most solar radiation and have the highest melt rates.

History of Snow Surveys:

Early westerners realized the ties between the size of the winter snowpack in the high mountain ranges—Rockies, Cascades, Sierra Nevada—and their summer water supply. Some attempts to measure the snow and predict runoff had been made in the East as early as 1834, but it wasn't until 1904 that a systematic survey was undertaken in the West. Dr. James Church, a classics professor at the University of Nevada in Reno, made his first surveys on Mt. Rose in the Sierra Nevada. He developed measuring equipment and sampling techniques that led to the first water supply forecasts by 1906. Success in Nevada soon caught attention of others.

In 1934, a particularly severe drought across much of the nation resulted in farmers demanding better predictions of the streamflows available for growing crops. Others who counted on water for industry, power generation, and domestic use echoed this request. Congress responded in 1935 by passing legislation creating a federal snow survey and water supply forecasting program under the direction of the Bureau of Agricultural Engineering in the Department of Agriculture. By the end of 1935, at least nine independent snow surveys were being conducted.

Dr. James Church

Since that time, most of the American West has relied on the U.S. Department of Agriculture's cooperative Snow Survey Program for predictions of meltwater runoff. This program is a Federal, State, and local partnership directed by the Natural Resources Conservation Service. Its survey activities encompass Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming. Alaska and southern Canada are partners also. California has an independent program. Data from all partners is available on the Internet.

The next three decades saw a proliferation of snow survey activity throughout the West. In some states, independent power or irrigation companies spearheaded the surveys; in other states, universities or state engineers were in charge. Because many Western watersheds and streams are interstate, Federal help was needed to coordinate the surveys and to develop uniform procedures and equipment for surveying and forecasting.

To find out how much water will be available in summer, snow surveyors from NRCS and the other cooperating agencies collect data from some 1,600 snow measurement sites throughout each winter. They determine the depth and water content of snowpacks and estimate the amount of runoff from the mountain watersheds.

Until 1977, snow measurements were all done manually, at snow courses. A snow course is a permanent site that represents snowpack conditions at a given elevation in a given area. Typically, they are about 200 feet long.

Surveyors approaching a snow course marker.

In 1977, NRCS began developing a network of automated radio telemetry data sites for collecting snow survey data. This snowpack telemetry (SNOTEL) network provides NRCS offices with daily or more frequent information on streamflow potential. The information is especially valuable during periods of flood or drought.

Manual Snow Surveys:

Manual surveys require two-person teams to measure snow depth and water content at designated snow courses. A particular snowpack may have several courses. Generally, the courses are situated in small meadows protected from the wind.

Measurements generally are taken on or near the first of every month during the snowpack season. The frequency and timing of these measurements varies considerably with the locality, the nature of the snowpack, difficulty of access, and cost. On occasion, special surveys are scheduled to help evaluate unusual conditions. The manual surveys involve travel and work in remote areas, often in bad weather, but reliable data are obtained. Locations that are too hazardous or costly to measure on the ground can be equipped with depth markers that can be read from aircraft (fig. 7). Snow depth can be measured in this way with a high degree of accuracy. Although the amount of water in the snowpack is not measured, it can be reliably estimated from the observed snow depth. Continuing periodic measurements at some 800 snow courses provide insight into snowpack accumulation patterns.

Another form of manual surveying is reading depth markers from aircraft for locations too hazardous or costly to measure from the ground.

Conducting a Manual Survey

Before plunging the snow tube into the snowpack, the surveyor first makes certain that the tube is clear of all snow and soil before taking a snow core sample. The team uses a strong, light-weight, graduated aluminum snow tube and a weighing scale.

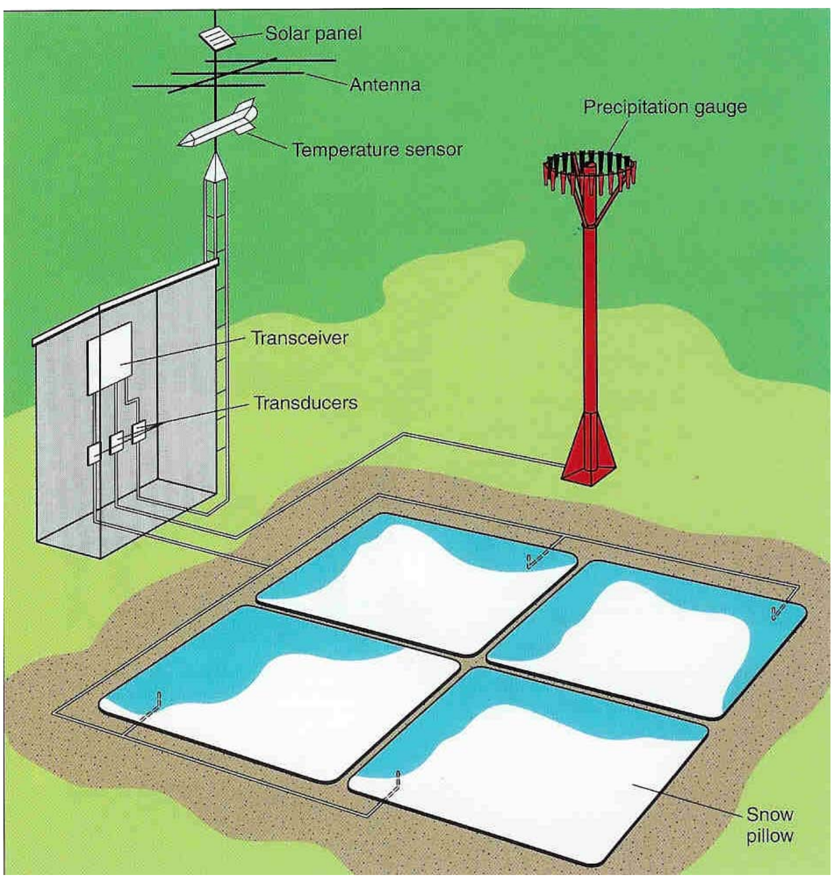
One surveyor measures the snow depth while the other records data. From 5 to 10 measurements are taken at regular intervals along a snow course. Snow depth is measured by pushing the tube down through the snowpack to the ground surface and extracting a core.

In taking an accurate snow core sample, the surveyor must verify that the tube has reached ground level by examining the base of the tube and finding soil.

After clearing out the soil from the tube, the surveyor determines the amount of water in the snowpack by weighing the tube with its snow core and subtracting the weight of the empty tube. An average of all samples taken is calculated and used to represent the snow course.

Automatic Snow Surveys and the Development of SNOTEL:
Even though the data from manually measured snow courses provide a valuable body of information, the typical schedule for manual surveys results in weeks with no specific insight into the condition of the snowpack. In that time, intense storms may be adding an abnormally large amount of snow or rain; perhaps an unseasonable warm spell at high elevation is resulting in a rapid melt with ensuing flood hazards. Snow surveyors and water managers realized early in the development of the program that timely forecasting and management decisions required more frequent measurements and additional information. They also needed a way to survey particularly remote and hazardous snowpacks. SNOTEL's automatic sensing and data transmission were the solution.

Sensing Devices—A typical SNOTEL site consists of measuring devices and sensors, a shelterhouse for the radio telemetry equipment, and an antenna that also supports the solar panels used to keep batteries charged. A standard sensor configuration includes snow pillows, a storage precipitation gauge, and a temperature sensor. The snow pillows are envelopes of stainless steel or synthetic rubber, about 4 feet square, containing an antifreeze solution. As snow accumulates on the pillows, it exerts pressure on the solution. Automatic measuring devices in the shelter house covert the weight of the snow into an electrical reading of the snow's water equivalent—that is, the actual amount of water in a given volume of snow.



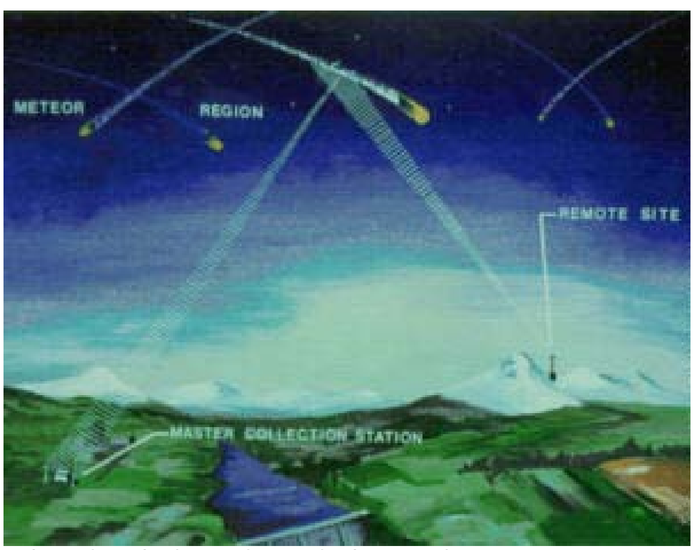
This drawing depicts a typical remote SNOTEL site. Pressure pillows are used for measuring snowfall, a storage precipitation gauge provides current information about conditions at the site, and a temperature sensor measures the existing temperature.

The precipitation gauge measures all precipitation in any form that falls during the year. The temperature sensor determines the minimum, maximum, and average daily readings.

Additional sensors can be incorporated into a particular site for measuring wind speed and direction, soil temperature, snow depth, and a variety of other weather and environmental aspects. The configuration at each site is tailored to the physical conditions, the climate, and the specific requirements of the data users.

Telemetry—SNOTEL uses the principle of radio transmission by meteor burst. Radio signals are aimed skyward where trails of meteorites reflect the signals back to Earth. The meteor burst technique allows communications between two locations as much as 1,200 miles apart. Two master stations—at Boise, Idaho, and Ogden, Utah—cover the 11 Western states, an area of about one million square miles. By cable, the master stations feed the data to SNOTEL's Centralized Forecasting System in Portland, Oregon. Alaska's Meteor Burst Communication System (AMBCS) for snow surveys is similar. All remote SNOTEL sites are interrogated daily on a regular schedule. Additional interrogations can be conducted on demand, and any special reporting requirements can be programmed into the site's microprocessors. In the Alaskan system, hourly interrogations are conducted, and the data are made immediately available to cooperating agencies.

Quality Control—Sites are designed to operate unattended for a year in severe climates. Each site receives preventative maintenance and sensor adjustment annually. The reliability of each SNOTEL site is verified by ground truth measurements taken during regular manual surveys. These readings are compared with telemetered data to check that values are consistent and compatible. Any values found to be beyond specified limits are carefully examined and edited to ensure a continuous, high-quality record. Every year each site's performance is compared against established performance standards. Sites not meeting rigid criteria undergo a thorough field evaluation to correct any site deficiencies.



Artist's schematic of meteor burst technology at work.

Meteor Burst Technology—Billions of sand-sized meteorites enter the atmosphere daily. As each particle heats and burns in the region 50 to 75 miles above the Earth's surface, its disintegration creates a trail of ionized gases. The trails diffuse rapidly, usually disappearing within a second, but their short lifespan is adequate for SNOTEL communications to be completed.

Using "meteor burst technology," sites as far apart as 1,200 miles can communicate with one another for very short periods ranging from fractions of a second up to several seconds. This interval is sufficiently long to "burst" relatively short data messages between sending and receiving stations. This method of communications is ideally suited for interrogating remote data sites on a schedule of several polls per day. For the SNOTEL system, meteor burst technology overcomes interference to more conventional types of communications signals often caused by interceding mountains. Mountains pose no problem for a meteor burst system.

The process has three major steps: (1) master stations request data from remote sites; (2) sites respond by transmitting their current data; (3) and finally a master station acknowledges receipt and signals the site transmitter to stop. This complex exchange, taking place in a fraction of a second, is possible thanks to microprocessors. SNOTEL was the first and remains the largest user of meteor burst technology in the world.

NRCS's Centralized Forecasting System—In Portland, Oregon, the NRCS National Water and Climate Center, operates the Central Forecasting System (CFS), where all the SNOTEL data ends up for storage, processing, and analysis. CFS was developed in the 1980s to automatically handle information related to water supply forecasting such as streamflow, precipitation, snow depth and snow water equivalent, and reservoir data. These data are available for the current water year (October 1 through September 30) as well as for historical water years. Numerous routines and interactive programs for manipulating water supply data are included in utility programs within CFS. These are mainly intended to aid in applying snow survey program information for conservation in the field.

CFS was developed by NRCS and was originally accessible via approximately 40 telephones lines and the early Internet. Today, most of the products are available on the World Wide Web. CFS is the primary focal point for snow survey data analyses, streamflow forecasting, data exchange, and product dissemination. It serves as the delivery system to make snow survey and related planning information available to local conservation districts and NRCS offices where it is incorporated into their conservation application programs. CFS also provides access to hydrologic data and interpretative products for a wide variety of governmental agencies and to interested citizens.

Hydrologists use the computer programs in CFS to generate streamflow predictions throughout the West and to analyze and interpret hydrologic and meteorological data into meaningful products useful at the local level. The data in CFS are also important for natural resources management planning. These data reside in an automated database consisting of monthly data for 1,600 snow measurement sites, 1,000 stream gauges, 333 reservoirs, and 2,000 precipitation stations as well as daily data from the 700-plus SNOTEL sites and 17,500 climatological stations. Data are exchanged routinely with the National Weather Service, numerous other agencies, and private entities.

The 12 Western states and Alaska publish a monthly "Water Supply Outlook Report" which is generated via CFS. Special reports can be created and stored that include data for specific SNOTEL sites and during specific time intervals. Several utility programs are available that are designed for snow survey personnel use in quality control for measured data and forecast. Various hydrologic models in CFS provide users with an array of forecast products.

Other CFS programs relate snow survey streamflow forecasts to irrigation planning at the farm level. These programs incorporate crop consumptive use data and irrigation planning routines from NRCS State Irrigation Guides. Several other routines concern topics such as center-pivot sprinkler evaluation, irrigation project screening, and regression analysis for relation of streamflow forecasting to local farm and irrigation district supply ditches.

A center pivot irrigates an Idaho field.

Because of the very low annual rainfall in the West, many growing areas depend on irrigation. (Courtesy of Oregon Department of Agriculture)

Forecasting Water Supply

Any discussion of snowpack and water supply leads almost inevitably to the question, "How does this year compare to average?" This question is particularly relevant during a drought or flood. An examination of this and related questions and attempts to produce answers are the heart of water supply forecasting.

The information collected by the telemetry system and snow surveyors is translated into water supply forecasts that NRCS State offices issue monthly from January to June in cooperation with the National Weather Service. Major sectors of the Western economy—agriculture, industry, and recreation—base their plans on these forecasts.

Predictions Allow for Water Management

The Western United States requires a dependable supply of reasonably priced, good-quality water if the economy is to prosper and the quality of life is to remain high. Vast areas that receive just a few inches of annual rainfall produce bountiful crops, but only with irrigation. Decisions on the types of crops to plant, the number of acres, and irrigation scheduling all depend on reliable forecasts of the year's water supply. Much of the power for cities as well as agriculture and industry is generated by hydroelectric energy. Water is truly the life blood of the West.

Wise management of existing water resources in the United States is essential. Water management, however, is complex even under the best of circumstances. Supply, demand, and cost are subject to the climate and to numerous economic and social influences, domestic and international. The decisions made early in the year, based on the best available information, often require significant revision as more data become available.

The Columbia and Colorado rivers are two examples of extremely complex snowmelt-fed river systems. The area draining into the Columbia River comprises about 258,000 square miles, which includes 40,000 square miles in Canada. Along the river, Federal agencies have built 30 major dams for power generation, flood control, and irrigation storage. The Columbia and its tributaries support a wealth of fish and wildlife, including several species of fish such as salmon, which live in the sea but spawn in the river's fresh water. Barge traffic on the river is a major link in the area's transportation network for marketing agricultural and other products. Because many communities and industries and millions of acres of agriculture depend directly on this river system for survival, effective and timely management is critical.

Sockeye salmon (Courtesy U.S. Fish & Wildlife Service)

Like the Columbia, the Colorado River also begins in high mountain country. It drains about 247,000 square miles. Huge population centers in southern California and Arizona consume enormous quantities of water, as do the expanding agricultural developments, and demands for water of the Colorado are intense. As in the Columbia, numerous storage facilities have been constructed, impounding snowmelt water to produce electricity, irrigate farms, supply water to cities and towns, and prevent floods. Unlike the Columbia, however, the Colorado picks up dissolved salts as it flows through ancient deserts and areas shaped by prehistoric inland seas. Heavy withdrawal of water, evaporation, and irrigation return flows can increase salt concentration downstream and thereby lower the quality of the water. Because multistate agreements and compacts regulate the quality and quantity of streamflow on the Colorado River, accurate management of streamflow and water use is imperative.

Most smaller river basins throughout the West also have management requirements for limited water resources that are just as important for their users. Management decisions are vital every year for big rivers or small, but the years of vast surplus and extreme shortage intensity the demands for management excellence and the importance of snow surveys.

Reservoirs such as Anderson Ranch Reservoir in Idaho are dependent on snowmelt. (Courtesy of Idaho Travel Council)

Water supply varies greatly from season to season and from year to year, and water is often located great distances from where it is needed. Snowmelt from winter accumulations in the high mountains is the source of about 75 percent of the region's water supply. Typically, irrigators and communities collect, store, and transport water to regulate quantity and ensure availability when and where it is required. With about 40 million acres under irrigation, modern agriculture together with the pressures of a rapidly expanding society make heavy demands on this water. NRCS Snow Surveys contribute to these water management decisions.

Water supplies are no longer a mystery thanks to this systematic snowpack inventory and monitoring program and advanced computer technology. Managers are alerted early in the water year to expect normal flows, water shortages, or floods, and they can make plans while there is still time to take effective action. Snow surveys and water supply forecasting do not create water, but they do the next best thing: They provide the tools for conservation of this most precious of the West's resources.

In Summary

The major reason for the Snow Survey Program with its extensive data collection network has always been the forecasts of annual streamflow volume at specific points along a river system. These forecasts are a vital input to water management. Irrigation, reservoir operation, domestic water use, power generation, fisheries management, and flood control are typical of the activities dependent on streamflow. Others are concerned with the actual measurements rather than forecasts, and the management of certain resources such as wildlife and range can be tied directly to these data. Traditionally, information has been distributed by NRCS in each State through the monthly mailing of printed water supply outlook reports from January through May. Also, water supply products for the Western United States (including snowpack, precipitation, and streamflow forecast maps) produced jointly by the NRCS and the National Weather Service are available from their respective web sites for the same period. The final product for the water year is an annual snow data summary. Snow data are maintained in a national archive.

Range management, such as grazing by these cattle in Arizona, can be tied directly to annual streamflow volume data.

The modern Snow Survey Program, with real-time data provided by SNOTEL and CFS, is delivering a broader range of more timely information than is possible with printed reports. And the information is keyed to the specific needs of NRCS and soil and water conservation district offices and an expanding user community: news media, civic organizations, emergency agencies, recreation manager, and others.

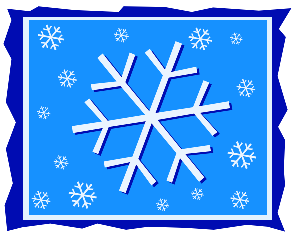
Resources management agencies such as USDA's Forest Service, U.S. Department of the Interior's Bureau of Land Management and Bureau of Indian Affairs, or state departments of fish and game and forestry require up-to-date water supply information. CFS presents opportunities for NRCS to work cooperatively with these agencies to accomplish soil and water conservation objectives.

Demands are increasing for the often limited water supply in the Western river systems, and forecasts must be as current and reliable as possible. The computer access provided through CFS not only makes the latest data instantly available, but it provides many standard and customized analysis procedures to support specific needs for information.

Many Americans mistakenly believe that there is an inexhaustible supply of water. But rivers like the Klamath, of Oregon and California, face increasing demands for this limited resource. (Courtesy of U.S. Fish & Wildlife Service)

Section C

Accessing SNOTEL Data on the Internet



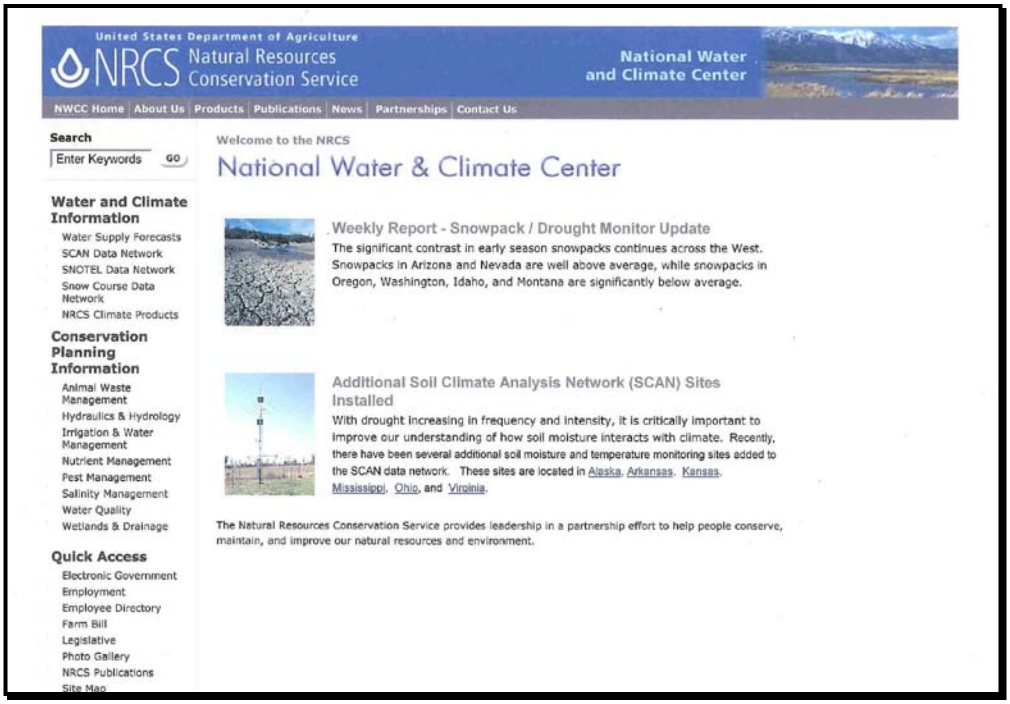
Like a snowpack in a mid-winter storm growing flake by flake, the SNOTEL system accumulates data bit by bit. A massive amount of SNOTEL data can be readily accessed via the Internet, many on the same day they were collected. This section provides lists of common Internet addresses, along with explanations to a couple of key menus. Plus, we've included a bit of guidance for navigating the collection of NRCS sites where SNOTEL, other snow measurement, and water forecast products are available.

As long as you have computer access to the Internet and a World Wide Web browser, you'll be able to quickly and easily get all the snow measurement data you need to supply snow-based lessons for your place of learning. The purpose of this section is to provide enough information on how to get your adopted SNOTEL site's data as well as other potentially useful NRCS data. After a short time's experience at navigating these SNOTEL-related sites, we're sure you'll become more comfortable and be able to explore on your own.

As you'll ascertain soon after you begin to navigate these NRCS websites, the SNOTEL system generates thousands and thousands of measurements across an array of parameters and locations. These data are the basis for many tables, charts, graphs, maps, narratives, and other reports that support water management in the West. What's more, much of the historical record of NRCS snow measurement is also available.

Getting SNOTEL Data and Reports

NRCS National Water and Climate Center: http://www.wcc.nrcs.usda.gov/



All data collected and transmitted by the SNOTEL system, as well as manually collected snow course data, are sent to the NRCS National Water and Climate Center (NWCC). Located in Portland, Oregon, NWCC houses and operates a networked computer group for data storage and analysis. This set-up is referred to as the Central Forecasting System (CFS) within NRCS and by water forecast users. Within CFS's battery of programs, numerous routines and interactive programs for manipulating water supply data are included. These are mainly intended to aid in applying snow survey and water supply forecasting information for conservation in the field.

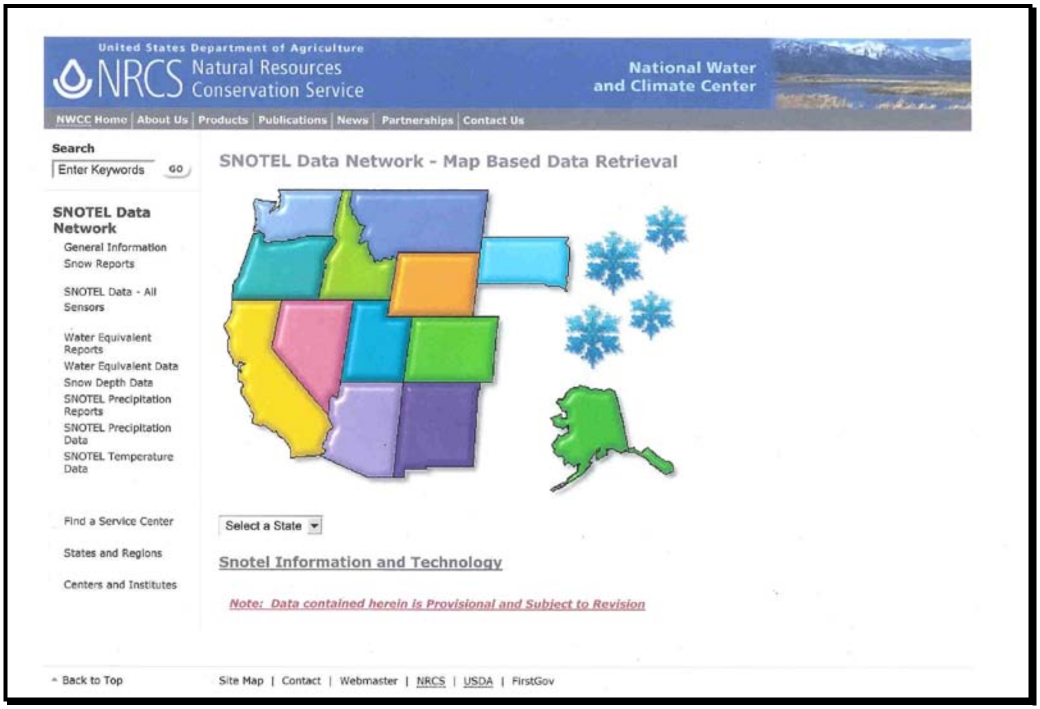
From the homepage of the NWCC, you have one-click access to menus of water supply forecasts, the SNOTEL Data Network, and the Snow Course Data Network. These links are located in the left-hand column under "Water and Climate Information." The link "SNOTEL Data Network" takes you to the page we'd like to discuss next.

Data from Your Adopted SNOTEL Site:

On your first on-line voyage in search of SNOTEL data, a great place to start is "SNOTEL Data Network—Map Based Data Retrieval" within the NRCS National Water and Climate

Center website. This page allows you to access SNOTEL sites via interactive maps of each of the 13 Western states.

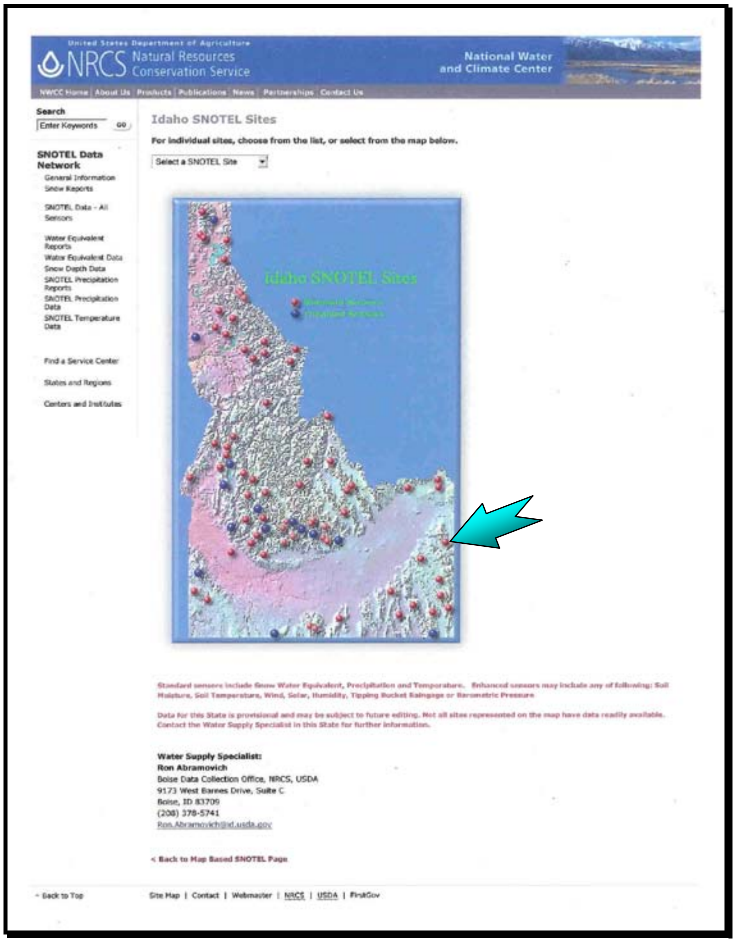
SNOTEL Data Network—Map Based Data Retrieval:
http://www.wcc.nrcs.usda.gov/snotel/



From the “Map Based Data Retrieval” page, you are two selections away from accessing a full page of information on any SNOTEL site. First, place your cursor icon over the map of the state in which the SNOTEL site of interest is located; then click on that state. As an alternative, there is a drop-down menu listing the states just below the colorful map. Selecting a state, by either method, opens a map of that state with map pin graphics noting the locations of SNOTEL sites. Red map pins denote SNOTEL sites with standard sensors; blue map pins denote sites with additional sensors such as soil moisture and soil temperature. A mouse click on top of a map pin opens an information and data retrieval page for the particular SNOTEL site chosen. As before, a drop-down menu of the SNOTEL site names is available. Look for the drop-down menu above the map, if you need it.

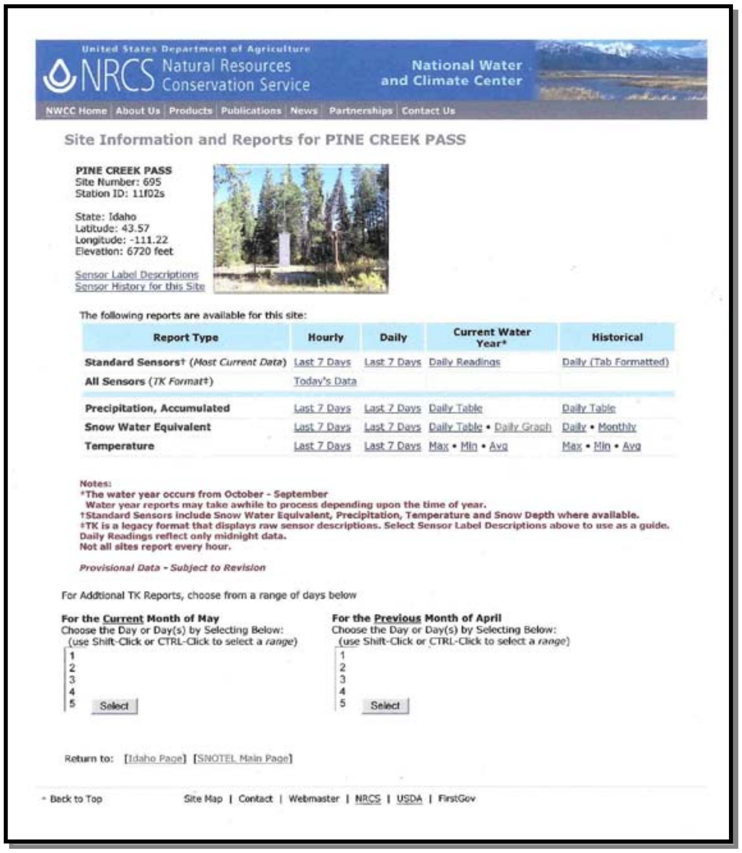
An Example—Two Clicks to an Idaho SNOTEL Site's Information:

Idaho SNOTEL Sites: http://www.wcc.nrcs.usda.gov/snotel/Idaho/idaho.html



From the map of Idaho, we've selected a SNOTEL site to use as an example. (Note the arrow pointing to its location.) This site, named Pine Creek Pass, sits at the watershed divide between the Teton River and south fork of the Snake River, in the Big Hole Mountains of far eastern Idaho, near the border with Wyoming.

Site Information and Reports for PINE CREEK PASS:
http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=695&state=id


United States Department of Agriculture
NRCS Natural Resources Conservation Service
National Water and Climate Center

NWCC Home | About Us | Products | Publications | News | Partnerships | Contact Us

Site Information and Reports for PINE CREEK PASS

PINE CREEK PASS
Site Number: 695
Station ID: 11f02s

State: Idaho
Latitude: 43.57
Longitude: -111.22
Elevation: 6720 feet

Sensor Label Descriptions
Sensor History for this Site

The following reports are available for this site:

Report Type	Hourly	Daily	Current Water Year*	Historical
Standard Sensors† (*Most Current Data*)	Last 7 Days	Last 7 Days	Daily Readings	Daily (Tab Formatted)
All Sensors (*TK Format*‡)	Today's Data			
Precipitation, Accumulated	Last 7 Days	Last 7 Days	Daily Table	Daily Table
Snow Water Equivalent	Last 7 Days	Last 7 Days	Daily Table • Daily Graph	Daily • Monthly
Temperature	Last 7 Days	Last 7 Days	Max • Min • Avg	Max • Min • Avg

Notes:
***The water year occurs from October - September**
Water year reports may take awhile to process depending upon the time of year.
†Standard Sensors include Snow Water Equivalent, Precipitation, Temperature and Snow Depth where available.
‡TK is a legacy format that displays raw sensor descriptions. Select Sensor Label Descriptions above to use as a guide.
Daily Readings reflect only midnight data.
Not all sites report every hour.

Provisional Data - Subject to Revision

For Addtional TK Reports, choose from a range of days below

For the Current Month of May
Choose the Day or Day(s) by Selecting Below:
(use Shift-Click or CTRL-Click to select a *range*)
1
2
3
4
5
Select

For the Previous Month of April
Choose the Day or Day(s) by Selecting Below:
(use Shift-Click or CTRL-Click to select a *range*)
1
2
3
4
5
Select

Return to: [Idaho Page] [SNOTEL Main Page]

Back to Top
Site Map | Contact | Webmaster | NRCS | USDA | FirstGov

Once you call up a "Site Information and Reports" page, you've found the treasure trove of information for your selected SNOTEL site. SNOTEL sites with the standard sensors—Snow Water Equivalent, Precipitation and Temperature—will have a table of available reports like the one pictured above.

From this interactive table, you can call up tabular and graphical from today back through previous years. In the following list, we present the data options available. Those selections denoted with an indigo asterisk (*) are suggested for straightforward classroom use. Other data displays may be more difficult to understand and work with, for your students.

- Standard Sensors

  Hourly—Last 7 Days: A table with a week's worth of hourly sensor readings, with military-style times.

*Daily—Last 7 Days**: A table with a week's worth of midnight sensor readings. This provides an easily-grasp snapshot of the conditions during the week's worth of time just past.

*Current Water Year—Daily Readings**: A table with the current water year's worth of midnight sensor readings. The water year begins on October 1. This display shows the accumulating-then-melting snowpack, the year-to-date overall precipitation, and the correlation of temperature to the presence of snow.

Historical—Daily (Tab Formatted): A second screen will ask you to select a historical year from a drop-down menu. A selection there produces a tab-formatted table of daily sensor readings for an entire water year, 365 lines of data. With such a table you can make date-to-date comparisons.

- All Sensors—Hourly—Today's Data: A table with raw data from today. Because these are displayed in what NRCS calls the "TK Format", they can be more difficult to understand.

- Precipitation, Accumulated

  Hourly—Last 7 Days: Produces the same table as "Standard Sensors—Hourly—Last 7 Days."

  *Daily—Last 7 Days**: Produces the same table as "Standard Sensors—Daily—Last 7 Days."

  Current Water Year—Daily Table: A table of amount of total precipitation, beginning with October 1 in the upper left-hand corner. Each month's daily data are presented in a column. The total is cumulative.

  Historical—Daily Table: Produces a series of tables of amount of total precipitation, beginning with October 1 in the upper left-hand corner of teach separate table. Each month's daily data are presented in a column. The total is cumulative. Averages, maximums, and minimums are given at the bottom of each separate table. To find the year that each table represents, look for the number in its first line circled in this following example:

```
/cdbs/id/snot16  89  Accumulated Precipitation - Since Oct. 1

Station : ID11F02S, PINE CREEK PASS
-------   Unit = inches

day    oct   nov   dec   jan   feb   mar   apr   may   jun   jul
aug   sep
---    ---   ---   ---   ---   ---   ---   ---   ---   ---   ---
---   ---
  1    0.0   0.0   9.2  11.8  16.6  19.3  26.3  27.4  31.1  32.2
32.6  33.8
  2    0.0   0.0   9.3  12.0  16.6  19.5  26.7  27.6  31.1  32.2
32.7  33.8
  3    0.0   0.9   9.4  12.2  16.6  20.1  26.7  27.7  31.1  32.2
32.7  33.8
```

- Snow Water Equivalent

  Hourly—Last 7 Days: Produces the same table as "Standard Sensors—Hourly—Last 7 Days."

  *Daily—Last 7 Days**: Produces the same table as "Standard Sensors—Daily—Last 7 Days."

  *Current Water Year—Daily Table**: A table of amount of SWE (snow water equivalent), beginning with October 1 in the upper left-hand corner. Each month's daily data are presented in a column. The total is cumulative and shows the accumulating-then-melting snowpack.

  *Current Water Year—Daily Graph**: Produces a graph showing the current water year's amount of total precipitation and SWE (snow water equivalent) as well as long-term averages for both values. This display gets to the heart of the important information provided by SNOTEL.

  Just below the graph, you'll find a drop-down menu and two "Select Here" links which will lead you to additional graphs. The drop-down menu allows you to draw a graph from any available year's data. The first "Select Here" link will display data from this year, last year, and long-term averages, for a powerful comparison. The second "Select Here" link produces a series of graphics beginning with the current water year and ending with the first year for which automated data are available.

  Historical—Daily: Produces a series of tables of amount of SWE (snow water equivalent), beginning with October 1 in the upper left-hand corner of each separate table. Each month's daily data are presented in a column.

Averages, maximums, and minimums are given at the bottom of each separate table. To find the year that each table represents, look for the number in its first line, such as circled in the example above under "Precipitation, Accumulated—Historical—Daily Table."

Historical—Monthly: A table of monthly SWE (snow water equivalent) data derived from both automated and manual snow measurements. Though a bit difficult to read, this table can provide insight into the long-term average and variability of snowpack for a location. A helpful key can be found at the very bottom of the table, under "NOTES."

- Temperature

  Hourly—Last 7 Days: Produces the same table as "Standard Sensors—Hourly—Last 7 Days."

  *Daily—Last 7 Days**: Produces the same table as "Standard Sensors—Daily—Last 7 Days."

  Current Water Year—Max: A table of maximum daily temperatures, beginning with October 1 in the upper left-hand corner. Averages, maximums, and minimums, for this table's data, are given at the bottom.

  Current Water Year—Min: A table of minimum daily temperatures, beginning with October 1 in the upper left-hand corner. Averages, maximums, and minimums, for this table's data, are given at the bottom.

  Current Water Year—Avg: A table of average daily temperatures, beginning with October 1 in the upper left-hand corner. Averages, maximums, and minimums, for this table's data, are given at the bottom.

  Historical—Max: Produces a series of tables of maximum daily temperatures, beginning with October 1 in the upper left-hand corner of each separate table. Each month's daily data are presented in a column. Averages, maximums, and minimums are given at the bottom of each separate table. To find the year that each table represents, look for the number in its first line, such as circled in the example above under "Precipitation, Accumulated—Historical—Daily Table."

  Historical—Min: Produces a series of tables of minimum daily temperatures, beginning with October 1 in the upper left-hand corner of each separate table. Each month's daily data are presented in a column. Averages, maximums, and minimums are given at the bottom of each separate table. To find the year that each table represents, look for the number in its first line, such as circled in the example above under "Precipitation, Accumulated—Historical—Daily Table."

Historical—Avg: Produces a series of tables of average daily temperatures, beginning with October 1 in the upper left-hand corner of each separate table. Each month's daily data are presented in a column. Averages, maximums, and minimums are given at the bottom of each separate table. To find the year that each table represents, look for the number in its first line, such as circled in the example above under "Precipitation, Accumulated—Historical—Daily Table."

Please refer to explanations on the website for more details on your particular SNOTEL site. Note that the current month's and the previous month's "All Sensors" reports can be accessed using one of the two selector lists toward the page's bottom. Because these are displayed as raw data (using what NRCS calls the "TK Format"), they are not as easy to comprehend as the other tables and graphs.

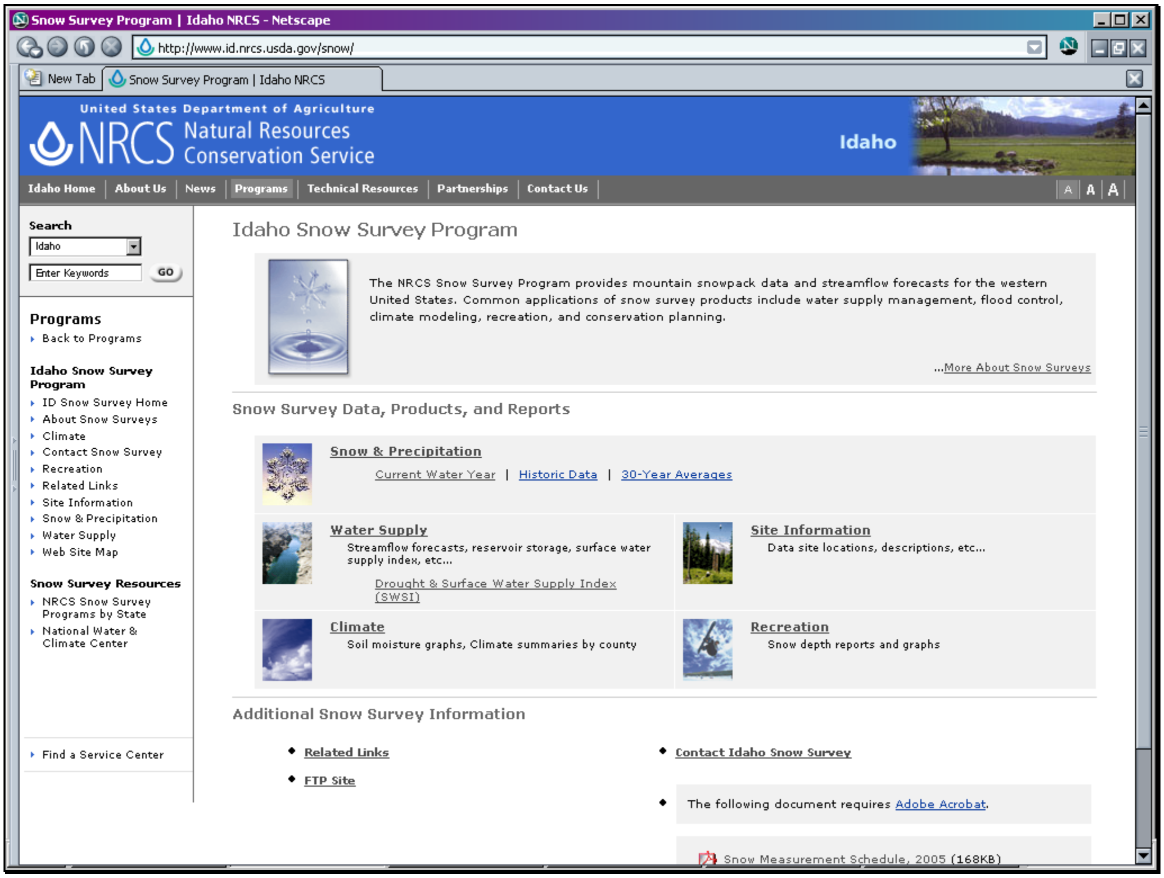
State Snow Survey homepages

Here is a list of links to the homepages for each Western state's snow survey program. From each, you can link to data for that state's SNOTEL sites and some state-specific information, such as the best contact person if you have questions or need more information. If you access a "Site Information and Reports" page for a specific SNOTEL site, you may notice that you're redirected to the NWCC; so, you're receiving the exact same information as you would starting at the "SNOTEL Data Network—Map Based Data Retrieval" page.

Alaska Snow, Water and Climate Services: http://www.ambcs.org/
NRCS **Arizona** Snow Survey: http://www.az.nrcs.usda.gov/snow/
NRCS **California** Snow Survey: http://www.ca.nrcs.usda.gov/snow/
California Cooperative Snow Surveys: http://cdec.water.ca.gov/snow/
NRCS **Colorado** Snow Survey: http://www.co.nrcs.usda.gov/snow/snow-index.htm
NRCS **Idaho** Snow Survey: http://www.id.nrcs.usda.gov/snow/
NRCS **Montana** Snow Survey: http://www.mt.nrcs.usda.gov/snow/
NRCS **Nevada** Snow Programs: http://www.nv.nrcs.usda.gov/snow/index.html
NRCS **New Mexico** Snow Survey: http://www.nm.nrcs.usda.gov/snow/
NRCS **Oregon** Snow Survey: http://www.or.nrcs.usda.gov/snow/index.html
South Dakota SNOTEL Sites:
http://www.wcc.nrcs.usda.gov/snotel/South_Dakota/south_dakota.html (NRCS South Dakota does not maintain a separate page for its two SNOTEL sites)
NRCS **Utah** Snow Survey: http://www.ut.nrcs.usda.gov/snow/
NRCS **Washington** Snow Survey: http://www.wa.nrcs.usda.gov/Snow/

Wyoming Snow Survey (a joint project of NRCS and the Water Resources Data System for the State of Wyoming): http://www.wrds.uwyo.edu/wrds/nrcs/nrcs.html

The NRCS Idaho Snow Survey page is typical of most states' Internet homes.



In the Canadian Rockies, provincial governments operate similar automated snow measuring stations, as well as maintained snow courses, in Alberta, British Columbia, and the Yukon Territory. Below are links for seeing Canadian data. British Columbia's system is displayed in a manner fairly similar to SNOTEL and the NRCS Snow Surveys; Alberta's and Yukon's are not and it will take more perseverance to locate snow measurements within their pages.

British Columbia: http://wlapwww.gov.bc.ca/rfc/index.htm
Alberta: http://www3.gov.ab.ca/env/water/index.cfm
Yukon: http://www.environmentyukon.gov.yk.ca/epa/waterresources.html

Getting Other Snow Measurement Data, Reports and Water Supply Forecasts

Aside from data and reports directly from the SNOTEL system, NRCS also has available a lot of other snow measurement and water supply forecast information. From the NWCC home page (http://www.wcc.nrcs.usda.gov/), you have one-click access to water supply forecasts, Soil Climate Analysis Network (SCAN) information and data, manual snow course information, and climate products. SCAN is a comprehensive soil moisture, soil temperature, and weather/climate collection network, which—incidentally—also uses meteor burst technology to transmit its data.

There are numerous ways to connect with numerous resources via NRCS websites. Again, using the NRCS Idaho Snow Survey (http://www.id.nrcs.usda.gov/snow/) as an example, there are quick links to:

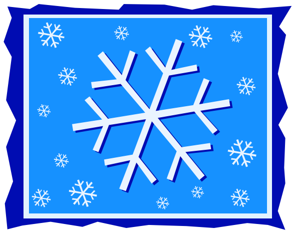
- Climate information: http://www.id.nrcs.usda.gov/snow/climate/
- Recreation information: http://www.id.nrcs.usda.gov/snow/recreation/
- The most recent data and reports: http://www.id.nrcs.usda.gov/snow/data/current.html
- Even more links: http://www.id.nrcs.usda.gov/snow/links/
- Water supply information: http://www.id.nrcs.usda.gov/snow/watersupply/
- A website map: http://www.id.nrcs.usda.gov/snow/sitemap.html
- SNOTEL site information: http://www.id.nrcs.usda.gov/snow/siteinfo/
- Snow and precipitation data: http://www.id.nrcs.usda.gov/snow/data/
- Idaho's Drought and Surface Water Supply Index (SWSI): http://www.id.nrcs.usda.gov/snow/watersupply/swsi-main.html—The SWSI is being relied on more and more by water managers, as a predictive indicator of the surface water available in a basin compared to historic supply. SWSI is calculated by summing the two major sources of irrigation water supply: reservoir carryover and spring/summer runoff. These two sources, current reservoir storage and April-September streamflow, are analyzed together when determining the total surface water supply available for the season. SWSI uses probabilities to normalize the magnitude of water supply variability between basins. SWSI values range from +4.1 (extremely wet) to -4.1 (extremely dry). A SWSI value of 0.0 indicates a median water supply as compared to historic occurrences. NRCS calculates the SWSI by adding the estimated or actual March 31 reservoir storage to the April-September streamflow forecast. This value is then used in the results table to determine the non-exceedance probability and corresponding SWSI value.
  The SWSI can also be used to determine if the current year will have a shortage or surplus of water for the irrigation season. For example, an adequate water supply for Magic Reservoir water users is around 270,000 to 290,000 acre-feet. This adequate water supply equals a SWSI value of -1.2. When the SWSI value is less than -1.2, water supply shortages may be expected. Since the SWSI is based on projected streamflow values, the SWSI value may change from month to month as

the projected streamflow forecasts change. All five exceedance streamflow forecasts are included in the results table: the 90%, 70%, 50% (Most Probable), 30%, and 10% Chance of Exceeding Forecast. These additional forecasts are included to statistically illustrate the possible outcomes based upon the current streamflow forecasts.

As a final tip in finding the SNOTEL and NRCS information you seek, most NRCS websites contain a "Search" function. Access to this built-in search engine is available, on most NRCS pages, in the gray-shaded frame on the left side of the browser window. To use this function, enter a keyword or two related to whatever it is you're trying to find, designate from the drop-down menu the extend of websites you wish to search (*i.e.*, just the state whose website you're within, all of NRCS, or more broadly across USDA), and then click "Go" or hit return. NRCS search engines are powered by Google; you may also be able to use the main Google search engine (http://www.google.com/), or other search engine of your choice, successfully.

Section D

Understanding SNOTEL Data



Throughout the West, water managers rely on SNOTEL data for informing their decisions. Students can be guided through interpretations of SNOTEL data in a manner similar to what professionals do. Systematic observations over a long term give teachers opportunities to structure projects leading to student-generated conclusions, real-world recommendations, and evidence-supported predictions. As such, interpreting data is one of the key skills educators attempt to build within their learners. Without interpretation, data remains a loose collection of observations without much context and with little meaning.

For you and your students, the Adopt-a-SNOTEL Site Program can provide an opportunity to use the computer in a real-world setting. Computer operations are an exciting part of the modern learning experience, as well as an integral part of the workday for many professionals, including NRCS scientists. Through the text and illustrations in Sections C and D of this curriculum guide, we've tried to make for smooth on-line operations, so that students can enjoy the excitement of monitoring the conditions at their site without too many computer hassles. While daily access may be interesting during storms and periods of rapid melting, weekly access has been found to be sufficient for periods of more routine weather.

In the previous section, we pointed you toward "Site Information and Reports" pages for SNOTEL sites as part of the NRCS Internet presence. These pages are built using a standard template, the objective being that similarity makes navigation easier. A page, based on the standard look, is available for each operating SNOTEL site and can be your source for lots of data from any selected site.

This section of *Adopt-a-SNOTEL Teacher's Guide* provides details about what you're seeing when you examine tables and graphs for a SNOTEL site. We focus on highlighted data displays—marked in the previous section with indigo asterisks—which are less difficult to comprehend, provide a lot of potential information, and fit readily into classroom needs.

From our explanation of a sample “Site Information and Reports” web page for a particular SNOTEL site named Pine Creek Pass (pp. 31-35), you can see that the suggested tables and graphs are:

- Standard Sensors—Daily—Last 7 Days
- Standard Sensors—Current Water Year—Daily Readings
- Precipitation, Accumulated—Daily—Last 7 Days (same as “Standard Sensors—Daily—Last 7 Days”)
- Snow Water Equivalent—Daily—Last 7 Days (same as “Standard Sensors—Daily—Last 7 Days”)
- Snow Water Equivalent—Current Water Year—Daily Table
- Snow Water Equivalent—Current Water Year—Daily Graph
- Temperature—Daily—Last 7 Days (same as “Standard Sensors—Daily—Last 7 Days”)

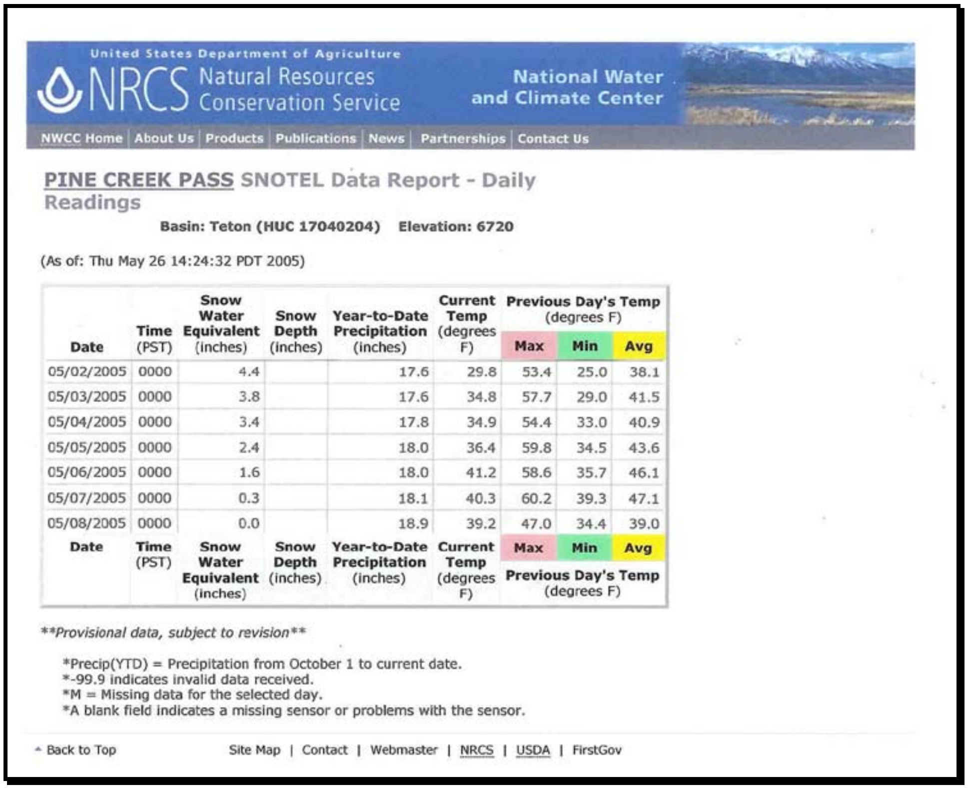
Now, again continuing to use Pine Creek Pass SNOTEL site as an example, we have found and reproduced data displays from each of these selections below, along with short explanations. We hope this section can serve as a reference for your understanding of SNOTEL data. You may not even need it, but if you do, it is here!

What the Data Displays Can Tell You

The tables and graphs shown here can be accessed via the “Site Information and Reports for PINE CREEK PASS” page. Point you web-browser to:
http://www.wcc.nrcs.usda.gov/snotel/snotel.pl?sitenum=695&state=id

Standard Sensors—Daily—Last 7 Days:

http://www.wcc.nrcs.usda.gov/nwcc/sntl-data0000.jsp?site=695&days=7&state=ID



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PINE CREEK PASS SNOTEL Data Report - Daily Readings

Basin: Teton (HUC 17040204) Elevation: 6720

(As of: Thu May 26 14:24:32 PDT 2005)

Date	Time (PST)	Snow Water Equivalent (inches)	Snow Depth (inches)	Year-to-Date Precipitation (inches)	Current Temp (degrees F)	Previous Day's Temp (degrees F) Max	Min	Avg
05/02/2005	0000	4.4		17.6	29.8	53.4	25.0	38.1
05/03/2005	0000	3.8		17.6	34.8	57.7	29.0	41.5
05/04/2005	0000	3.4		17.8	34.9	54.4	33.0	40.9
05/05/2005	0000	2.4		18.0	36.4	59.8	34.5	43.6
05/06/2005	0000	1.6		18.0	41.2	58.6	35.7	46.1
05/07/2005	0000	0.3		18.1	40.3	60.2	39.3	47.1
05/08/2005	0000	0.0		18.9	39.2	47.0	34.4	39.0
Date	Time (PST)	Snow Water Equivalent (inches)	Snow Depth (inches)	Year-to-Date Precipitation (inches)	Current Temp (degrees F)	Max	Min	Avg
						Previous Day's Temp (degrees F)		

Provisional data, subject to revision

*Precip(YTD) = Precipitation from October 1 to current date.
*-99.9 indicates invalid data received.
*M = Missing data for the selected day.
*A blank field indicates a missing sensor or problems with the sensor.

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This table summarizes a week's worth of midnight readings (which is 1 a.m. for the Mountain Time Zone, as the main computer hub is in Portland, OR, in the Pacific Time Zone). Columns of the table are labeled, top and bottom, with their parameter and units. Following Date and Time columns are:

- Snow Water Equivalent—This reading is provided by the displacement of antifreeze from the snow pillow. Note that, for the week shown, the snowpack melted away.
- Snow Depth—Tells how deep snow is on the pillow and helps to provide an indication of snow density. This site just received a snow depth sensor in the summer of 2005. As of 2005, approximately half of the SNOTEL sites had snow depth sensors.
- Year-to-Date Precipitation—A running total of snow, rain, and other forms of precipitation for the current water year. From the last two data, you can deduce that it was probably raining at the site; this is because the final 0.3 inch of snow water melted, while 0.8 inch of precipitation fell.
- Current Temp—Temperature at the time of reporting.

- **Previous Day's Temp**—Divided into three sub-columns, for **Max** (maximum), **Min** (minimum), and **Avg** (average).

As you can see, this table provides a concise snapshot of the conditions at the site during the last week.

Note that this table is identical to that displayed by selecting any of these:

- Standard Sensors—Daily—Last 7 Days
- Precipitation, Accumulated—Daily—Last 7 Days
- Snow Water Equivalent—Daily—Last 7 Days
- Temperature—Daily—Last 7 Days

Standard Sensors—Current Water Year—Daily Readings:

http://www.wcc.nrcs.usda.gov/nwcc/sntl-data0000.jsp?site=695&days=0&state=ID

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PINE CREEK PASS SNOTEL Data Report - Daily Readings

Basin: Teton (HUC 17040204) Elevation: 6720

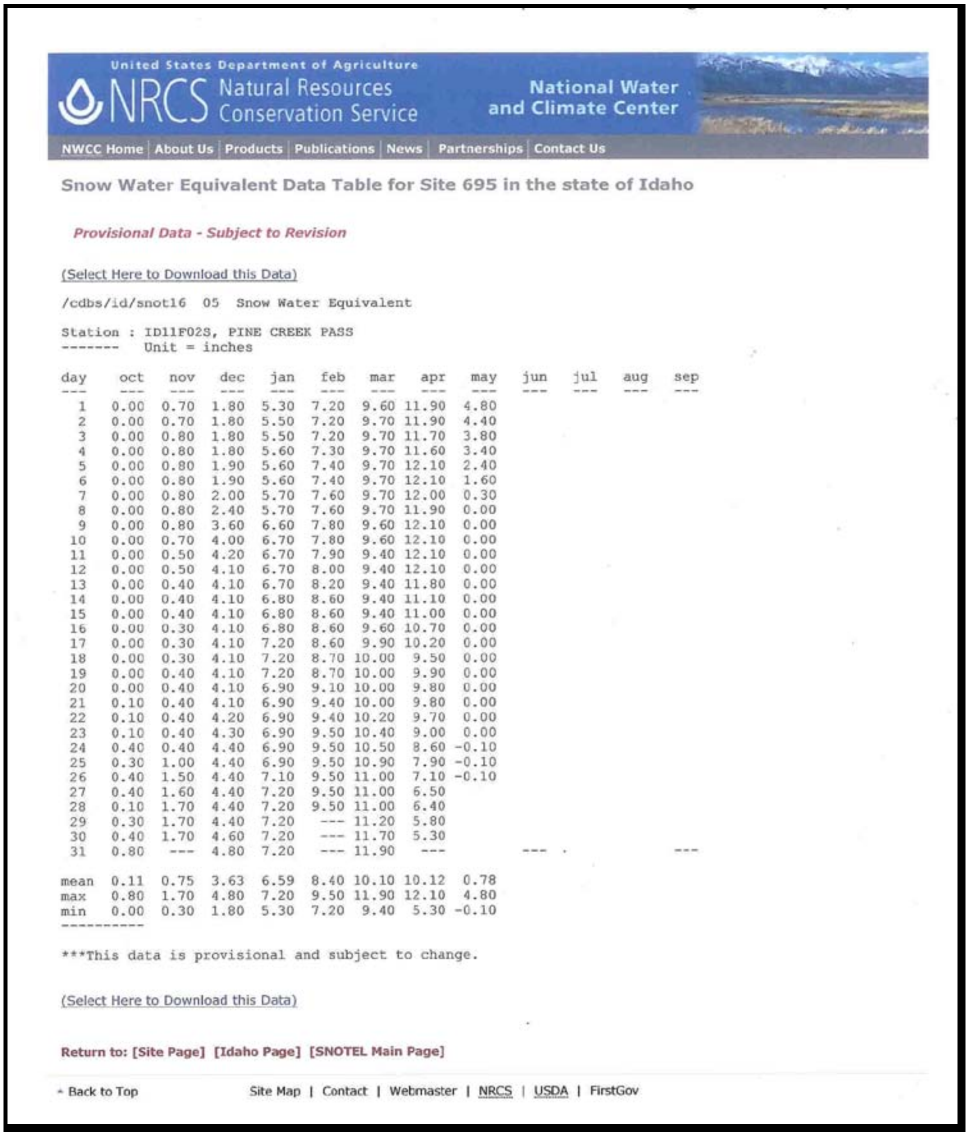
(As of: Thu May 26 14:29:18 PDT 2005)

Date	Time (PST)	Snow Water Equivalent (inches)	Snow Depth (inches)	Year-to-Date Precipitation (inches)	Current Temp (degrees F)	Previous Day's Temp (degrees F)		
						Max	Min	Avg
10/01/2004	0000	0.0		0.0	37.0	57.4	36.7	45.1
10/02/2004	0000	0.0		0.0	40.2	60.3	35.7	45.2
10/03/2004	0000	0.0		0.0	42.7	64.4	38.5	48.5
10/04/2004	0000	0.0		0.1	41.1	68.4	38.6	48.5
10/05/2004	0000	0.0		0.1	39.5	66.1	38.6	48.1
10/06/2004	0000	0.0		0.1	40.0	66.2	38.1	47.7
10/07/2004	0000	0.0		0.1	44.3	67.3	37.0	47.7
10/08/2004	0000	0.0		0.1	41.2	67.2	40.3	49.4
10/09/2004	0000	0.0		0.1	54.3	70.1	38.7	53.2
10/10/2004	0000	0.0		0.1	41.5	67.5	41.5	55.5
10/11/2004	0000	0.0		0.1	36.2	48.3	36.2	41.2
10/12/2004	0000	0.0		0.1	39.7	63.2	34.0	45.4
10/13/2004	0000	0.0		0.1	34.7	55.4	34.0	43.3
10/14/2004	0000	0.0		0.1	36.2	58.7	29.1	40.8
10/15/2004	0000	0.0		0.1	44.7	61.4	33.9	45.3
10/16/2004	0000	0.0		0.2	49.4	60.1	37.5	48.2
10/17/2004	0000	0.0		0.2	42.9	62.1	42.6	51.5
10/18/2004	0000	0.0		0.2	43.1	57.9	37.9	47.1
10/19/2004	0000	0.0		0.5	29.1	42.7	29.1	33.8
10/20/2004	0000	0.0		0.5	38.9	46.4	29.0	36.7
10/21/2004	0000	0.1		1.1	35.0	40.2	34.6	38.4
10/22/2004	0000	0.1		1.2	31.0	42.0	31.0	35.5
10/23/2004	0000	0.1		1.3	34.6	39.7	27.2	33.5

This table has one row of data for every day of the current water year. So, on October 1 of any year, the table would generate with just one line. On September 30 of a year, you'll get 365 lines (366 on leap years) of data. The column headings are the same as "Standard Sensors—Daily—Last 7 Days." Within this table, you can see evidence of accumulating snowpack, melting snowpack, total precipitation, their relationship to each other, and—most importantly—their relationship to air temperature.

Snow Water Equivalent—Current Water Year—Daily Table:

http://www.wcc.nrcs.usda.gov/snotel/snotelday2.pl?site=695&station=11f02s&state=id&report=swe



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Snow Water Equivalent Data Table for Site 695 in the state of Idaho

Provisional Data - Subject to Revision

(Select Here to Download this Data)

/cdbs/id/snot16 05 Snow Water Equivalent

Station : ID11F02S, PINE CREEK PASS
-------- Unit = inches

day	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
1	0.00	0.70	1.80	5.30	7.20	9.60	11.90	4.80				
2	0.00	0.70	1.80	5.50	7.20	9.70	11.90	4.40				
3	0.00	0.80	1.80	5.50	7.20	9.70	11.70	3.80				
4	0.00	0.80	1.80	5.60	7.30	9.70	11.60	3.40				
5	0.00	0.80	1.90	5.60	7.40	9.70	12.10	2.40				
6	0.00	0.80	1.90	5.60	7.40	9.70	12.10	1.60				
7	0.00	0.80	2.00	5.70	7.60	9.70	12.00	0.30				
8	0.00	0.80	2.40	5.70	7.60	9.70	11.90	0.00				
9	0.00	0.80	3.60	6.60	7.80	9.60	12.10	0.00				
10	0.00	0.70	4.00	6.70	7.80	9.60	12.10	0.00				
11	0.00	0.50	4.20	6.70	7.90	9.40	12.10	0.00				
12	0.00	0.50	4.10	6.70	8.00	9.40	12.10	0.00				
13	0.00	0.40	4.10	6.70	8.20	9.40	11.80	0.00				
14	0.00	0.40	4.10	6.80	8.60	9.40	11.10	0.00				
15	0.00	0.40	4.10	6.80	8.60	9.40	11.00	0.00				
16	0.00	0.30	4.10	6.80	8.60	9.60	10.70	0.00				
17	0.00	0.30	4.10	7.20	8.60	9.90	10.20	0.00				
18	0.00	0.30	4.10	7.20	8.70	10.00	9.50	0.00				
19	0.00	0.40	4.10	7.20	8.70	10.00	9.90	0.00				
20	0.00	0.40	4.10	6.90	9.10	10.00	9.80	0.00				
21	0.10	0.40	4.10	6.90	9.40	10.00	9.80	0.00				
22	0.10	0.40	4.20	6.90	9.40	10.20	9.70	0.00				
23	0.10	0.40	4.30	6.90	9.50	10.40	9.00	0.00				
24	0.40	0.40	4.40	6.90	9.50	10.50	8.60	-0.10				
25	0.30	1.00	4.40	6.90	9.50	10.90	7.90	-0.10				
26	0.40	1.50	4.40	7.10	9.50	11.00	7.10	-0.10				
27	0.40	1.60	4.40	7.20	9.50	11.00	6.50					
28	0.10	1.70	4.40	7.20	9.50	11.00	6.40					
29	0.30	1.70	4.40	7.20	---	11.20	5.80					
30	0.40	1.70	4.60	7.20	---	11.70	5.30					
31	0.80	---	4.80	7.20	---	11.90	---		---			---
mean	0.11	0.75	3.63	6.59	8.40	10.10	10.12	0.78				
max	0.80	1.70	4.80	7.20	9.50	11.90	12.10	4.80				
min	0.00	0.30	1.80	5.30	7.20	9.40	5.30	-0.10				

***This data is provisional and subject to change.

(Select Here to Download this Data)

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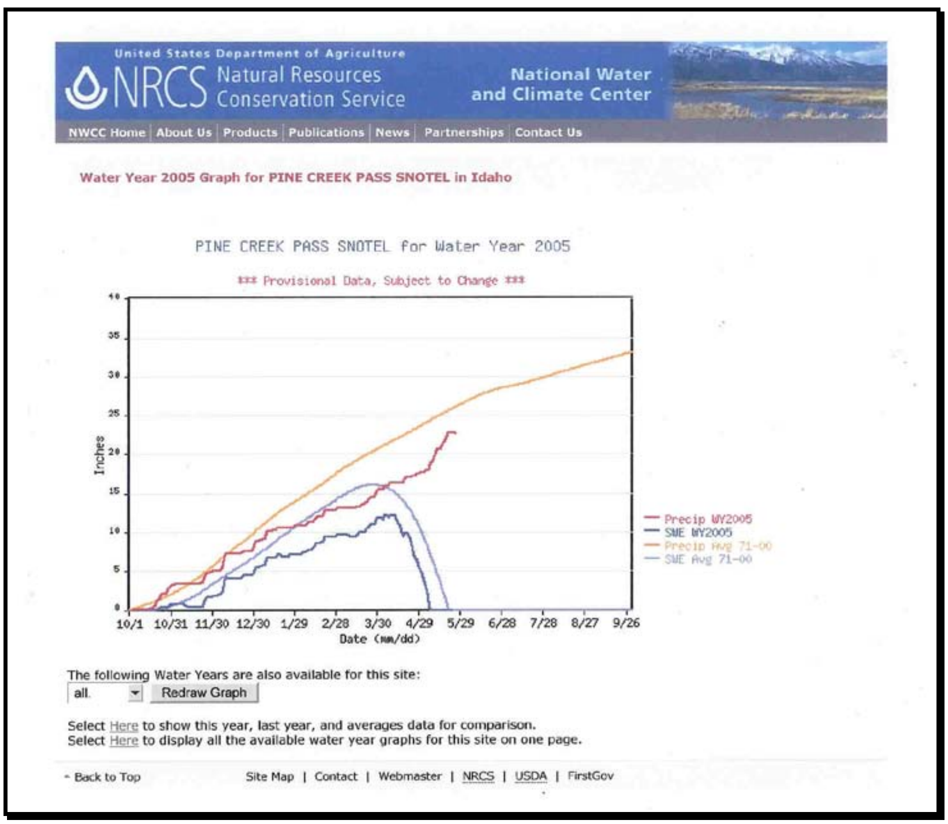
The measurements from the snow pillow, translated into equivalent inches of standing water in the snowpack or rainwater, form the basis for this table. As record of the current water year, it begins on October 1. Each month has a column; each day, a row. So, reading the data chronologically requires going down the first column, then to the top of the next. A scan of the table shows how the snowpack for the 2005 water year began accumulating on October 21, 2004. It peaked in April at 12.10 inches and melted away by May 8. At the bottom of the table, you can find automatically calculated means, maximums, and minimums for each month. Note that negative readings (such as -0.10 on the last three days of May shown) will be corrected to 0.00 when the data are verified. Real-time data will have errors and is edited and re-posted. Teachers and students will occasionally see bad data (in the real-time mode) and have to deal with it the same manner as NRCS hydrologists and decision-makers do—by estimating the data or waiting until more data are available to verify a decision. Recall that hourly SNOTEL data become available. Notwithstanding, this kind of table provides a clear numerical picture of growth and decline of a snowpack at each site.

Snow Water Equivalent—Current Water Year—Daily Graph:

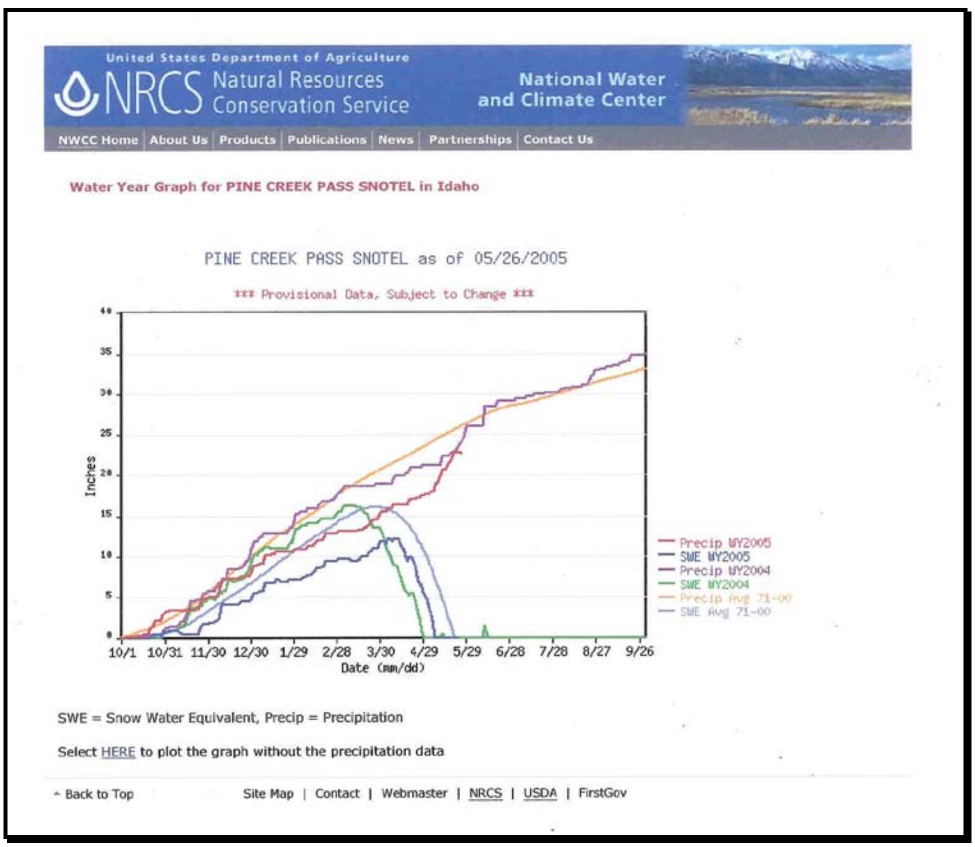
http://www.wcc.nrcs.usda.gov/cgibin/wygraph-multi.pl?state=ID&wateryear=2005&stationidname=11f02s-PINE%20CREEK%20PASS



For a graphic display of growth and reduction of a snowpack at a SNOTEL site, select this type of display. Selection of "Snow Water Equivalent—Current Water Year—Daily Graph" generates a lined chart, with four curves of data across a water year. The ordinate/Y-axis measures water in inches. The abscissa/X-axis shows dates for the water year. Together, they allow the relationship of both snowpack to time of year as well as snowpack's contribution to a running total of precipitation to be seen. As noted by the legend on the right of the graph, the four lines correspond to total precipitation for the current water year ("Precip WY2005"), snow water equivalent for the current water year ("SWE WY2005"), 30-year average total precipitation ("Precip Avg 71-00"), and 30-year average snow water equivalent ("SWE Avg 71-00"). The averages shown are for the particular SNOTEL site being viewed and are helpful in seeing how the current year compares to what is often called "normal."

Snow Water Equivalent—Current Water Year—Daily Graph, then "Select Here to show this year, last year, and averages data for comparison.":

http://www.wcc.nrcs.usda.gov/cgibin/wygraph.pl?stationidname=11f02s-PINE%20CREEK%20PASS&state=ID



Adding data from the previous water year deepens the context of the snowpack information. This enriched presentation allows for quick visual comparison between this year and last. In our example, snowpack for water year 2004 was deeper, but melted earlier. And, there was an early June snowfall that resulted in accumulated snow for a couple of days. Also of note for 2004, the snowpack reached its peak almost a month earlier. The beginning of April is the time of average peak for snowpacks.

When viewing "Snow Water Equivalent—Current Water Year—Daily Graph" page, you can see there are other options available for redrawing the graph using data for other years. From the drop-down menu next to the "Redraw Graph" button, you can select any year for which data are available. Similarly, a click on the link within the "Select Here to display all the available water year graphs for this site on one page" text will produce a whole series of graphs—excellent material for comparison and data interpretation activities.

Importance of Accuracy

NRCS snow survey personnel have this notice in all of their field collection notebooks:

"Accuracy is essential. A small error in snow sampling can produce a large error in the water supply forecast. An error in measurement affects not only current reports but also analyses of archival data in future years."

This is a sound message to give to your students as well.

Interpreting Streamflow Forecasts

As you and your learners gain skill in interpreting SNOTEL data, you might want to move into working with water supply forecasts. Water supply forecasting is the science and art of predicting the volume of water that will flow past a given point on a stream during a specific period of time. NRCS, in cooperation with the National Weather Service, provides seasonal water supply forecasts for more than 600 points along streams in the Western United States.

So, streamflow forecasts are a key type of water supply prediction. These forecasts reflect current conditions and project amount of water feeding into streams during spring and summer. Streamflow forecasts are for natural, unregulated flows and usually improve in accuracy as we near the snowpack peak in early April.

Each month, five forecasts are issued for each forecast point and each forecast period. Unless otherwise specified, all streamflow forecasts are for streamflow volumes that would occur naturally without any upstream influences. If they are to use the information correctly when making operational decisions, water users need to understand what the different forecasts represent. The following is an explanation of each of the forecasts.

Most Probable (50 Percent Chance of Exceeding) Forecast:

This forecast is the best estimate of streamflow volume that can be produced given current conditions and based on the outcome of similar past situations. There is a 50 percent chance the streamflow volume will exceed this forecast value. Likewise, there is a 50 percent chance the streamflow volume will be less than this forecast value.

The most probable forecast will rarely be exactly right, due to errors and unknowns resulting from future weather conditions and the forecast equation itself. This does not mean users should not use the most probable forecast. Rather, it means they need to evaluate existing circumstances and determine the amount of risk they are willing to take by accepting this forecast value.

To Decrease the Chance of Having Too Little Water:

If users want to make sure there is enough water available for their operations, they might determine a 50 percent chance of the streamflow volume being lower than the most probable forecast is too much risk to take. To reduce the risk of not having enough water available during the forecast period, users can base their operational decisions on one of the forecasts with a greater chance of being exceeded (or possibly some point in-between). These include:

- 70 Percent Chance of Exceeding Forecast—There is a 70 percent chance the streamflow volume will exceed this forecast value. There is a 30 percent chance the streamflow volume will be less than this forecast value.
- 90 Percent Chance of Exceeding Forecast —There is a 90 percent chance the streamflow volume will exceed this forecast value. There is a 10 percent chance the streamflow volume will be less than this forecast value.

To Decrease the Chance of Having Too Much Water:

If users want to make sure they don't have too much water, they might determine a 50 percent chance of the streamflow being higher than the most probable forecast is too much of a risk to take. To reduce the risk of having too much water available during the forecast period, users can base their operational decisions on one of the forecasts with a smaller chance of being exceeded. These include:

- 30 Percent Chance of Exceeding Forecast—There is a 30 percent chance the streamflow volume will exceed this forecast value. There is a 70 percent chance the streamflow volume will be less than this forecast value.

- 10 Percent Chance of Exceeding Forecast—There is a 10 percent chance the streamflow volume will exceed this forecast value. There is a 90 percent chance the streamflow volume will be less than this forecast value.

Using the forecasts—An example:
Refer to the table of "Streamflow Forecasts" for the upper Humboldt River in northern Nevada, below, for the data which are the basis for these explanations:

- Using the Most Probable Forecast—Users can reasonably expect 16,000 acre-feet to flow past the gauging station on the Mary's River near Deeth between May 1 and July 31.
- Using the Higher Exceedance Forecasts—If users anticipate a somewhat drier trend in the future (monthly and seasonal weather outlooks are available from the National Weather Service), or if they are operating at a level where an unexpected shortage of water could cause problems, they might want to plan on receiving only 11,300 acre-feet (from the 70 percent chance of exceeding forecast). In seven out of ten years with similar conditions, streamflow volumes will exceed the 11,300 acre-foot forecast.
- If users anticipate extremely dry conditions for the remainder of the season, or if they determine the risk of using the 70 percent chance of exceeding forecast is too great, then they might plan on receiving only 4,500 acre-feet (from the 90 percent chance of exceeding forecast). Nine out of ten years with similar conditions, streamflow volumes will exceed the 4,500 acre-foot forecast.
- Using the Lower Exceedance Forecasts—If users expect wetter future conditions, or if the chance that five out of every ten years with similar conditions would produce streamflow volumes greater than 16,000 acre-feet was more than they would like to risk, they might plan on receiving 21,000 acre-feet (from the 30 percent chance of exceeding forecast) to minimize potential flooding problems. Three out of ten years with similar conditions, streamflows will exceed the 21,000 acre-foot forecast.
- In years when users expect extremely wet conditions for the remainder of the season and the threat of severe flooding and downstream damage exists, they might choose to use the 28,000 acre-foot (10 percent chance of exceeding) forecast for their water management operations. Streamflow volumes will exceed this level only one year out of ten.

Streamflow Forecasts

UPPER HUMBOLDT RIVER BASIN Streamflow Forecasts - May 1, 2003

Forecast Pt	<==== Drier === Future Conditions === Wetter ====>						
	============ Chance of Exceeding * ===========						
Forecast	90%	70%	50% (Most Prob)		30%	10%	30 Yr Avg
Period	(1000AF)	(1000AF)	(1000AF)	(% AVG.)	(1000AF)	(1000AF)	(1000AF)
MARY'S R nr Deeth, Nv							
APR-JUL	12.3	18.7	23	59	27	34	39
MAY-JUL	4.5	11.3	16.0	55	21	28	29
LAMOILLE CK nr Lamoille, Nv							
APR-JUL	13.7	17.4	20	67	23	26	30
MAY-JUL	11.6	15.4	18.0	64	21	24	28
N F HUMBOLDT R at Devils Gate							
APR-JUL	5.1	11.0	15.0	44	19.0	25	34
MAY-JUL	1.7	7.2	11.0	50	14.8	20	22
HUMBOLDT R nr Elko, Nv							
APR-JUL	38	69	90	58	111	142	154
MAY-JUL	34	62	82	69	102	130	119
S FORK HUMBOLDT R at Dixie							
APR-JUL	7.2	39	60	79	81	113	76
MAY-JUL			54	82			66
HUMBOLDT R nr Carlin, Nv							
APR-JUL	96	125	145	61	165	194	238
MAY-JUL	85	115	135	71	155	185	189
HUMBOLDT R at Palisades, Nv							
APR-JUL	57	109	145	58	181	233	250
MAY-JUL	53	102	135	69	168	217	195

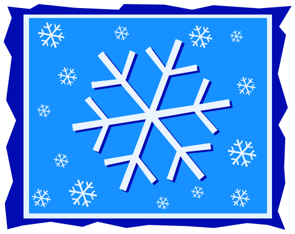
* 90%, 70%, 30%, and 10% chances of exceeding are the probabilities that the actual flow will exceed the volumes in the table.

(1) - The values listed under the 10% and 90% Change of Exceeding are actually 5% and 95% exceedance levels.

(2) - The value is natural flow - actual flow may be affected by upstream water management.

Section E

Adopt-a-SNOTEL Activities



This section contains four classroom activities about snow, measuring snow, and forecasting water supply. These Adopt-a-SNOTEL Site Program lesson plans use data available through NRCS Internet pages and also allow you to take your own readings, in some instances. The activities are grouped so they might form a multidisciplinary unit. They also can stand alone, or be reworked to meet your specific needs. Extension ideas are also included. We encourage you to adapt and to make these activities your own, as you know your needs best.

One task we have not attempted is to dictate these activities to certain grade levels. We trust in your abilities to adjust as needed for different ages.

These plans are meant to get your class started on some activities using SNOTEL data. We have developed lesson plans, with flexibility, usability, and integration within a larger curriculum in mind. See the next section for pointers on additional educational resources about snow, measuring snow, and water management.

The activities here are:

Do You Know Snow?

Summary

Kids *think* about snow, then *read* about snow, then *reflect* on what they understand, and finally *report* their findings.

Objectives

Your students will be able to…

…state their current knowledge about snow and express options for seeking more

…comprehend basic information on snow ecology

Materials and Set Up

Thinking Log for each student (For elementary, use the front of a single sheet of paper lined so as to divide into fourths. For middle ages, a single sheet with both the front and back divided into half by a line. For high schoolers, try four separate sheets.)

White board, easel paper or other means of collecting whole group notes

Copies of the selected reading, either *Who Lives in the Snow?*, "The Bustle Below," or another of your choosing.

Highlighters, pencils and/or pens

A comfortable setting suitable for whole group discussion, small group discussion, and individual reading and reflection. Small groups of 2-6 are suggested.

Procedure

Warm Up

K-W-H-L on S-N-O-W—By facilitating a discussion of your student's knowledge and attitudes about snow, you'll be able to pre-assess their abilities vis-à-vis your plans with Adopt-a-SNOTEL Site activities and to establish a student-centered focus for learning about this topic.

If you aren't familiar with the K-W-H-L process, it's a guided brainstorming designed to explore existing knowledge base and generate paths of inquiry for your group of learners. Students respond to what they Know already, what they Wonder or Want to know, and How they might go about learning about the topic at hand. Following a period of investigation of study materials—in this activity's case, we provide a selected reading—they reflect and report on what has been Learned, both individually and by the group.

1. Hand out or have the students each prepare a Thinking Log. This will become a record of their K-W-H-L on S-N-O-W. Label the sections:
   - K—What I know about snow
   - W—What I wonder about snow/What I want to know about snow
   - H—How I might learn more about snow
   - L—What I learned about snow

   As they do this, summarize the K-W-H-L process, explaining what each section involves. Tell students that during this first portion of the activity, they'll focus on the first two initials: K and W.

2. Briefly introduce the topic of snow, the need to measure snowpack in the West, and the role of water supply forecasting in your community. Quickly turn this introduction into an invitation to share. Allow discussion to flow, with your guidance as facilitator. You may wish to capture collective thinking with notes on a white board, easel paper, etc.

3. After gaining adequate coverage for Know and Wonder, try to elicit some early ideas for the third section: How might you learn more about snow, measuring snow, and predicting water supply?

4. Save the Thinking Logs and collective notes, as you move into the "Read and Reflect" activity.

Activity

Read and Reflect—Introduce and distribute copies of the reading you have selected. You can choose to provide individual copies, one copy per group, or make the reading a whole group activity. Encourage students to record ideas, facts, and questions using their Thinking Log. Highlighters can help students to note main points in the reading.

NB: Two reading selections follow. Both accurately and intriguingly introduce snow ecology.

- The first, *Who Lives in the Snow?* by Jennifer Berry Jones and illustrated by Consie Powell, is for elementary aged readers. (Used with permission from Roberts Rinehart and © 2001 by Jennifer Berry Jones and Consie Powell.)

- Second, "The Bustle Below" by Ted Kerasote, originially appeared in *Audubon*, January-February 2000, pp. 20-25, and is reproduced with permission (©1999 by National Audubon Society). It is meant for secondary readers.

1. Read the selection, using a method suitable for your group, from individual time to teacher reading.

2. Assist students with any difficulties—new words, difficult concepts, etc. These readings were selected to provide some challenge.

3. Ask groups to identify key ideas, facts, and questions to add to the Thinking Logs. Identify the section—K, W, or H—to which comments belong. Encourage students to hypothesize on methods of seeking answers to questions they have.

Wrap Up

Snow Report—Invite individuals and small groups to share their learnings with the whole group. An informal report can be given immediately following reading and reflection. A more structured presentation or even performance would require more preparation. Be sure to have clear expectations if a more polished report is assigned.

Summarize, record, and post Thinking Logs to show the results of the K-W-H-L process. Note especially opportunities for application of this activity to further SNOTEL investigations. Unanswered questions are the basis of scientific inquiry!

Assessment

Have students complete the L section, putting what they learned from this activity in writing. This might be done at the end of the "Read and Reflect" or might take place later, after further investigation.

Extensions

- Use the reading to practice paraphrasing and summarizing. Summarizing covers the main points of a piece of writing, but results in a new piece of writing a great deal shorter than the original. Paraphrasing differs, taking excerpts from a piece of writing and putting them in different words while retaining the same meaning and having similar length.

- Find a snow-covered meadow and explore. Seek real ecological examples from the subnivean zone. Observe tracks and seek signs of life. Record observations with field notes and sketches.

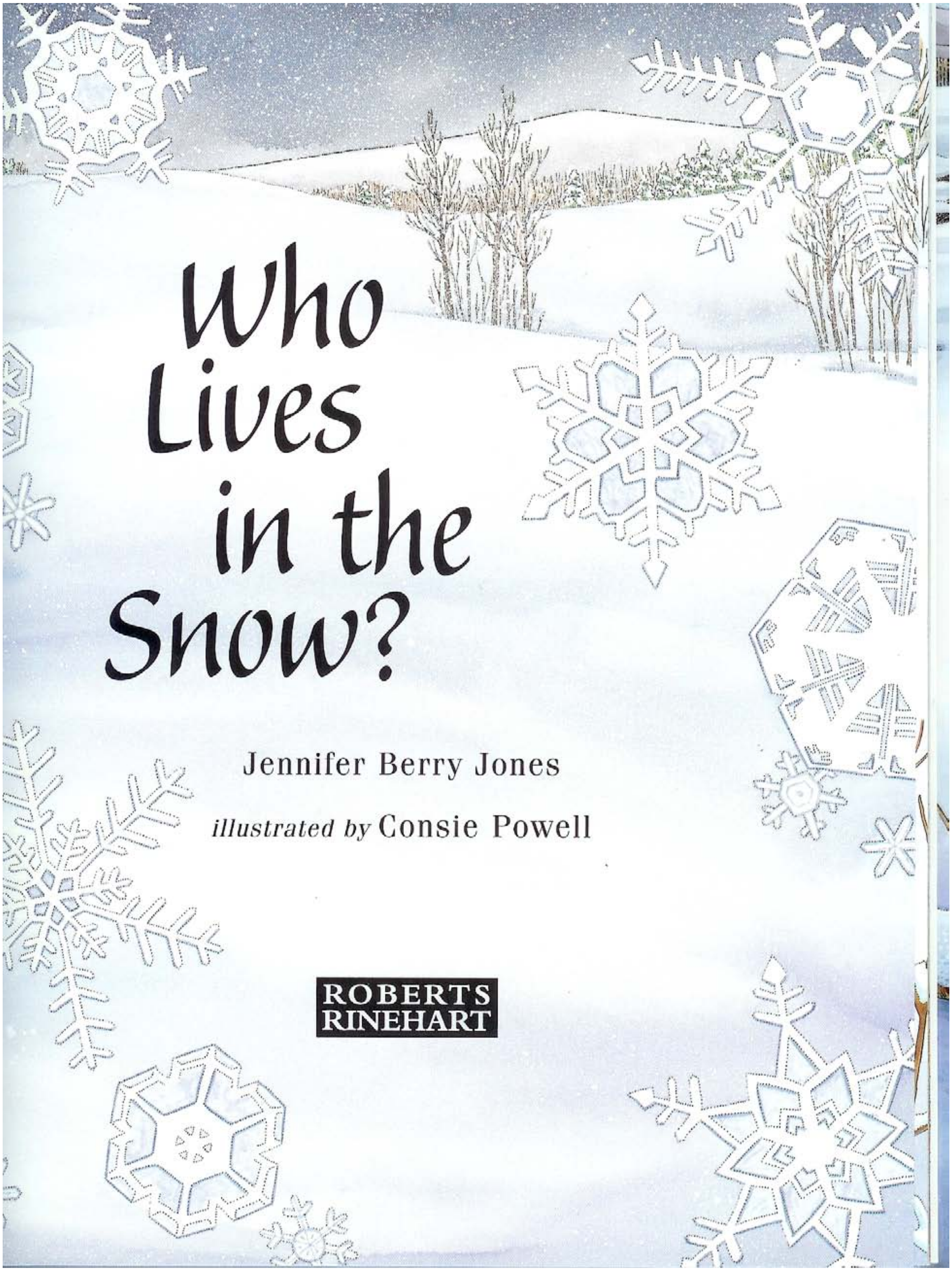
- Create a whole group concept map of snow knowledge. Give everyone a chance to help, whether by adding concepts, clarifying relationships, adding artwork, or making the map into a display for all to see.

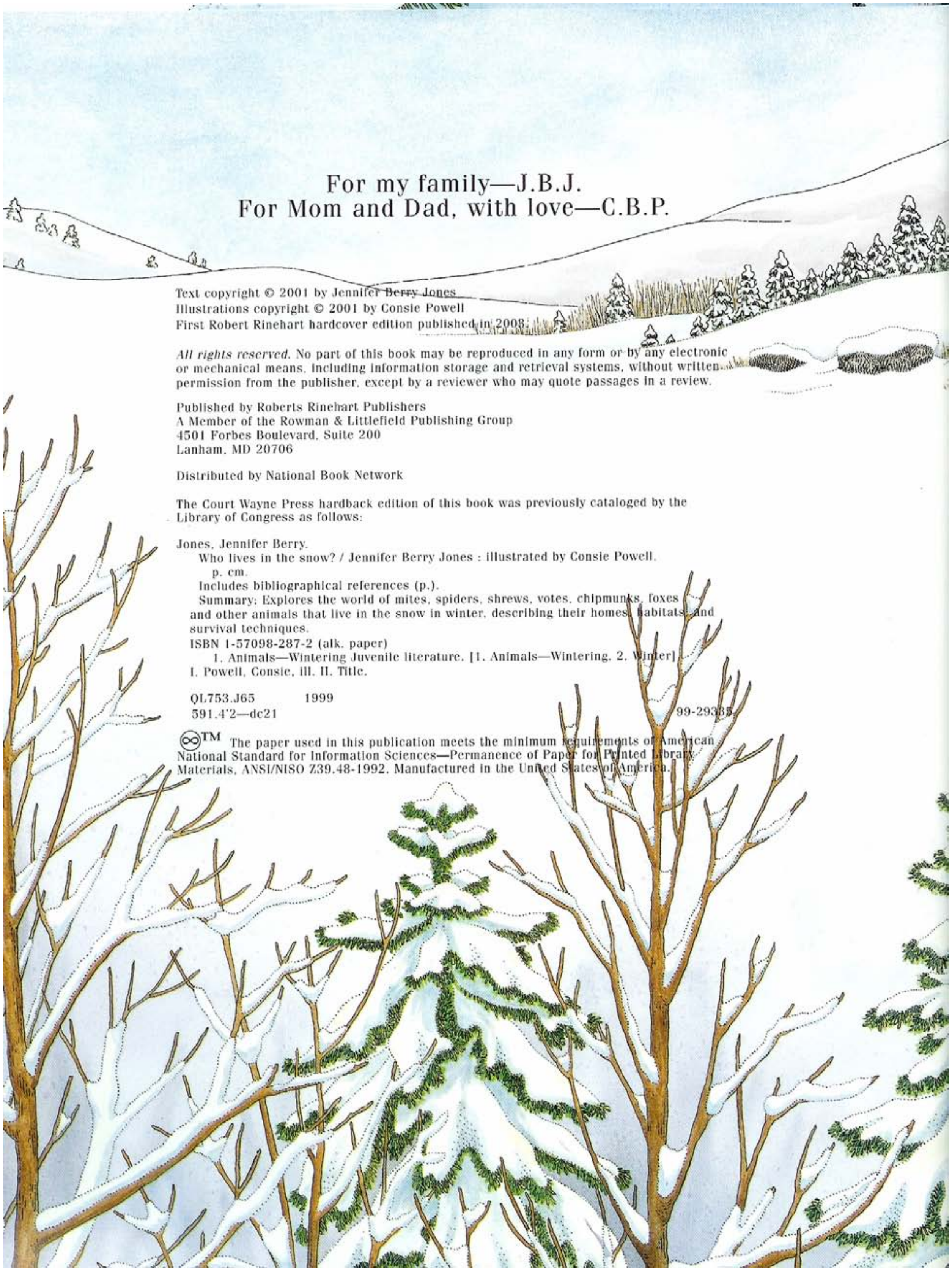
- Begin to explore the role of snow in your community's water supply. Work with your students to find community members directly affected by snowpack and invite them to speak to your students. Encourage lots of questions and answers during the visit.

- Watch newspapers, magazines, and newsletters (many available on-line) for stories about snow. Use your findings to supplement the K-W-H-L process and add to the Thinking Logs. These sources can also be a great entrée into long-term data collection, analysis, and application.

Readings

These selections which follow are used with written permission from their respective publishers. *Who Lives in the Snow?* by Jennifer Berry Jones and illustrated by Consie Powell, is for elementary aged readers. "The Bustle Below" by Ted Kerasote, from *Audubon*, January-February 2000, pp. 20-25, is for secondary readers.


Who Lives in the Snow?
Jennifer Berry Jones
illustrated by Consie Powell
ROBERTS RINEHART



For my family—J.B.J.
For Mom and Dad, with love—C.B.P.

First Robert Rinehart hardcover edition published in 2008.

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Jones, Jennifer Berry.
Who lives in the snow? / Jennifer Berry Jones : illustrated by Consie Powell.
p. cm.
Includes bibliographical references (p.).
Summary: Explores the world of mites, spiders, shrews, votes, chipmunks, foxes and other animals that live in the snow in winter, describing their homes, habitats, and survival techniques.
ISBN 1-57098-287-2 (alk. paper)
1. Animals—Wintering Juvenile literature. [1. Animals—Wintering. 2. Winter] I. Powell, Consie, ill. II. Title.

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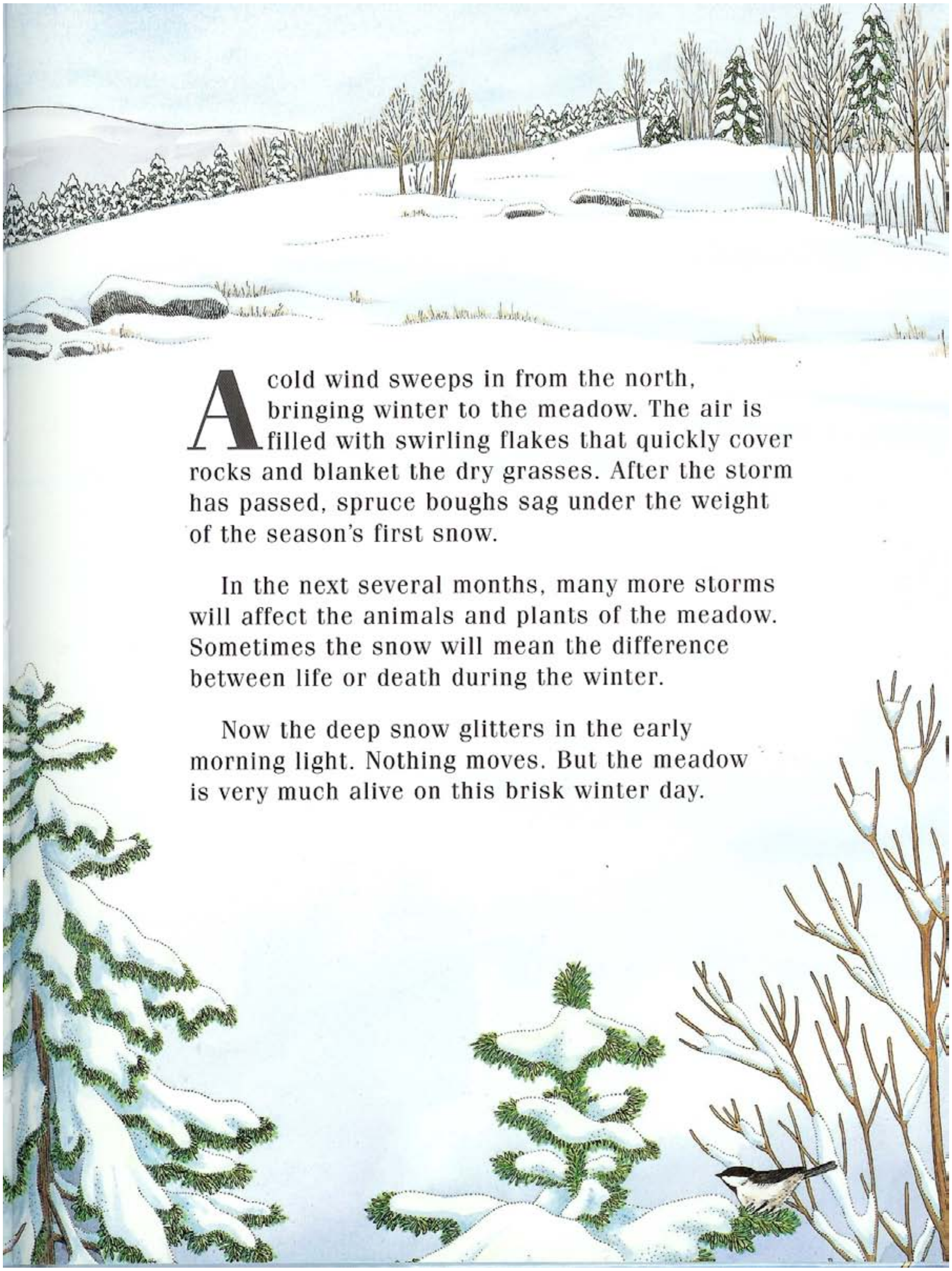
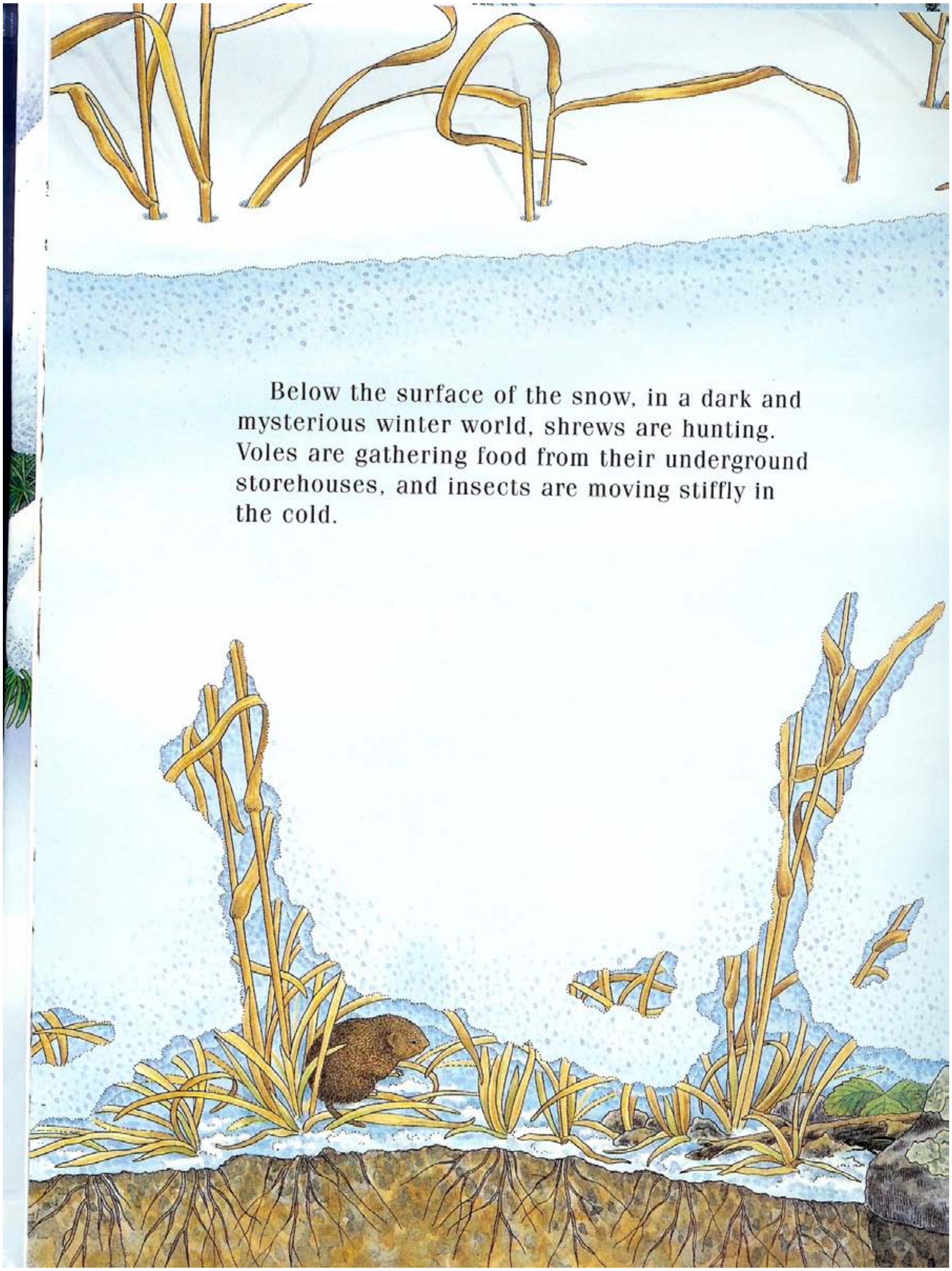


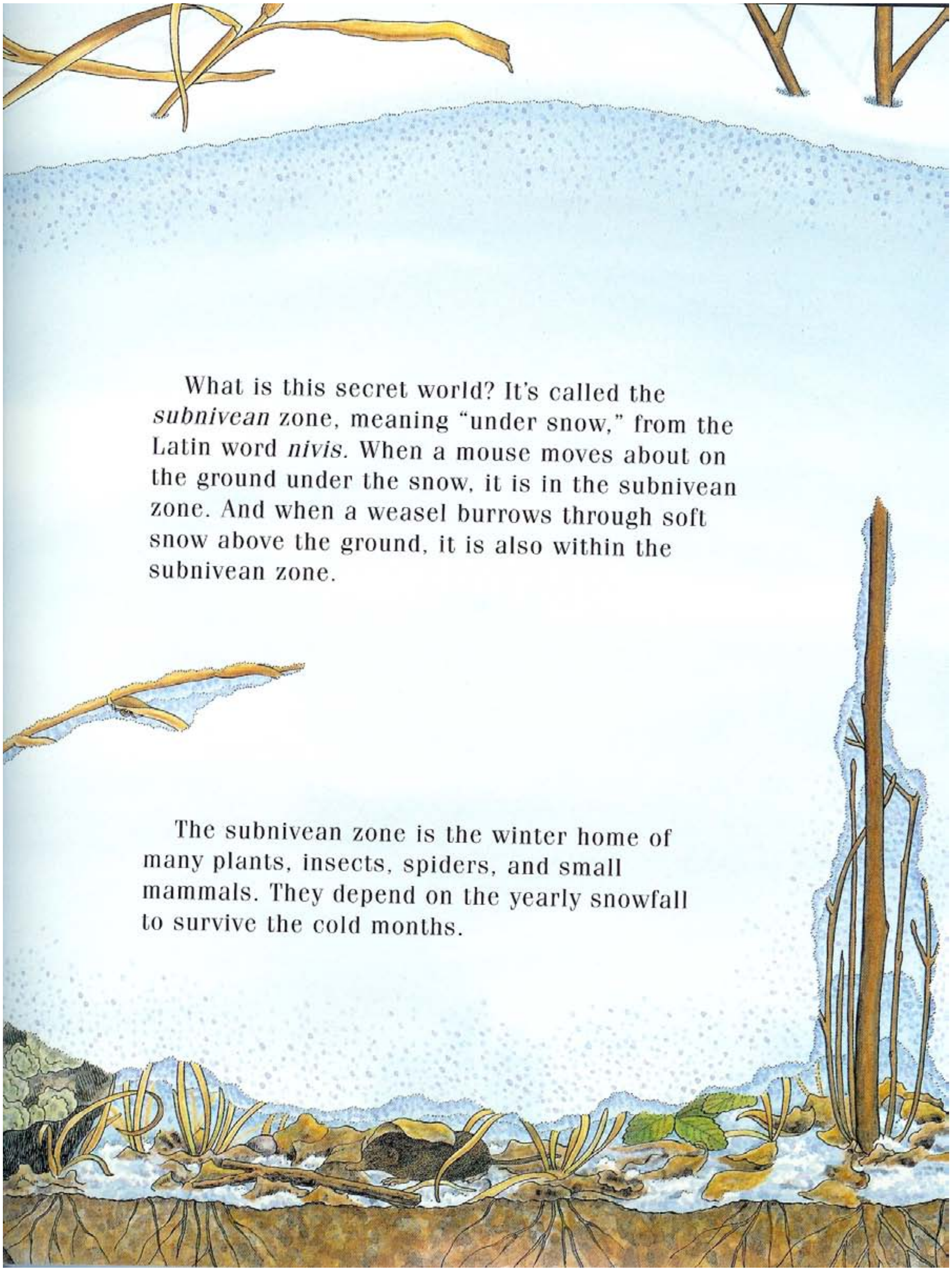
A cold wind sweeps in from the north, bringing winter to the meadow. The air is filled with swirling flakes that quickly cover rocks and blanket the dry grasses. After the storm has passed, spruce boughs sag under the weight of the season's first snow.

In the next several months, many more storms will affect the animals and plants of the meadow. Sometimes the snow will mean the difference between life or death during the winter.

Now the deep snow glitters in the early morning light. Nothing moves. But the meadow is very much alive on this brisk winter day.

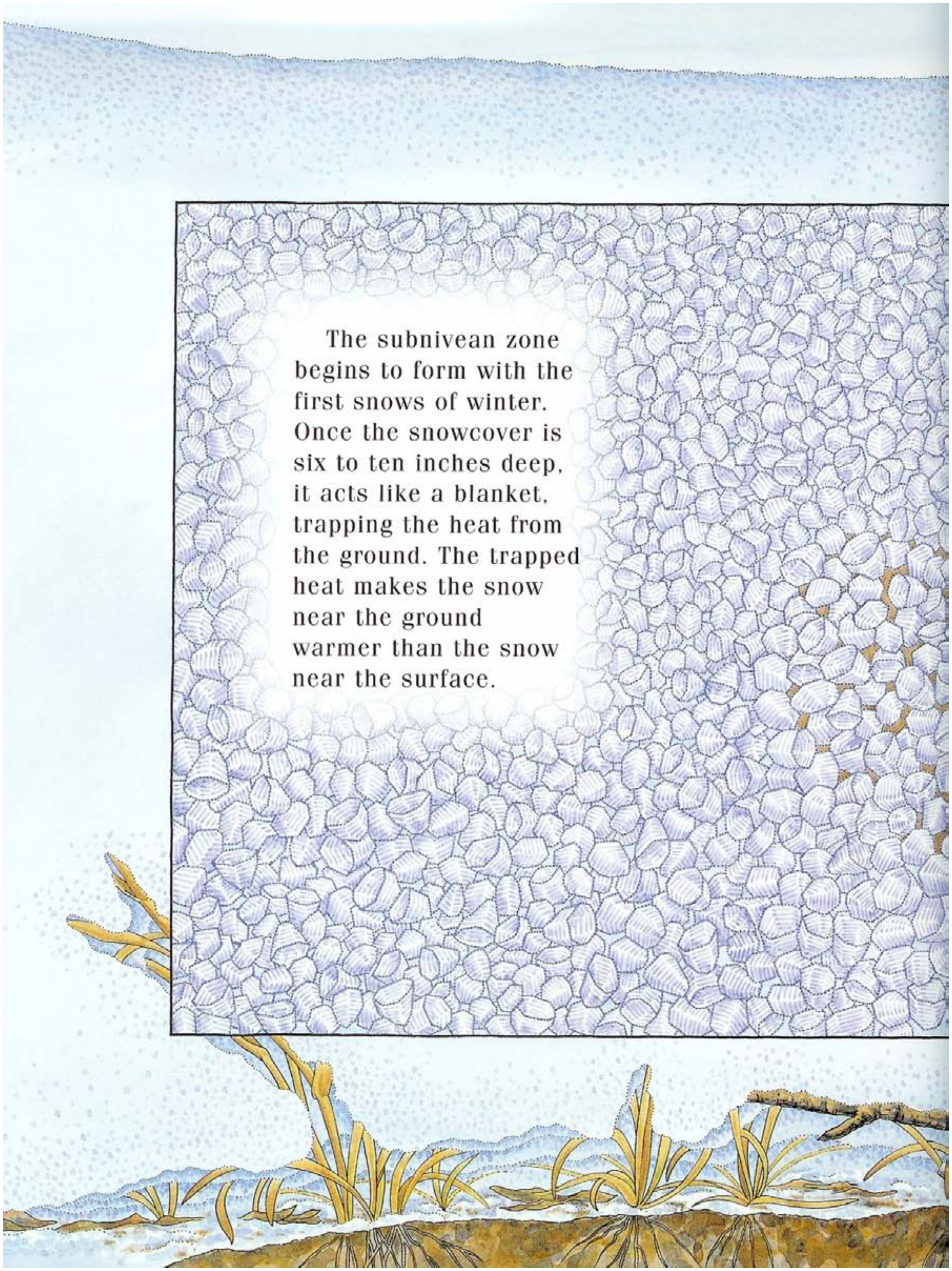


Below the surface of the snow, in a dark and mysterious winter world, shrews are hunting. Voles are gathering food from their underground storehouses, and insects are moving stiffly in the cold.

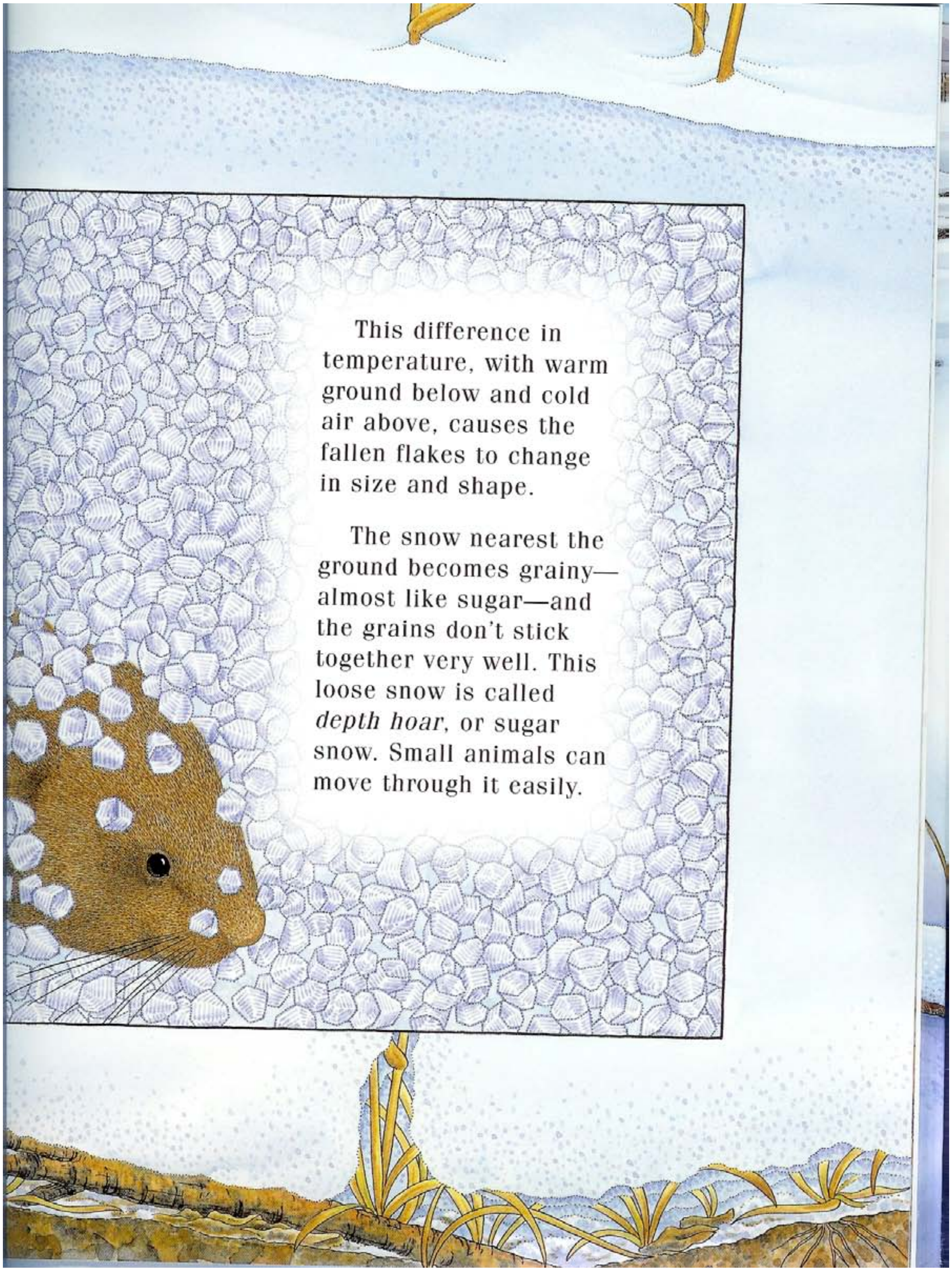


What is this secret world? It's called the *subnivean* zone, meaning "under snow," from the Latin word *nivis.* When a mouse moves about on the ground under the snow, it is in the subnivean zone. And when a weasel burrows through soft snow above the ground, it is also within the subnivean zone.

The subnivean zone is the winter home of many plants, insects, spiders, and small mammals. They depend on the yearly snowfall to survive the cold months.



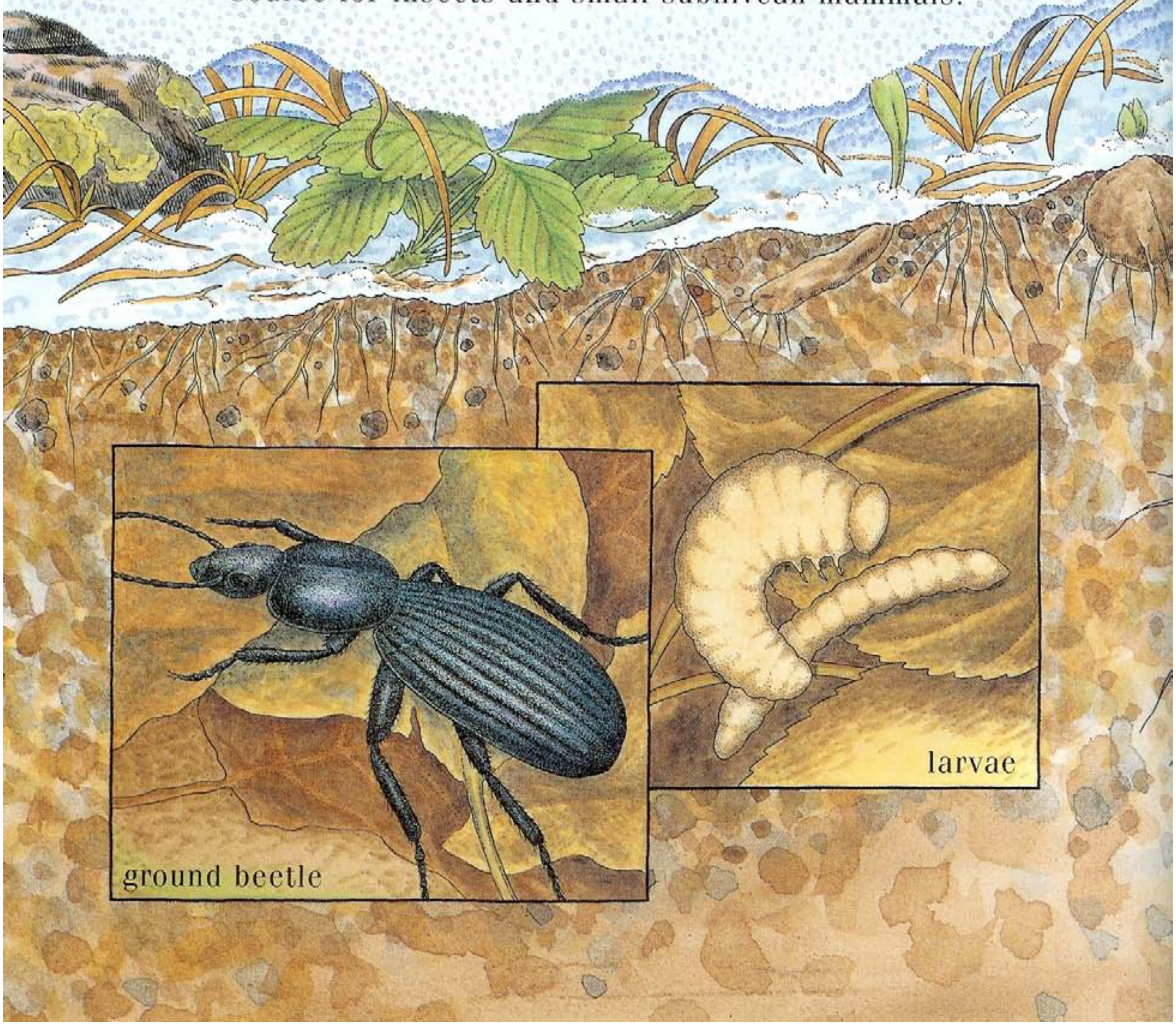
The subnivean zone begins to form with the first snows of winter. Once the snowcover is six to ten inches deep, it acts like a blanket, trapping the heat from the ground. The trapped heat makes the snow near the ground warmer than the snow near the surface.



This difference in temperature, with warm ground below and cold air above, causes the fallen flakes to change in size and shape.

The snow nearest the ground becomes grainy—almost like sugar—and the grains don't stick together very well. This loose snow is called *depth hoar*, or sugar snow. Small animals can move through it easily.

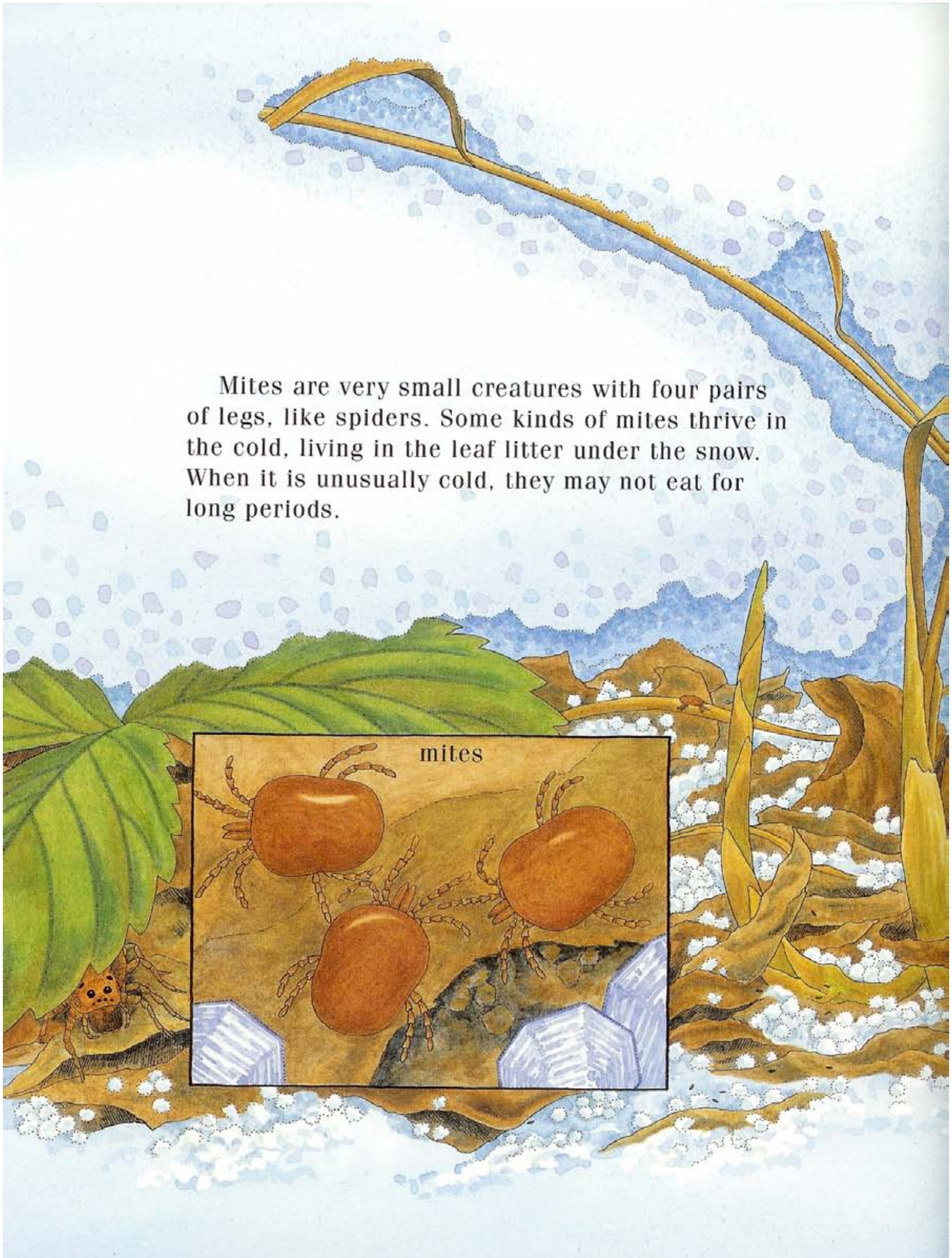
By blocking winter winds, the *snowpack* provides a relatively warm living space for animals and plants. Many plants enter a *dormant,* or resting, stage during winter. But some plants, protected by the snow, are still green and actively growing. Certain seeds can actually sprout under six feet of snow! These under-snow plants are a vital food source for insects and small subnivean mammals.

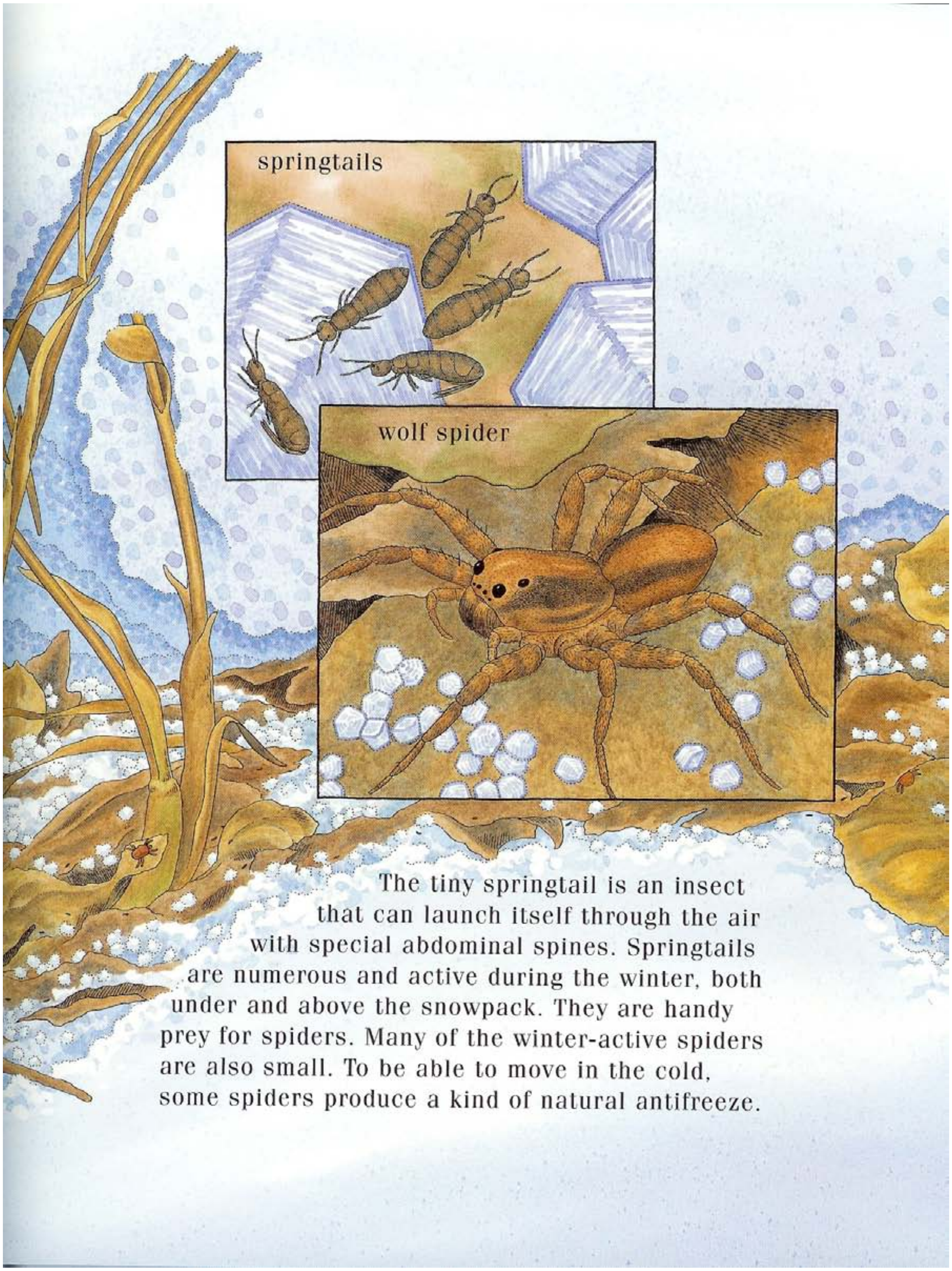


Many kinds of insects die in the fall or become dormant in the winter. But a few insects are active all winter long, under and in the snow.

By digging deep into the soil, ground beetles and grubs—wormlike *larvae* that later grow into beetles—find protection from the cold. The beetles eat the *leaf litter*, which is made up of rotting leaves and bark on the ground. Other insects search for green plants.

Mites are very small creatures with four pairs of legs, like spiders. Some kinds of mites thrive in the cold, living in the leaf litter under the snow. When it is unusually cold, they may not eat for long periods.

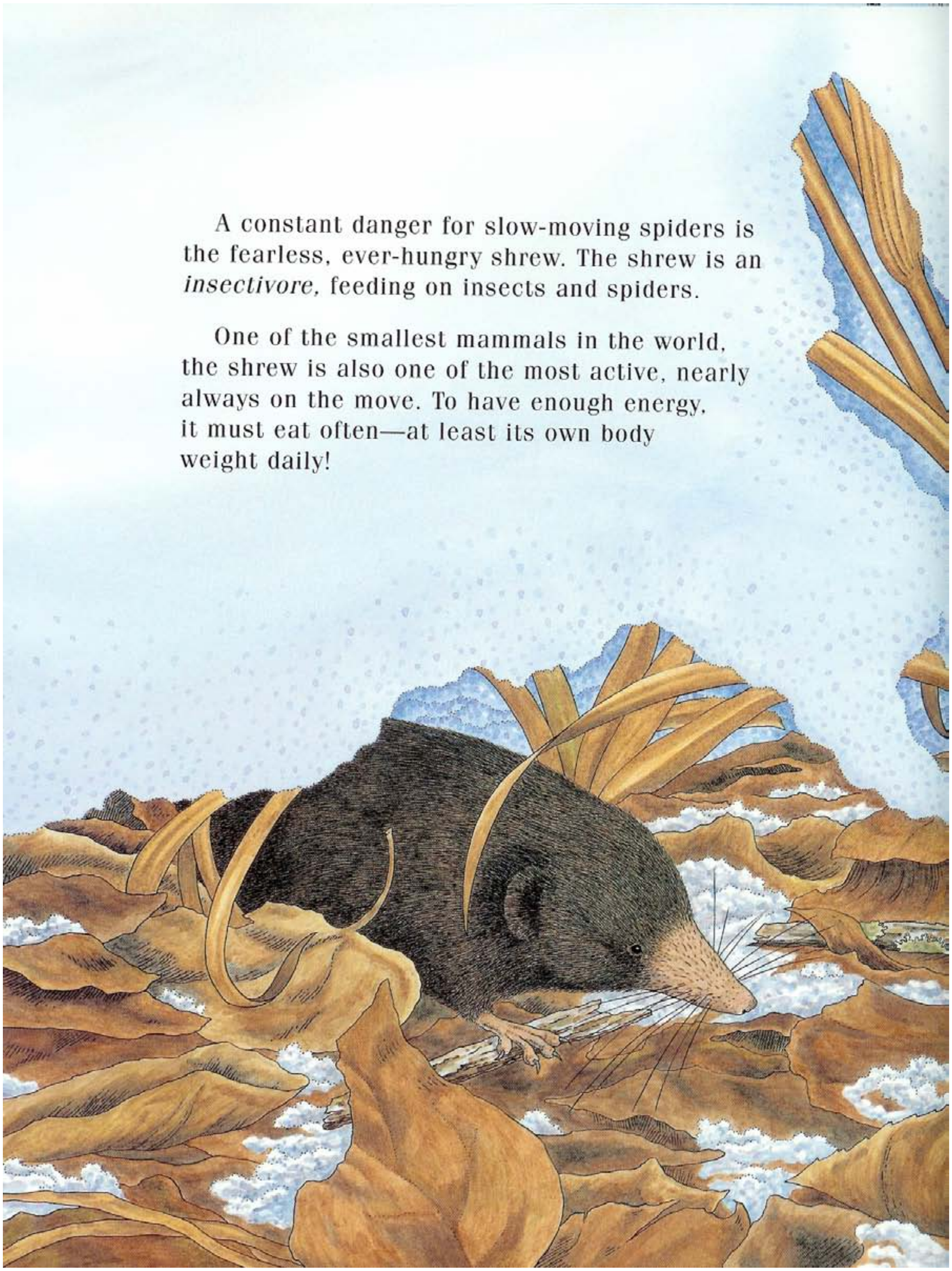




The tiny springtail is an insect that can launch itself through the air with special abdominal spines. Springtails are numerous and active during the winter, both under and above the snowpack. They are handy prey for spiders. Many of the winter-active spiders are also small. To be able to move in the cold, some spiders produce a kind of natural antifreeze.

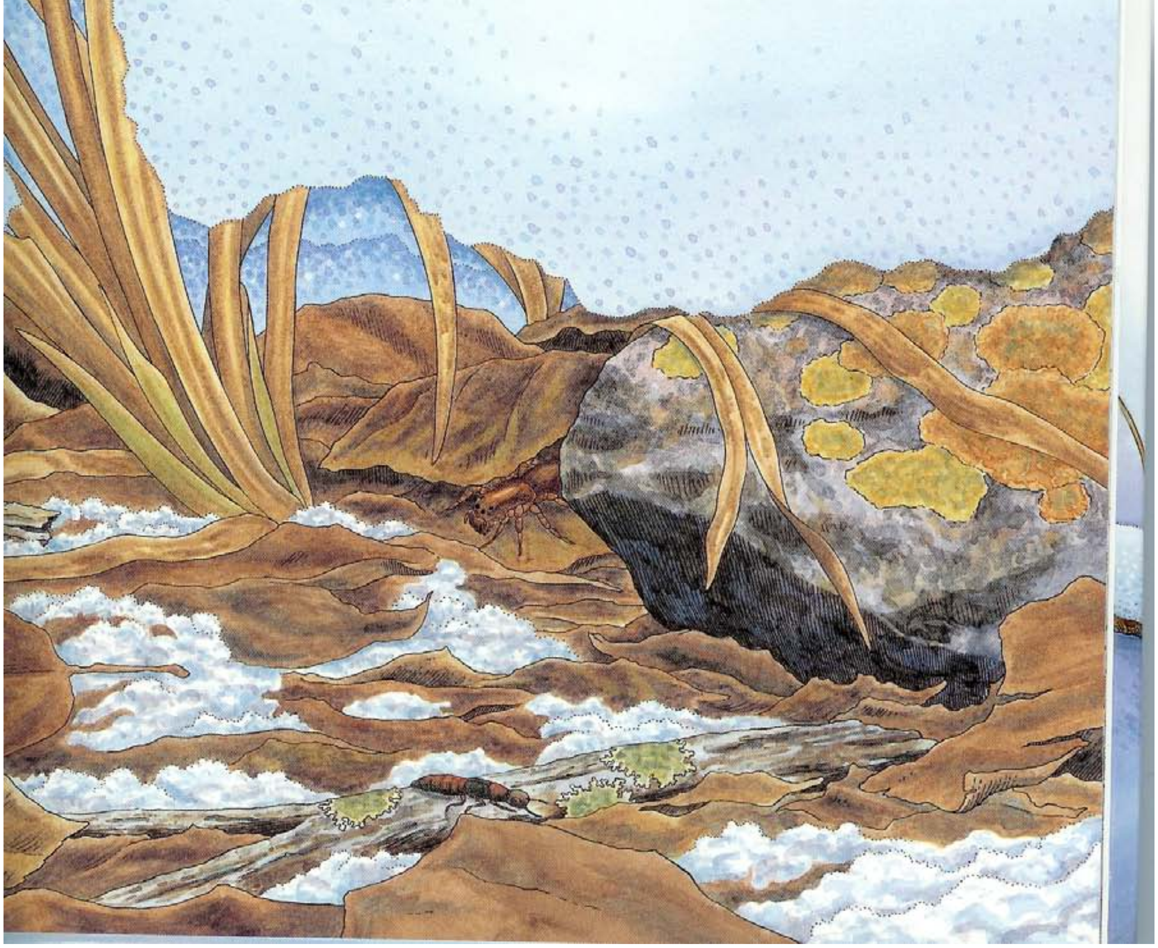
A constant danger for slow-moving spiders is the fearless, ever-hungry shrew. The shrew is an *insectivore,* feeding on insects and spiders.

One of the smallest mammals in the world, the shrew is also one of the most active, nearly always on the move. To have enough energy, it must eat often—at least its own body weight daily!



The shrew isn't sociable. Between frequent hunting trips, it rests alone in a well-insulated nest. To help keep warm, the animal depends on its special heat-producing brown fat.

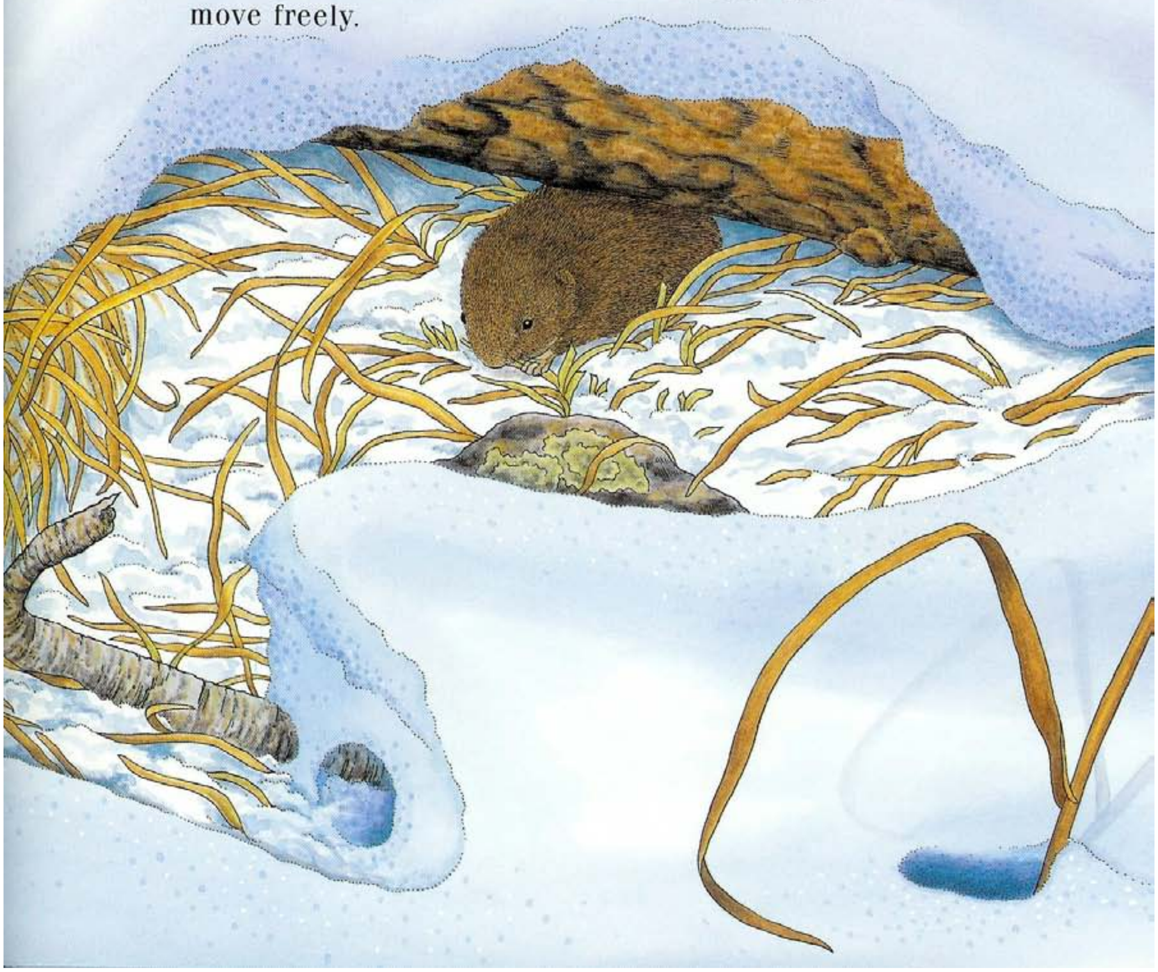
The shrew's winter world is completely dark for several months, because the snow reflects most sunlight. In the darkness under the snow, the shrew's whiskers help it navigate along tunnels built by neighboring voles.

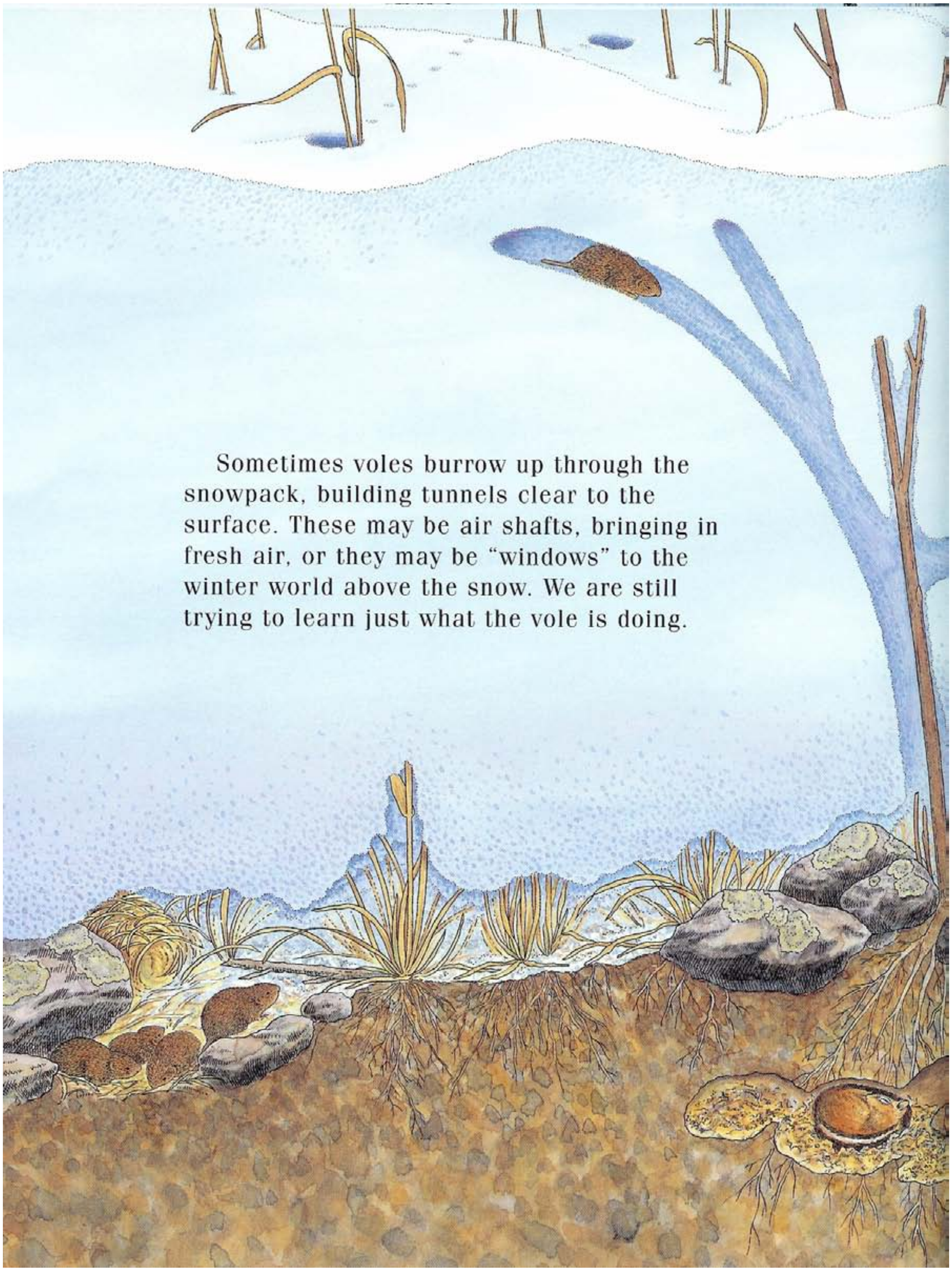


The vole, or meadow mouse, is a plant-eating *herbivore*. In the winter, some voles share a shallow underground nest, huddling with other voles. Small mammals sometimes pile together like this in cold weather to save body heat.

To reach its underground store of leaves and roots, the vole uses a network of tunnels it has built. Voles also use the clear spaces that are often found against logs or rocks under the snow.

Snow can actually flow like water, but very slowly. Sliding over a log like a snow waterfall, it flows straight down, leaving a tunnel against the log. Here small animals and insects can move freely.





Sometimes voles burrow up through the snowpack, building tunnels clear to the surface. These may be air shafts, bringing in fresh air, or they may be "windows" to the winter world above the snow. We are still trying to learn just what the vole is doing.

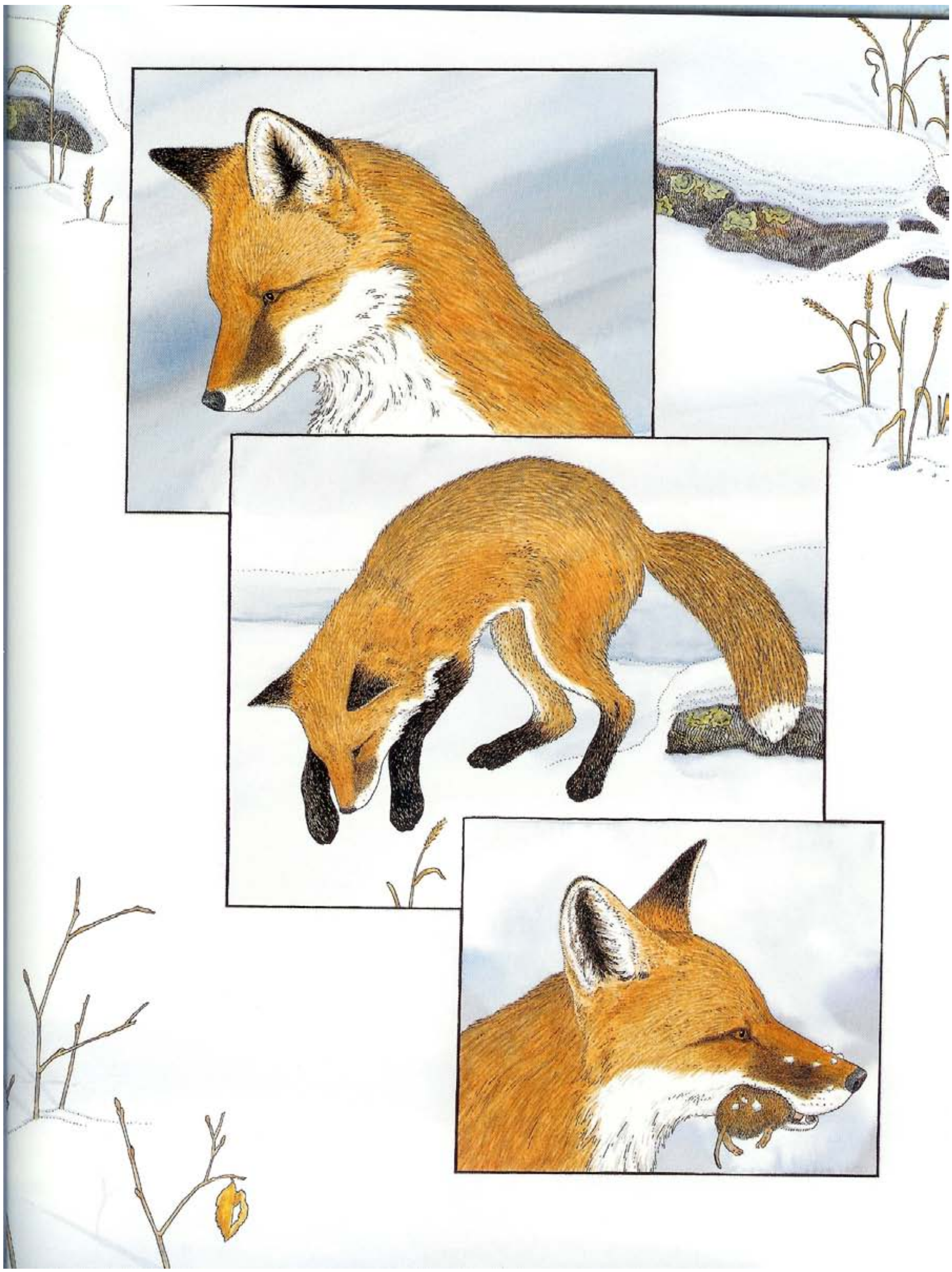
Near the vole's nest, but deeper in the ground, a chipmunk is curled tight in its winter bed, *hibernating*. Several times during the winter, it will slowly awaken from this deep sleep to eat. The chipmunk will nibble on seeds that it stored under its mattress of leaves

Like its neighbor the vole, the chipmunk wants to see how winter is progressing. On warmer days, it may venture up through its tunnel to peek outside. And it may see danger at the edge of the meadow.

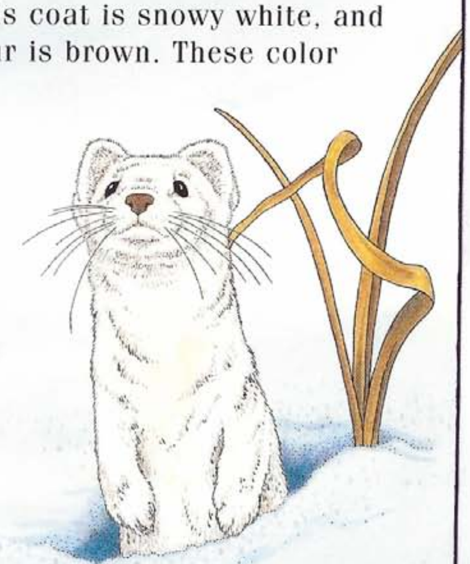
A red fox is looking for breakfast as she quietly surveys the meadow. To survive the winter, she hunts daily. The fox will eat whatever she can find, from insects to rabbits—and even dried berries left over from summer.

The alert fox moves softly. Suddenly she stops. Her keen ears have picked up faint sounds from deep under the snow.

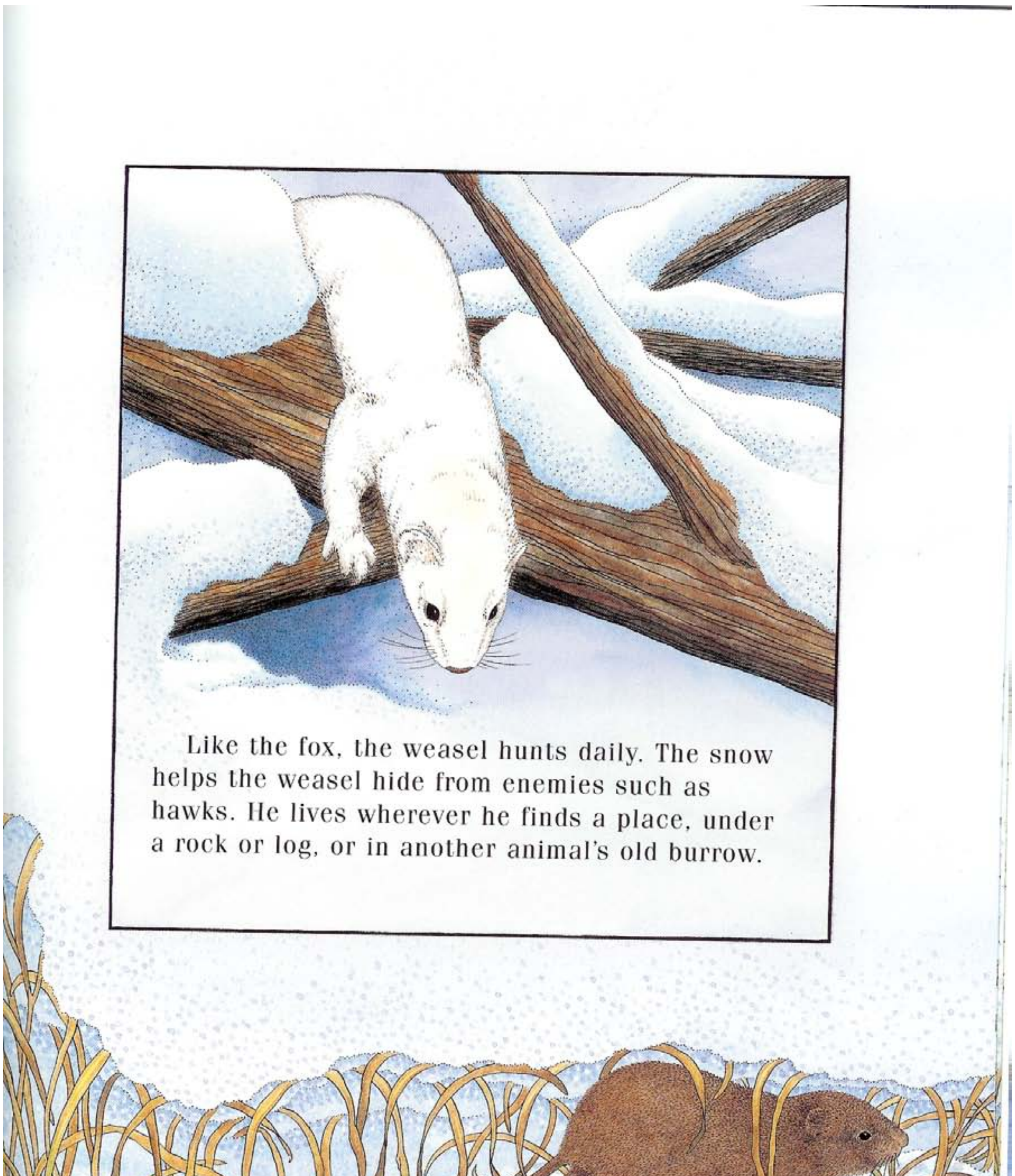
Something small is rustling on the ground. Plunging nose-first into the soft snow, the fox snatches up a vole. She gobbles it down, but one vole isn't enough for a hungry fox on a cold day. She listens patiently. But there are no more voles here today, so the red fox moves on.



A small head pops up from the snow. Another *predator,* or hunter, is the long-tailed weasel. The tip of his tail is black all year round. In winter, the rest of his coat is snowy white, and in the summer his fur is brown. These color changes help the weasel to live without being seen by its enemies.



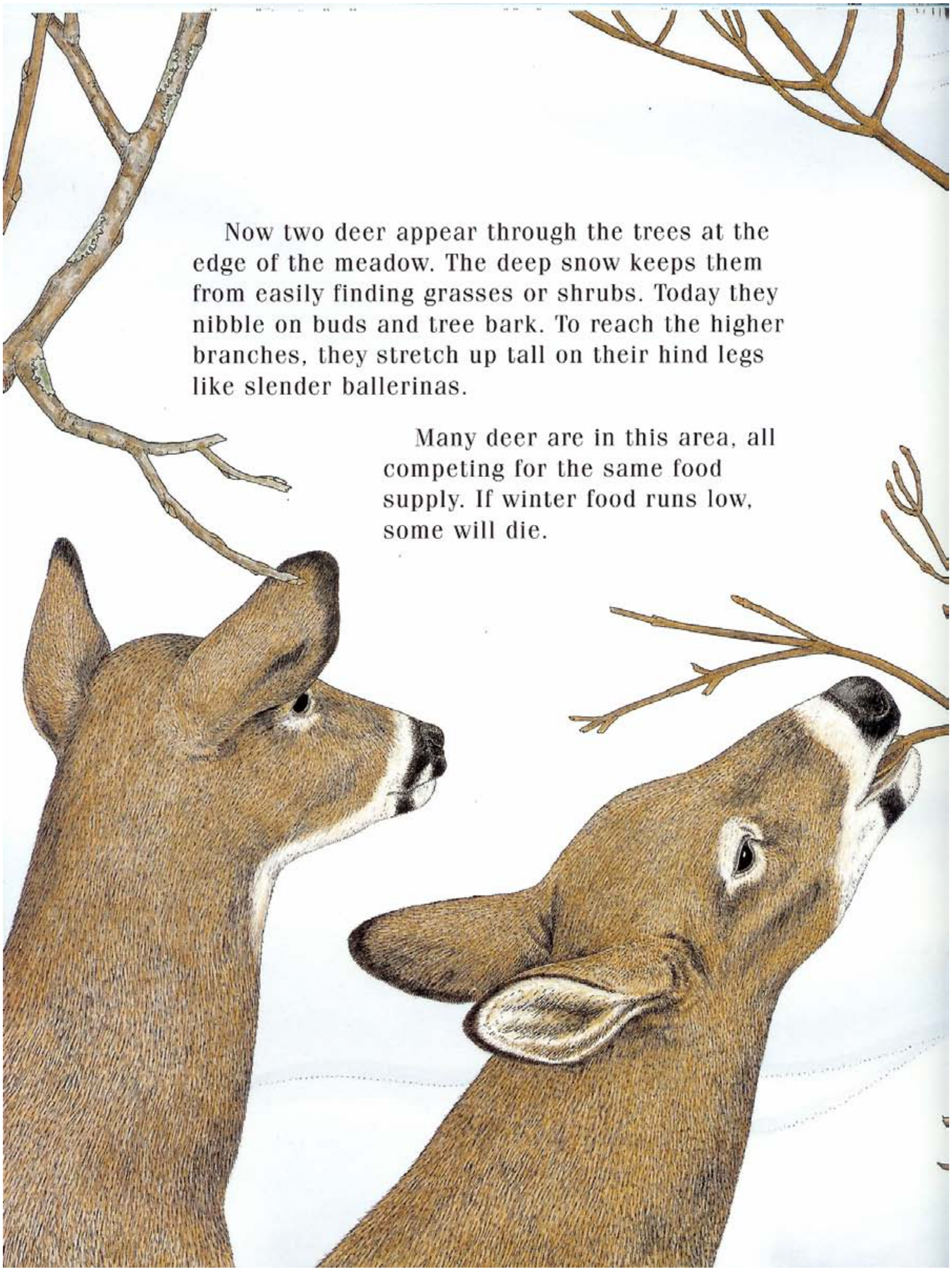
In winter, weasels hunt for small prey under the snow. The slender weasel burrows right through the snow and finds a mouse running along the ground.



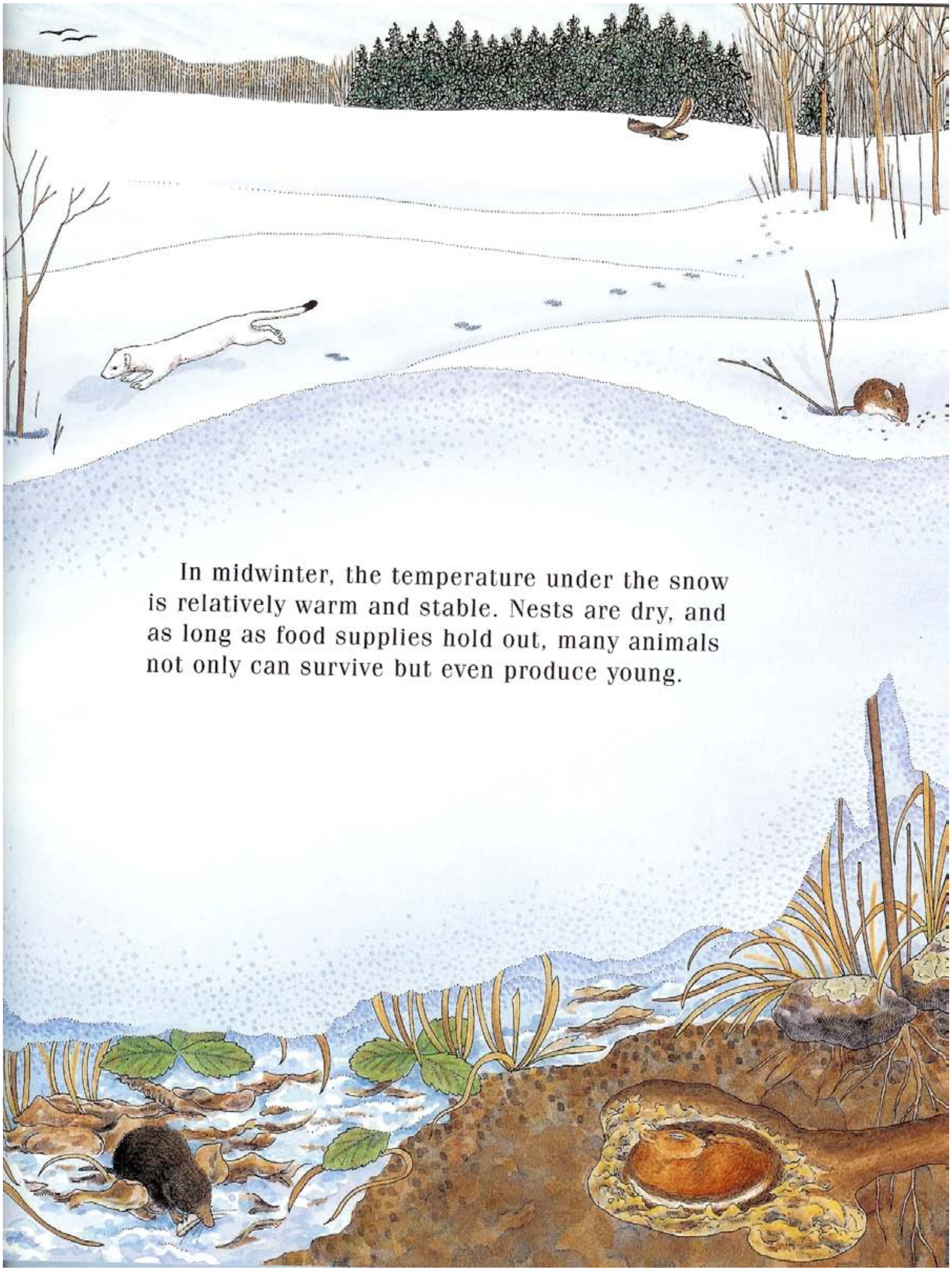
Like the fox, the weasel hunts daily. The snow helps the weasel hide from enemies such as hawks. He lives wherever he finds a place, under a rock or log, or in another animal's old burrow.

Now two deer appear through the trees at the edge of the meadow. The deep snow keeps them from easily finding grasses or shrubs. Today they nibble on buds and tree bark. To reach the higher branches, they stretch up tall on their hind legs like slender ballerinas.

Many deer are in this area, all competing for the same food supply. If winter food runs low, some will die.



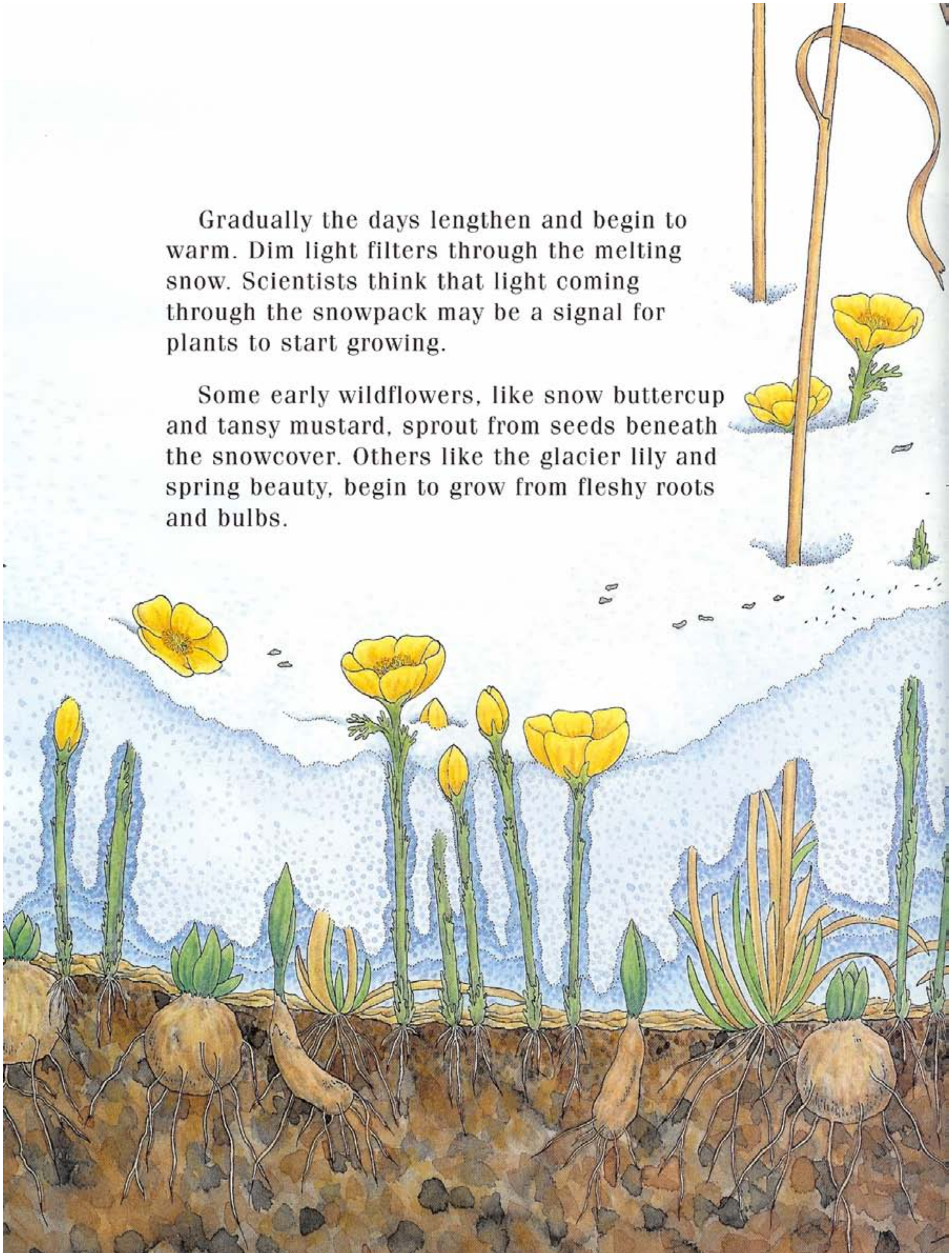
The winter months pass, and activity in the snow goes on. If alert predators like the fox and weasel don't disturb the residents below, midwinter is the best time for life in this hidden world.

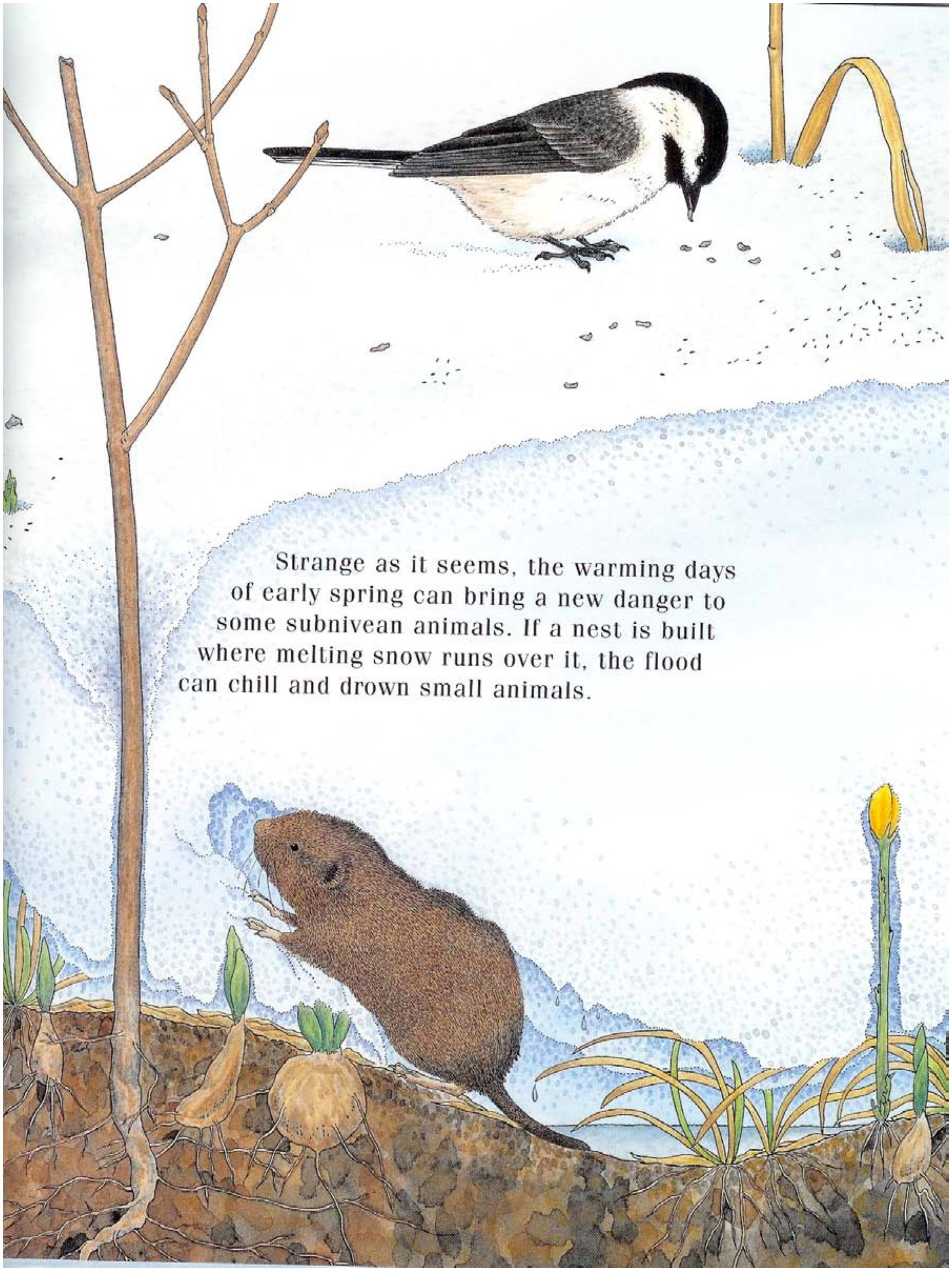


In midwinter, the temperature under the snow is relatively warm and stable. Nests are dry, and as long as food supplies hold out, many animals not only can survive but even produce young.

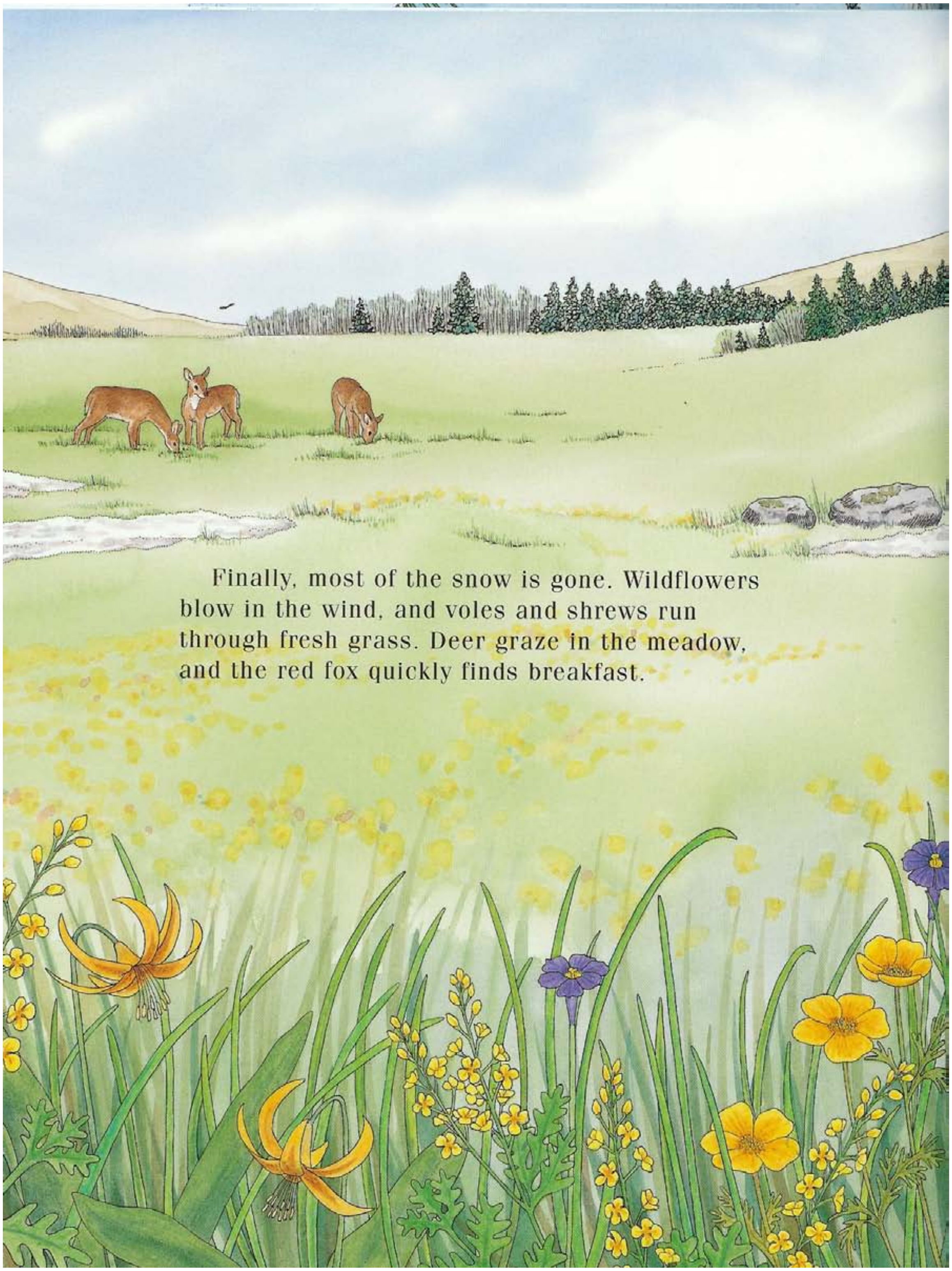
Gradually the days lengthen and begin to warm. Dim light filters through the melting snow. Scientists think that light coming through the snowpack may be a signal for plants to start growing.

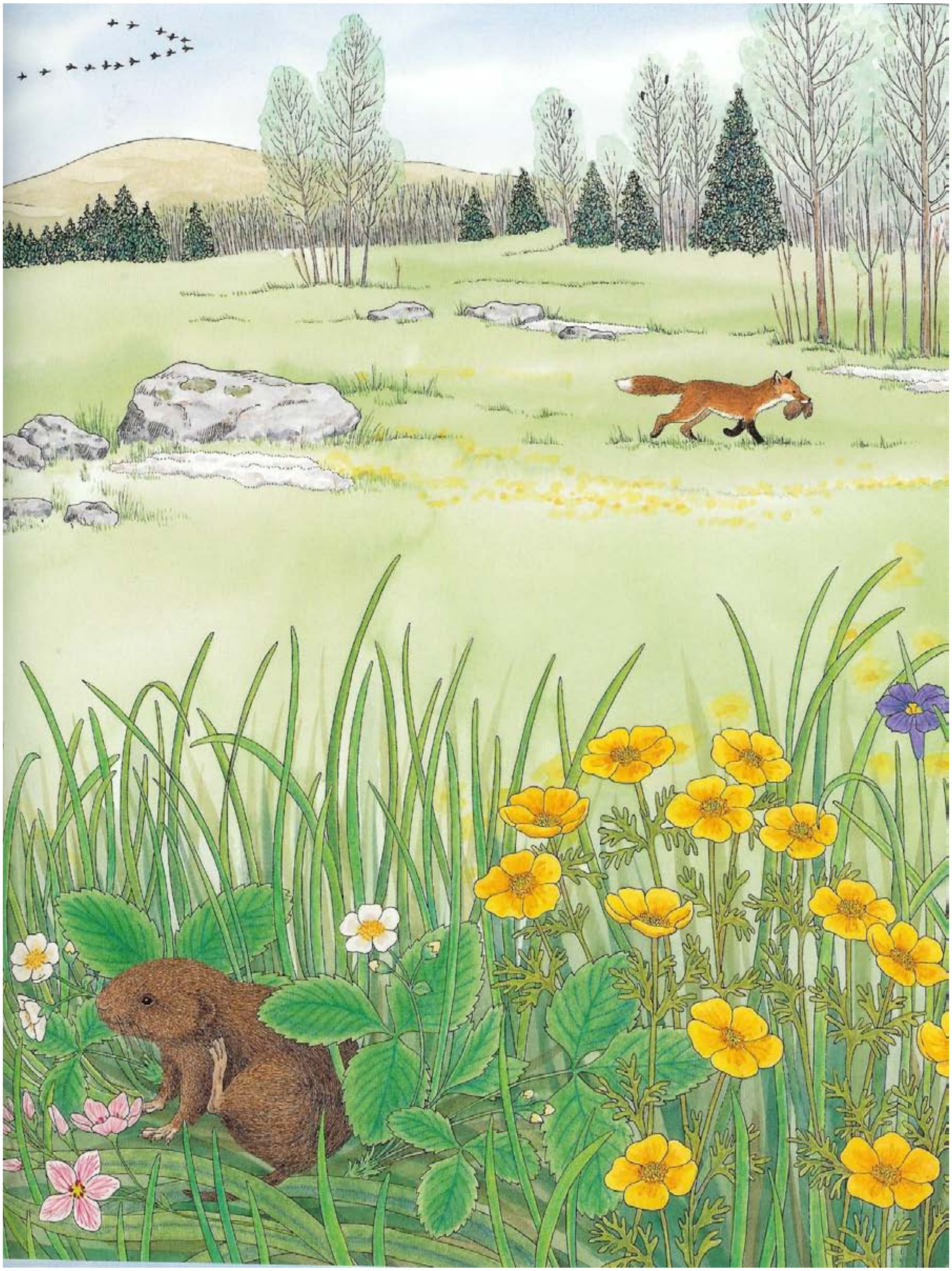
Some early wildflowers, like snow buttercup and tansy mustard, sprout from seeds beneath the snowcover. Others like the glacier lily and spring beauty, begin to grow from fleshy roots and bulbs.

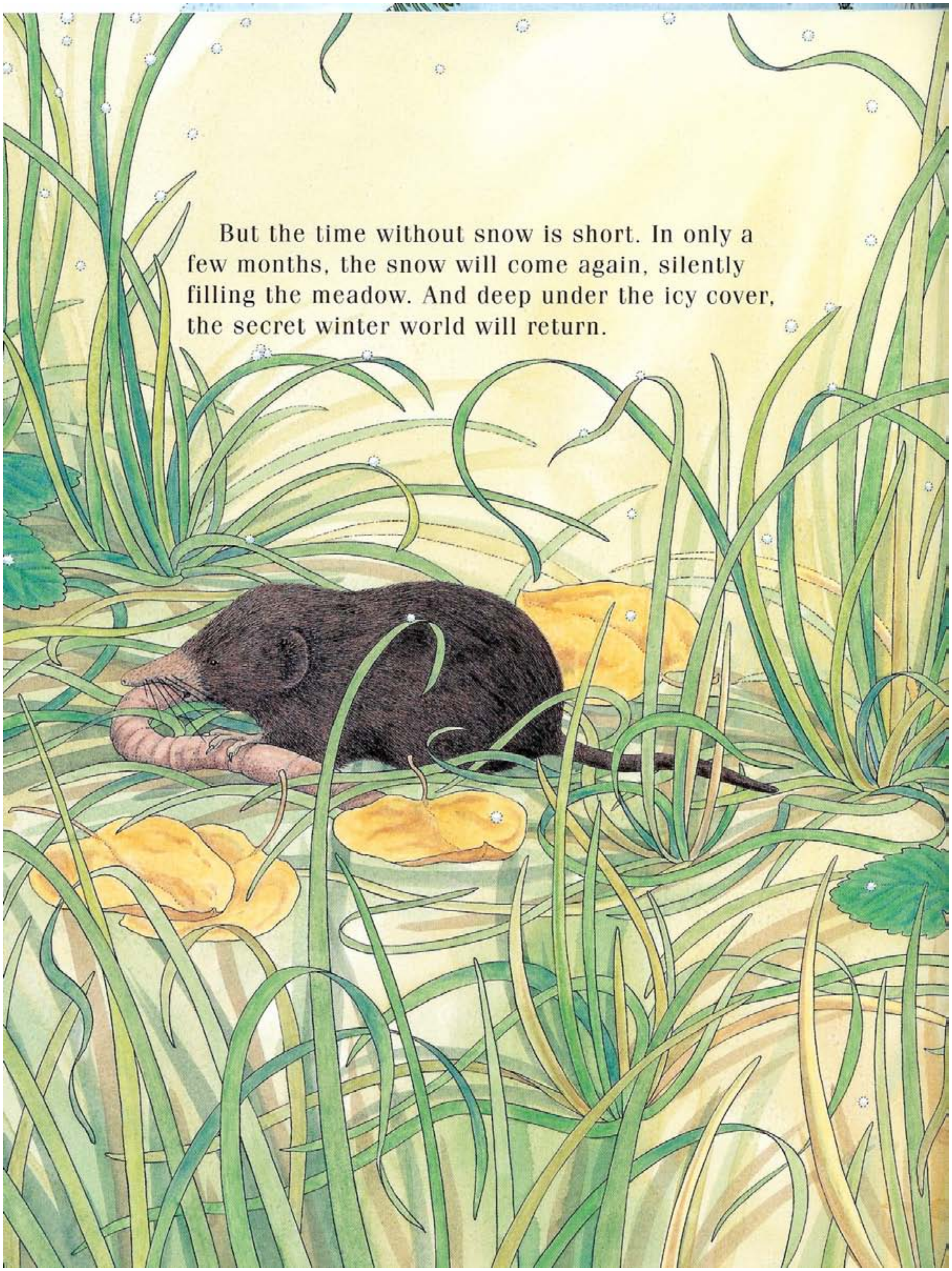




Strange as it seems, the warming days of early spring can bring a new danger to some subnivean animals. If a nest is built where melting snow runs over it, the flood can chill and drown small animals.


Finally, most of the snow is gone. Wildflowers blow in the wind, and voles and shrews run through fresh grass. Deer graze in the meadow, and the red fox quickly finds breakfast.





But the time without snow is short. In only a few months, the snow will come again, silently filling the meadow. And deep under the icy cover, the secret winter world will return.

GLOSSARY

Depth hoar: large snow crystals that often form at the bottom of a snowpack. This is also called **sugar snow**. It is easy for animals to dig through.

Dormant: sleeping; not active or growing.

Forage: to search or look for food.

Herbivore: a plant-eating animal, such as a vole.

Hibernate: to pass the winter in a sleeping state.

Insectivore: an insect-eating animal, such as a shrew.

Larva/larvae (pl.): the early wormlike form of many insects.

Leaf litter: rotting leaves and bark on the ground.

Predator: an animal that preys on, or hunts, other animals.

Snowpack: the layer of snow on the ground.

Subnivean: the area within and under the snowpack.

The Bustle Below

A snowpack is a pile of cold, icy crystals. It's also a vital—and warm—winter home for a variety of animals.

BY TED KERASOTE

TWO INCHES OF NEW snow has fallen overnight and swishes dryly around my skis as I cut a track across the white plain sprawling north toward the Gros Ventre Mountains. It's 18 degrees below zero this February morning in northwestern Wyoming—not unusual on a winter day in this part of the world, where the temperature sometimes drops to 30 below. The air is still and silent, but the snow underfoot is alive with life.

This winter the snow came late, the lower valley bare through most of December. Finally, on Christmas Day, it began to snow in earnest. By the end of January, 116 inches of snow lay on the ground, far more than the 8 inches needed to protect small mammals from the subzero air above. Indeed, fresh snow is one of the world's best natural insulators, better than sand, sawdust, or even synthetic glass wool.

I pick up a handful of snow and examine its individual building blocks, or crystals, with my magnifying glass. There are several classification systems that name these crystals, with a variety of astral, arboreal, and architectural similes: fernlike and stellar crystals, broken branch, column with dendrites. The shapes depend on the amount of water vapor that condenses out of the atmosphere and onto wind-borne microscopic particles of dust or salt. Temperature also plays a role: Stars form at about 10 degrees Fahrenheit, and columns at about 30 below. Many snow crystals look identical to the naked eye, and even under the micro-

The thickest fur of any mammal makes the Arctic fox the ultimate winter creature. It hunts rodents by hearing them through the snow.

GALEN ROWELL/MOUNTAIN LIGHT

Honeybees, *by their rapid and intense activity, are able to raise the temperature in their hives during winter.*

scope they may appear to be twins. However, no two crystals have yet been found that are perfectly alike. This morning I see mostly fernlike crystals, a tiny sampling of the trillions that make up this latest addition to the snowpack, which, at this elevation, has been evolving since fall.

During the deep cold spells we had in autumn, when the snowpack was thin and unconsolidated, a large temperature difference formed between the cold snow surface, at 20 below, and the warmer earth, at 32 degrees. Water vapor migrates from warm to cold, from the ground upward, along the way adding to the higher crystals above and causing them to grow in size. The result of those autumn cold spells is a layer of shardlike snow, called depth hoar, close to the ground. Loose and full of air spaces, it allows burrowing mammals free passage.

Where the valley floor gives way to the foothills, I cross two sets of wolf tracks; the pads are four inches long and almost as wide, and the paired front claws have etched the snow as cleanly as crampons would. Looking toward where the tracks lead, I see two dozen bull elk snuggled up against the conifers, their antlers like a tangled thicket, their breath steaming as they paw through the snow to graze. No ravens circle, no carcass is visible. The wolves, prudent and energy-conserving hunters, have gone on, searching for less healthy prey. Perhaps they'll find an arthritic old elk; when it turns to flee, it might flounder in the snow and become an easy meal for the more winter-adapted wolf.

The elk's disadvantage lies not only in its stiff bones but also in its hooves. Its "foot-load index"—a measurement devised by the Canadian biologists Edmund S. Telfer and John P. Kelsall that compares an animal's weight with the surface area of its feet—is 33. By this measurement, the wolf rates an 85, which means that it's better adapted than the elk for travel over snow. This gives the wolf a leg up, if you will, on the elk in winter. The ultimate winter traveler, of course, is the snowshoe hare, whose foot-load index is close to 100. Because of its large feet and light weight, the foot-load of the snowshoe hare is one-tenth that of the wolf.

I climb over the hill and ski down through an aspen grove to where the trees give way to a long, narrow clearing. Here the hopping, four-print track of a shrew dapples the snow. A tiny, voracious predator of the subnivean world, the shrew feeds mostly on

The snowshoe hare's large hind feet enable it to easily hop across deep snow.

JIM BRANDENBURG/MINDEN PICTURES

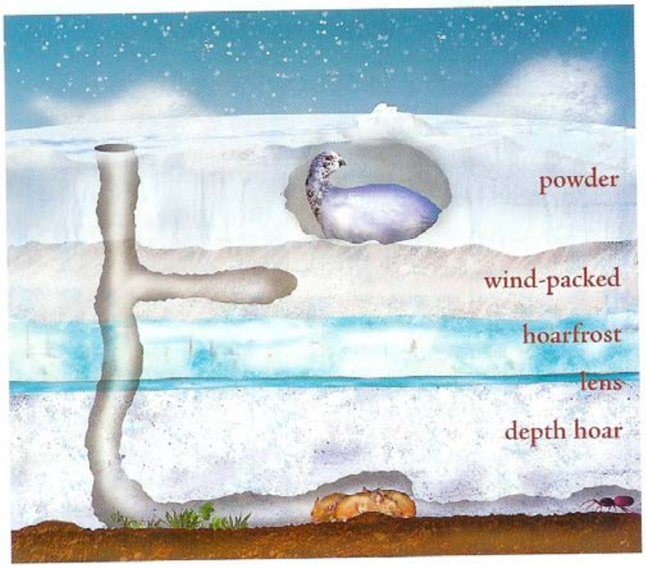
insects that stay active under the snow's protective insulation. After 20 yards the shrew's tracks disappear down an entryway, followed by an intersecting line of dumbbell-shaped prints: an ermine, or short-tailed weasel. The prints wander widely over the field, disappearing here and there where the animal has burrowed under the snowpack, hunting for shrews and rodents. Catching the trail of the shrew, the ermine has dived down the animal's hole in pursuit. I pause, staring into the dark hole below and thinking of the frenetic life going on beneath my skis: burrows that stretch for 10 and 15 yards, the shrew scurrying down its tunnels with icy depth hoar hanging over its head, pinning spiders with its sharp little teeth or now maybe fleeing

the ermine, which wants both the shrew's flesh and its pelt; it lines its own nest with the fur of its prey.

In fact, hunting is easier for the little weasel in winter, when many subnivean creatures like voles and mice, which are solitary in summer, become social, building communal nests six to eight inches across. The advantages of nests: warmer temperatures and a higher relative humidity, which reduces heat loss. In fact, nests of taiga voles have been found to be 50 degrees warmer than the air above the snow. One subnivean animal, the red-backed vole, does well enough under these conditions to reproduce in winter.

The disadvantages of communal life under the snow? According to Peter J. Marchand, a visiting professor of winter ecology at Colorado College, these include "increased vulnerability to location by predators, a greater possibility of disease or parasite transmission, and more competition for food." But, he adds, "these may be small trade-offs compared to the problems of maintaining normal body temperature." Some animals, of course, like ground squirrels and bears, avoid these hassles by hibernating, lowering their body temperatures and decreasing their energy needs.

TOASTY IN MY OWN BURROW of long underwear and fleece sweater, I cross the track-littered clearing and climb through the subalpine fir, heading for the crest of a ridge. Along the way, I catch sight of the twin craters of a ruffed grouse's snow roost, each a little larger than the bird itself and about a foot deep. The grouse, like other birds, can't generate brown fat in winter's decreased light and lower temperatures, as some mammals do. Brown fat, as opposed to white fat, burns oxygen more efficiently and produces more heat. Without it, birds must rely on shivering to maintain their body temperature during cold spells. While the repeated muscle contractions keep the bird warm, they require a steady supply of food. Ruffed grouse use the insulation of the snow-



The Nature of Snow

Adequate snow cover is crucial to the overwintering success of many small mammals. Although air temperature can be frigid, it increases rapidly under depths of snow. To keep warm, grouse dig snow roosts; taiga voles' communal nests can be 50 degrees warmer than the air above the snow. At the snowpack's bottom lies the depth hoar, a layer of sugarlike snow through which small animals can move easily. Various snow types can comprise a snowpack: A crustlike lens forms when snow melts, then refreezes. Hoarfrost, winter's equivalent of dew, resembles freezer ice. Strong winds produce densely packed snow. And in cold, dry conditions, snow falls as a light powder. A small fraction of sunlight can penetrate up to six feet of snow, allowing some plant activity. And some insects produce glycerol, which inhibits ice formation in their tissues, enabling survival in subzero temperatures.

GRANT JERDING

[TRUE NATURE]

pack to overcome this disadvantage, and a bird in a snow burrow expends 30 percent less energy than one in the open. The temperature in a grouse's snow roost has been measured at 40 degrees when the air temperature is zero. After a time in its roost, the bird doesn't shiver at all.

At the crest of the ridge, I remove my skis, shed my pack, take up my shovel, and dig a pit nearly seven feet down through the snow. I smooth off the wall, revealing layers that, like sedimentary rock, describe a history.

Eight inches of depth hoar lie above the pine needles. A foot above this sugary snow rests a lenslike crust formed during a period of clear weather in mid-December, when sunlight must have shone across the top of the ridge onto this spot. I continue to trace the personality of this year's snowpack upward: a band of hoarfrost (the winter equivalent of dew), followed by a very dense layer, several inches wide, that was formed by strong winds in mid-January. Above that lies a frozen band, indicating a week of warm temperatures that rounded the snowflakes into grains of ice, forming an interlocking structure. This sort of metamorphosis, occurring throughout the winter, is what causes the snowpack to shrink even when temperatures are below freezing.

Fortunately (for me the skier), a foot and a half of snow has fallen during the past week, and I gaze admiringly at the fluffy powder that has remained. Although these 18 inches have almost no current effect on the subnivean world deep below, when spring approaches their addition will be felt. Melting from the top, the pack will turn into a mass of rounded ice crystals and water.

For shrews, voles, and mice, this is one of the most dangerous times of the year. The snowpack that has preserved the animals can now kill them, as the water trickles into their burrows. The more bountiful the winter's snowfall, the longer the water may linger in the spring, with small mammals drowning or dying of hypothermia.

But that transitional period—for them and for me—is still weeks away. Stepping into my bindings and putting on my pack, I turn down the slope, leaving a snaky trail through the conifers, flying above the world of ermine and shrew, over hidden rocks and cliffs, snow making my travel easy and the dark season light.

Writer and avid skier Ted Kerasote lives in Wyoming. His most recent article for Audubon, *"The Untouchable Wild," appeared in September-October 1999.*

A Flurry of Numbers

Summary
Mathematical calculations, from simple to complex, are performed using SNOTEL data.

Objectives

Your students will be able to…
…demonstrate competency in a variety of mathematical operations
…apply their mathematical skills to generate evidence in support of contentions about snowpack and water supply

Materials and Set Up

White board, easel paper or other means of demonstrating and practicing as a whole group
Highlighters, pencils and/or pens, paper
Calculators (if desired)
Computer with Internet web-browser, for access to additional data

A setting, indoors or out, suitable for whole group, small group and individual work.

Procedure

Several suggestions for mathematical operations with SNOTEL data are listed below, with instructions for data analyses and displays. This is by no means an exhaustive list.

Amounts of Water from Precipitation Events:

For data from your selected SNOTEL site, open "Precipitation, Accumulated—Current Water Year—Daily Table" from the "Site Information and Reports" page. Once you have the table available, scan it for changes in the accumulated total, which is in inches of precipitation. Figuring amounts of precipitation during a period of time are found through subtraction. We give three easy examples here.

Daily

Inches	Date	Time
28.5	Jan 28	0400
27.0	Jan 27	0354

1.5 inches of precipitation fell on Jan 27 (actually between 3:54 AM on the 27th and 4:00 AM on the 28th)

Weekly

28.5	Jan 28	0400
25.0	Jan 21	0345

3.5 inches for week of Jan 21

Monthly

35.0	Mar 1	0310
29.0	Feb 1	0333

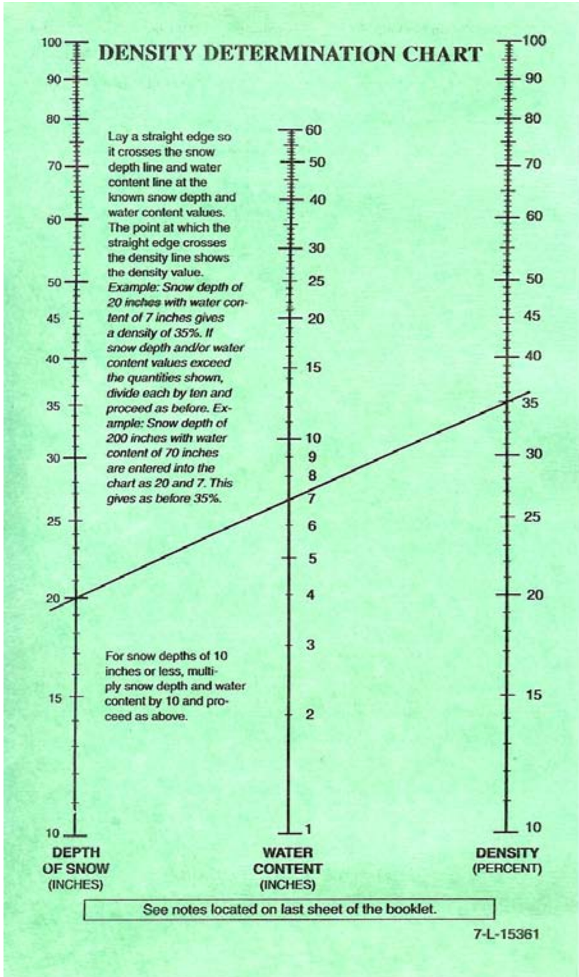
6.0 inches for month of February

Students could correlate this precipitation data with temperature data to predict whether the precipitation event was rain or snow. Then, SWE and snow depth data could be used to corroborate.

Density of Snow:

If one knows the snow depth and SWE from a site, the snow's density can be quickly calculated. Simply divide SWE by depth, then times 100 to convert to a percentage. Or, use the following "Density Determination Chart," which is taken from NRCS's "Snow Survey Notes" booklet used by all snow surveyors in the field.

Snow density can range from under 10% (dry newly fallen) to nearly 50% (very wet, melting). Ice has a density of roughly 90% (that is why ice cubes float in water). In mid-winter, the average snowpack will have a density of 20% to 30%. Older students may enjoy estimating snow densities throughout the season, based on SWE readings and inferences about snow depth.



Discussion

1. Compare the daily precipitation and/or SWE for one storm at two different SNOTEL sites. Also, use the precipitation that fell in your town or at your school and compare the amount to the SNOTEL site. Is there a relationship?
2. When a SNOTEL site malfunctions and fails to report that day's data, hydrologists have to estimate missing data by using a nearby SNOTEL site. Try estimating one site from another site for a storm event or even a week using ratios or "percent of average" discussed in Question 3. This could also be done using a simple regression with y = SNOTEL site to estimate x = the comparison SNOTEL site. How close are you when compared to actual data readings?
3. Compare the first of the month SWE readings to the 30-year average. What is the percent of average? Does it compare to the NRCS calculation?
4. What are some of the factors affecting the density of snow? Would the snow density be the same from the top to the bottom of a deep snowpack? Why or why not?

Scalar Bulletin Board Plotting:

Construct and place a vertical scale on a bulletin board for:

1. accumulated precipitation (from October 1 to date)
2. accumulated SWE (from October 1 to date)
3. acculumated snow depth (from October 1 to date)

at your SNOTEL site. You may use full scale—if you have enough height for the anticipated snow depth. Or, make a scaled-down version, for example where one foot equals one inch (12:1). Have students make the conversions. You may also wish to put up similar scales for both your SNOTEL site and your school location. Construct a pointer for each scale. When current data are retrieved, move each pointer to show the amount of accumulation to date.

BEARTOOTH LAKE SNOTEL SITE

Precipitation (inches)	Snow Water Equivalent (inches)
--50	--50
--	--
--45	--45
--	--
--40	--40
--	--
--35 ←	--35
--	--
--30	--30
--	-- ←
--25	--25
--	--
--20	--20
--	--
--15	--15
--	--
--10	--10
--	--
-- 5	-- 5
--	--
-- 0	-- 0

Discussion

Several observations and points of discussion can be drawn from this activity. These include:

1. It is interesting to watch the total depth of the precipitation and snow water accumulate. For younger students, the concept might be clearer if the 0 inch line is placed at the floor level. Make predictions each month for the season totals.
2. Why is it that the accumulated precipitation is greater than the SWE resting on the snow pillow? How much difference is there? Why is there a difference? What

factors affect this difference? Why would a few sites have a greater SWE on the pillow than accumulated precipitation (Hint: think about wind)?

3. If a comparison site is plotted, discuss the factors that might account for the difference we see.
   At least once during the snow season, the SNOTEL site will be visited by an observer. Measurements are taken to make sure that the snow pillow is accurately measuring the amount of snow water resting upon it. Pretend an inaccuracy was found and discuss how might the data be corrected.
4. As the weather warms in the spring and snowmelt begins, the students can monitor the decrease in SWE along with accumulated precipitation remaining the same or increasing. Talk about this relationship. Describe what is happening at the SNOTEL site, to the snowpack in that area, and within the watershed in feeds.

Snow-Temperature Relationships:

There are several mathematical ways of exploring the relationship between snow amount and temperature. These use SWE, precipitation, and temperature data.

On days when precipitation occurs, simple mathematical relationships can be used to estimate the form of precipitation—as either rain or snow. The results can then be compared to the actual data and differences noted. Many of the differences, other than those caused by equipment malfunction, can then be explained by analyzing the extracted data. Refinements to the relationships can also be attempted, by advanced students, to better simulate the actual data (see example #1).

Energy is needed to melt the snowpack and to produce streamflow runoff. Temperature can be accumulated and used as an index of this energy. When snow has attained its maximum potential to store water, it is "ripe." This is referred to in scientific circles as an isothermic condition, meaning the snowpack is the same temperature throughout its depth. The students could plot accumulated degree-days to determine the amount needed to ripen the snowpack and/or to estimate the date when the snowpack will ripen. When this point has been past, the snowpack begins to lose its water content through melting. This continues until the snowpack is completely melted out (see example #2).

Example #1:

From the example SNOTEL data report below, determine the form of precipitation on November 26 and compare the result with the observed water content data.

The amount of precipitation on the 26th was 0.7 inches:

 11.6 inches (11/27 @ 2:58 a.m.)
-10.9 inches (11/26 @ 3:00 a.m.)

0.7 inches (increase)

On 11/27, the previous day's average temperature was 29˚ F. Furthermore, since the maximum temperature was 31˚ F and our rain/snow threshold is normally about 35˚ F, all of the precipitation fell as snow. The observed water content accumulated on the 26th was 0.6 inches.

 1.9 inches (11/27 @ 2:58 a.m.)
-1.3 inches (11/26 @ 3:00 a.m.)

 0.6 inches (increase)

Where did the extra 0.1 inch of precipitation go? Are there minor errors caused by the electronic equipment? Are the snow pillows more accurate than the precipitation gauge? Is 35˚ F the correct rain/snow factor to use? Seek additional information to support your contentions.

SNOTEL DATA REPORT
11/28/89 09:46 PST

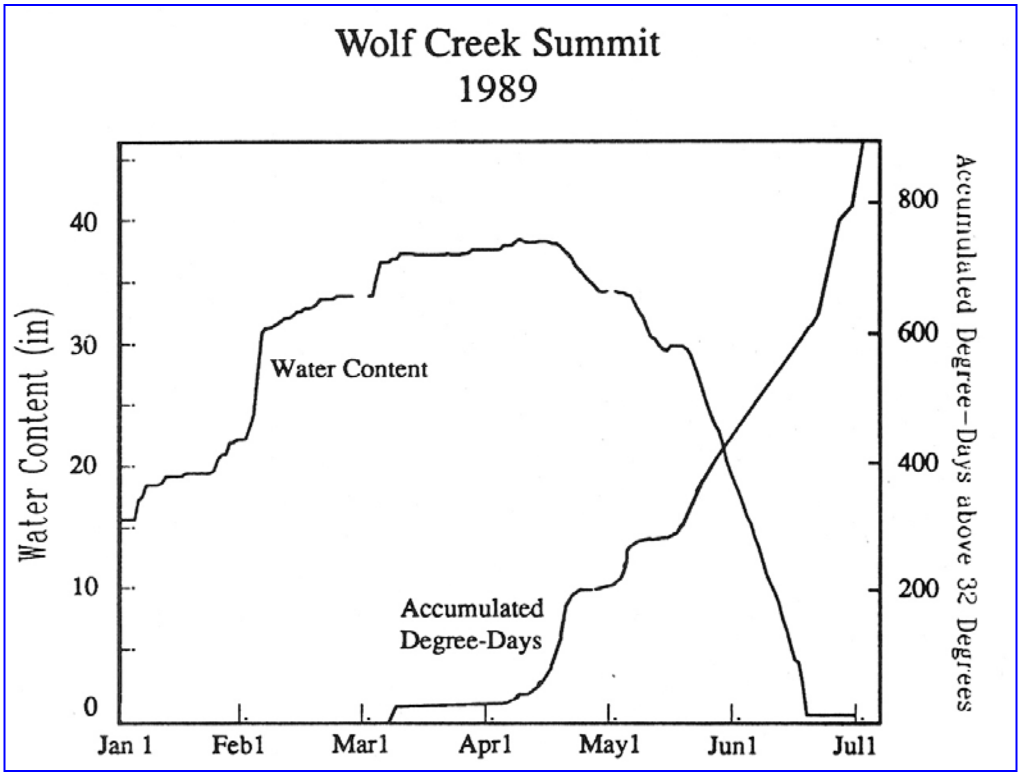
Site Name	MM/DD (PST)	Water Content	Precip (YTD)	AM Temp	Previous Day-Max	Previous Day-Min	Previous Day-Avg
SANTIAM JCT	11/24 0302	0.0	9.0	31	37	28	33
	11/25 0301	0.4	9.8	30	33	30	31
	11/26 0300	1.3	10.9	30	34	30	31
	11/27 0258	1.9	11.6	30	31	28	29
	11/28 0257	2.2	11.8	26	43	22	32
HOGG PASS	11/24 0307	1.6	9.3	26	39	27	32
	11/25 0306	2.6	10.4	27	39	27	32
	11/26 0305	3.4	11.4	26	31	26	28
	11/27 0249	4.3	12.2	26	27	24	25
	11/28 0248	4.2	12.3	23	35	26	29

- ➔ Precip (YTD) – October 1 to date
- ➔ Water Content and Precipitation is recorded in Inches.
- ➔ Temperature data recorded in degrees Fahrenheit.
- ➔ Current days SNOTEL data posted after 6:30 PST daily.

Example #2:

The example graph below is a SNOTEL site in southern Colorado. The SWE was plotted against the accumulated degree-days. The same data could be plotted for other years to see if the same snow-temperature relationship exists. Students might also be able to establish a relationship between accumulated degree-days and the date when the snowpack is ripe. In this example, the snowpack ripens or turns isothermal in mid-April.

Students could also plot streamflow from a location in or adjacent to the basin where the SNOTEL site is located to observe how the snowmelt processes affect the spring runoff.



Discussion

The form in which precipitation occurs is particularly important in snow hydrology. Surface air temperature is as reliable as any other variable for differentiating between rain and snow. Scientists have learned the differentiation between rain and snow can be estimated from surface temperatures by assuming rain to occur whenever the air temperature is 35˚ F or greater and assuming snow to occur whenever the air temperature is less than 35˚ F. About 90 percent of the cases would be correctly designated by this 35˚ F division between rain and snow.

Temperature indexes have been widely used to estimate snowmelt. The purposes of indexes are to allow a readily observed measurement to represent a physical process not ordinarily measured, such as the melting of snow into liquid water. In areas where snowmelt is an important factor in runoff, air temperature measurements are the only data available from which snowmelt can be estimated. So, temperature indexes are the most widely used method of computing snowmelt. The most commonly used index in relating snowmelt to temperature is degree-days above freezing. That is, accumulated mean daily temperature in excess of 32˚ F. Your SNOTEL data can be used to determine the number of degree-days above freezing at your site, which will then give a good indication of when the snowpack will begin to melt.

Histograms and Graphs:

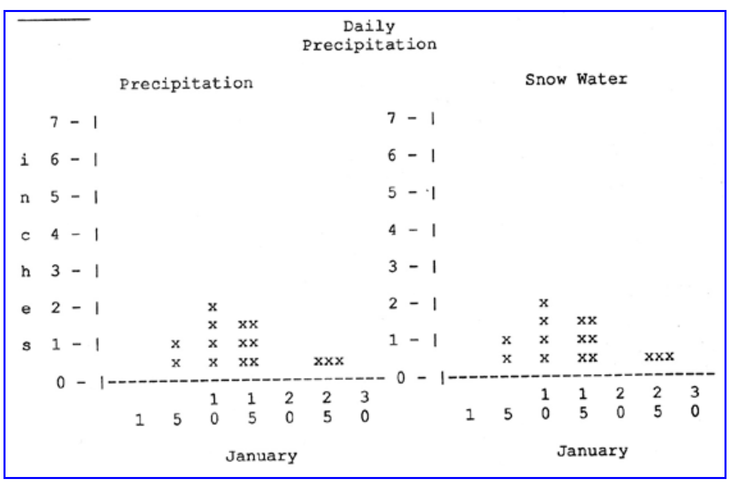
Histograms (bar charts) are useful for displaying the amount of precipitation and snow water accumulated over a specific period of time. Histograms can easily be maintained for:

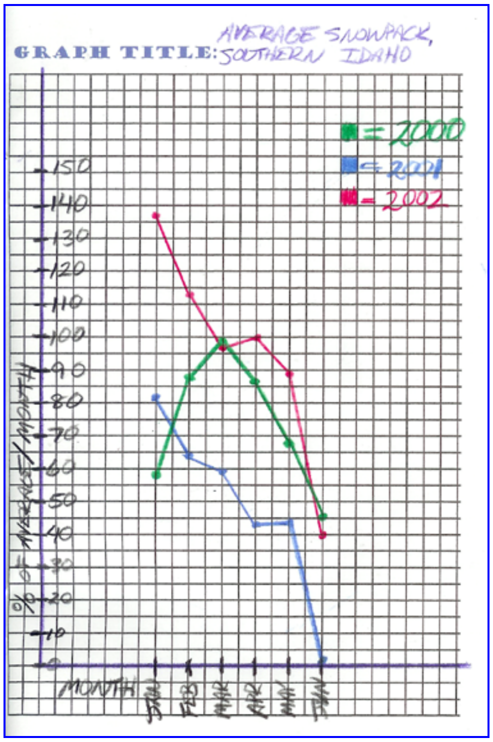
1. daily accumulation
2. weekly accumulation
3. monthly accumulation

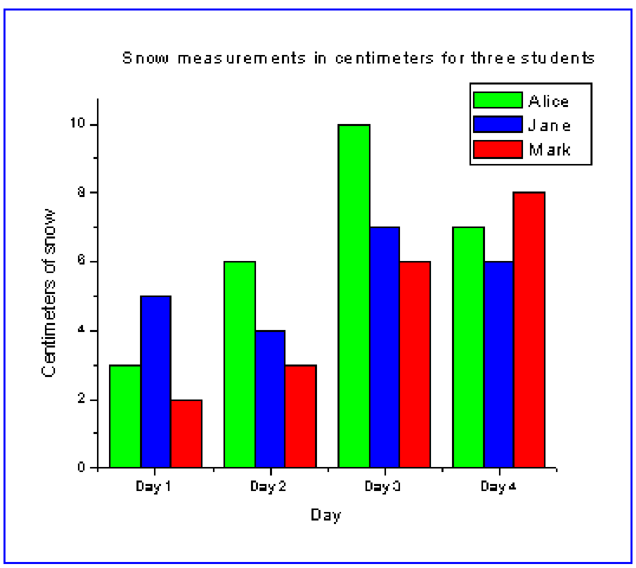
Construct histograms for each of the above periods. The ordinate (x-axis) will reflect time (one month for daily, one year for weekly and monthly plots). The abscissa (y-axis) will be scaled in inches. The range of the abscissa will have to be different for each period as the likely accumulation will be larger as the period increases.

When SNOTEL data are retrieved, update each of the histograms. To do this, the change in accumulation will have to be calculated for each of the periods. If data are retrieved weekly, seven daily accumulations and one weekly accumulation must be calculated and plotted. Save the first of month readings to calculate and plot the monthly accumulation.

Samples of student histograms and graphs







Discussion

Several topics can be discussed using simple graphical displays of data. These include:

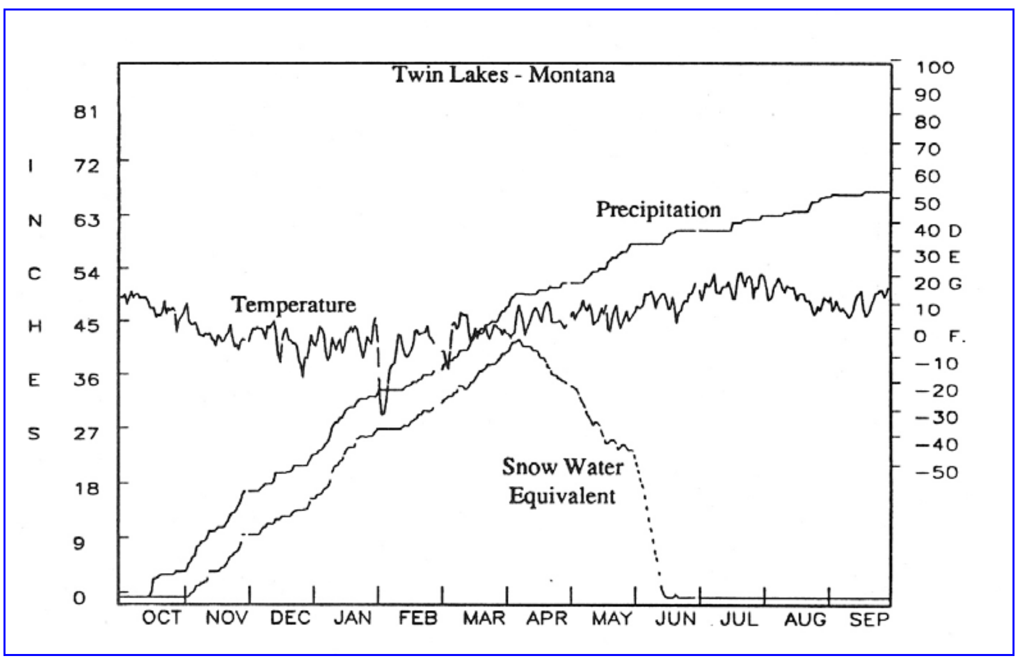
1. Discuss and decide what scale is appropriate for each axis, considering the type of data to be displayed and the length of time being represented. Discuss why it is important to have each scale begin with a zero value.
2. Relate each of the scales to local weather conditions during the past (1) few days, (2) week, and (3) month.

3. Compare daily, weekly, and monthly histograms/graphs. See how daily weather events affect the weekly histograms and how weekly conditions affect the monthly histograms.
4. Compare accumulated precipitation and snow water collected at your SNOTEL site and your comparison SNOTEL site. Discuss factors which may contribute to any observed differences.
5. Compare accumulated precipitation and SWE at your SNOTEL site. Notice that before temperatures become cold enough to accumulate snow, the accumulated precipitation may increase while SWE remains at zero. During mid-winter, accumulation of precipitation and SWE should be quite close. Discuss why this is the case and what might cause them to be slightly different.
6. Notice that once the snowpack has begun to melt, the accumulation of snowpack becomes negative and loses its comparative value with respect to accumulated precipitation. Having students draw a cross-section of a melting snowpack might help establish this spring-time relationship. Consider where the meltwater goes.

Time Plot Series

Using data from your SNOTEL site and at least one other for comparison, students can graph current conditions comparing values over time. Three distinctively different graphs can be made for precipitation, SWE, and temperature (Precipitation vs. Time, SWE vs. Time, and Temperature vs. Time).

EXAMPLE



Discussion

1. The graphs are useful for visualizing and comparing trends, such as lower temperature in winter and snowpack peaking around April 1. A variety of graphs and relationships can be realized by overlaying different graphs on one another. By graphing precipitation and SWE together, see how data values parallel each other until the snowpack starts to melt. Add temperature to observe its relationship with the snowpack (see Snow-Temperature Relationships). For SNOTEL sites where historical data are available, comparisons between periods and their deviation from normal or from last year can be observed.
2. Generally, a snowpack reaches its maximum SWE and becomes isothermal (equal temperature from top to bottom and about 32˚ F) around April 1. When a snowpack becomes isothermal, it begins to melt. The melt phase takes place at a constant rate, unless there is a cold spell or a large precipitation event. After the first week of the melt phase, use the graph line's slope to try to predict the exact day the SWE will reach zero.
3. Make a plot of temperatures—maximum, minimum, and average, verses time and observe their relationships.
4. Using the past year's data for your SNOTEL site, graph the current year's SWE and a high year's data of SWE on the same graph. Try it with a low water year also. For historic examples, use water year 1984 as a high and water year 1977 for a low. These were high and low years respectively in terms of SWE, for many western states.

Estimate Snow Loads:

Snow survey data can be used to help determine the weight the snowpack exerts at and near a site. To determine the snow load, one needs to know how much the snowpack weighs. The weight of the snow varies with water content of the snowpack.

One could isolate a column of snow, melt it, and weigh it to determine the weight over an area. This is very difficult, however, especially if the snowpack is more than 5 feet deep. It is almost impossible at depths of 10 feet or more. The average weight of water at 32˚ F is 62.418 pounds per cubic foot.

NRCS uses an easier method to determine snow loads. Using a set of snow measuring tubes, accurate measurement of SWE relies on the following formula. Many NRCS Field Offices (one is located in most counties) have snow tubes and can assist you in determining snow load information.

The full formula:

$$\frac{(1\text{ US gallon})}{(0.1337\text{ ft}^3)} \times \frac{(1\text{ ft}^3)}{(7.48\text{ gallons})} \times \frac{(62.418\text{ lbs})}{(1\text{ ft}^3\text{ of water})} \times \frac{(1\text{ ft})}{(12\text{ inches})} \times \text{SWE (inches)} = \text{Snow Load (lbs/ft}^2)$$

The simple formula:
…just remember the conversion factor of "5.2" (or rounded to 5) to multiply the SWE value to estimate the snow load.

SWE (inches) X 5.2 = Snow Load (pounds/square-foot)

SWE amounts can be quickly obtained through SNOTEL (SNOw TELemetry) data available on the Internet. The following table illustrates some ground snow loads.

Ground snow loads for selected measuring stations, Idaho Panhandle Region, 1997

Site Name	*Elevation (feet)*	*Date*	*Depth (inches)*	*SWE (inches)*	*Average SWE*	*Snow Load (pounds/foot^2)*
BENTON MEADOW	2370	1/03/97	37	11.8	2.7	61
BENTON SPRING	4920	1/06/97	65	22.0	8.0	114
SCHWEITZER BASIN	6090	1/01/97	114 est	41.4	22.1	215
LOST LAKE	6110	1/01/97	150 est	48.8	25.8	254
LOST LAKE	6110	4/01/97	230 est	97.9	63.2	500

The snow load calculated above is for ground snow loads and will provide an indication of the roof snow load. Roof snow loads can vary depending upon melting and re-freezing of snow and ice, roof slope, type of roof, aspect, drifting, etc. Building codes vary depending on the elevation zone and amount of snow and precipitation that falls. Building codes may also vary depending upon the codes in effect when the structure was built.

Students could contact city or county agencies for specific building codes in their area and the codes in effect when the structure was built. Calculating a snow load for your school building might be enlightening.

Additional rain on snow can quickly increase the snow load because a snowpack can absorb rain until its density is about 45%. Typically, snowpack is about 25-30% dense in January and 40-45% dense in April. The snowpack will start melting when the density is about 45%. New snowfall has an average density of 10%, *i.e.*, 1 inch of snow water or rainfall = 10 inches of new snowfall.

Assessment

Have students write a one-paragraph explanation of each mathematical operation they demonstrated. What do their calculations show? Why was this data analysis useful? How might they apply these mathematical lessons to more SNOTEL data? Collect student worksheets and explanations for teacher review.

Extensions

- Younger students can be guided to use SNOTEL data for practicing reading measurements from instruments, deciphering graphs, understanding place values and decimals, comparing amounts, etc.

- Older students can be encouraged to think of mathematical operations and statistical calculations as tools in their toolboxes to be selected and used within larger, long-term studies of snow and water supply.

Schoolyard Snow Surveying

Summary
Students work as a team to create their own version of a SNOTEL site. They place instruments, take routine weather-related measures, and emulate the work of NRCS snow survey professionals.

Courtesy of Pocatello Community Charter School

Objectives

Your students will be able to…
…cooperatively select a suitable spot for snow measurement instruments on the school's grounds
…use the instruments regularly to collect accurate data about weather conditions
…assemble the meteorological data into useable information
…analyze their data to explain conditions over time and make supported predictions about water supply
…understand the role of reliable data in water management

Materials and Set Up

For outside:

Snow depth measuring device (Schoolyard Snow Survey Cylinder, snow depth pole, or snow course)
Precipitation gauge
Thermometer, preferably with a daily maximum and minimum function
Data recording sheets and writing instruments
Warm outdoor clothing

For inside:

Data collection site, be it a computer, filing system, or large display/bulletin board

First and foremost, you'll need a dedicated snow station on your school grounds. Its location must be in an area with minimal disturbance to the snowpack, yet still accessible by your students. Here you'll place your Schoolyard Snow Survey Cylinder, snow depth pole, and/or have your snow course. The snow accumulating at this station should be representative for your school's location.

In your classroom, it would be helpful—but not requisite—to have a dedicated snow station work area where data compilation, analysis, and display can take place.

Procedure

Warm Up

In the 1980s, teachers and NRCS employees in Alaska piloted a cooperative program wherein schoolchildren collected climatological data from instruments at the schoolyard. This activity is based on the methods of that program.

Ideally, this activity will take the form of a year-long project. Steps in such an ideal case would be:

- Overview of SNOTEL site equipment and data
- Acquiring, fashioning, and placing your instruments
- Learning how to take measurements
- Establishing data collection routines
- Selection of a location on your school grounds for a snow measurement station
- Compiling data
- Analyzing data
- Reporting information and giving descriptions
- Making predictions
- Reviewing reliability and accuracy of your station operation

Portions of this long list of tasks can make for educational experiences almost as valuable as a full-blown long-term study. Consider your curriculum, the place of snow monitoring in it, and plan an appropriately sized project.

Activity

1. At the outset, you'll want to review the make-up of a typical SNOTEL site (pp. 2-4), noting the standard equipment—snow pillow, precipitation gauge, air temperature sensor, data logger, and radio transmitter. Review the three primary types of data collected:

- Snow-Water Equivalent (SWE)—A SNOTEL site's snow pillow weighs the accumulated snow resting on it. Then, measuring devices inside the shelter house automatically convert this into a reading of the water content of the snow. SWE is the amount of water contained in the snowpack if it were melted, so it represents the potential available water that will be released during spring and summer melting. To determine SWE, you need to know at least two of the following: snow depth, snow weight, snow density, or volume of snow. Another way to think of this is that SWE is dependent on at least two other types of data. An algebraic function of the two known variables can be solved to reveal the SWE. Equipment suggested here will give you a few options in gathering the needed data to figure SWE.

- Precipitation—Come rain, snow, sleet, hail or graupel, the amount of water falling from the sky is of vital importance to the ecology and economy of any given place. At SNOTEL sites, a sophisticated storage gauge measures precipitation in all its forms throughout the water year. For your schoolyard survey, you'll devise a simpler but functional piece of equipment.

- Temperature—In place of the heavy-duty air temperature sensor at SNOTEL sites, you can use an off-the-shelf thermometer. One that allows gathering of a daily maximum and minimum would add to the complexity of your data, deepening the depiction of climate you'll be able to deduce.

2. Discuss possible means of gathering these same types of data at your school. Record the ideas your learners have. Share with them the instruments available for their use in their own Schoolyard Snow Survey, pointing out similarities to their own ideas.

    - Schoolyard Snow Survey Cylinder—Developed in Alaska for use by schoolchildren, the Schoolyard Snow Survey Cylinder, including a 42-inch collecting tube and wind shield, is commercially available from its manufacturer, Plaschem Supply & Consulting Inc., 1415 Spar Ave., Anchorage, AK 99501 (Phone: 907-274-5505 and e-mail: plaschem@aol.com). Price is $510.00.

    - Snow depth pole—A piece of lumber at least as hefty as a 2 x 2, a reinforced yard stick, or dowel rod marked with measuring units firmly inserted into the ground will become your class's snow depth pole. An array of three poles can be devised to both share the data collection and practice with averages, once you have data. Make sure your pole can stay upright and firm in extremes of temperature, wind, and snow weight, as well as some pushing and pulling by curious hands.

    - Snow course—Collecting more than one snow depth measure and figuring an average is the central task used originally by predecessor scientists of the

NRCS. In fact, several hundred snow courses are still maintained by NRCS. For a schoolyard snow course, you'll need to have an area, at least 25 feet long and 10 feet wide, when the snow will not be disturbed. For taking a measurement of snow depth, students will take at least five readings using a yard stick, dowel rod, or other measuring device. From the readings, an average (mean) is calculated and used as the snow depth for that day. Careful not to ruin the snow for next time!

You'll need (at least) one method of measuring the depth of snow and another for measuring another variable such as snow density, so as to provide enough data to calculate SWE. Determining the best method for your situation can be a good group decision-making for your class. Make sure they also understand the algebraic function needed to convert the data you'll collect to SWE. This may take some step-by-step practice—both for the students and you!

- Thermometer—In place of the heavy-duty air temperature sensor at SNOTEL sites, you can use an off-the-shelf thermometer. One that allows gathering of a daily maximum and minimum would add to the complexity of your data, deepening the depiction of climate you'll be able to craft. Another alternative is to find an in-place thermometer near your school, from which data can be accessed as needed.

- Precipitation gauge—Many models of rain gauges are available from scientific supply companies. Or, you can craft your own. For regions where snowfall is the dominant form of precipitation in winter, a clear plastic cylinder attached firmly to a solid base and marked with measurement units fits the bill. The cylinder will need to be watertight—try a substantial bead of silicon caulking—and will need to have a base layer of about an inch of antifreeze solution in the bottom. The antifreeze allows all forms of precipitation to be caught and will melt the snow so you'll be able to get an accurate reading.

  Previous schoolyard snow surveyors report that a cylinder dimension of 8 inches in diameter by 40 inches tall work well. The orifice is a "standard" dimension and allows an accurate catch of snowfall; the height is sufficient to provide a complete schoolyear's catch of precipitation at the majority of locations, and puts the orifice at a height (approximately 7 feet) about the reach of vandal's hands, yet the fluid level is generally about eye level.

Bring this discussion—which can easily grow into a multi-day investigation in and of itself—around to reach agreement on your snow station's instrumentation. Reach consensus on the measuring devices your group will use to measure SWE, precipitation, and air temperature.

3. After your specific array of instruments is selected, consider how your team will cooperate to accurately and reliably collect the needed data. Outlining the goals

for your Schoolyard Snow Survey. Agree on the types of data you'll need to collect. Daily readings of snow depth, temperature, and precipitation should be taken. SWE can be calculated less frequently—weekly, biweekly, or month. If you have an advanced group, however, SWE could be calculated every day.

4. Commit your Schoolyard Snow Survey plan to writing, so all are in agreement on what will be done. One way of doing this is via an assignment board, in the open for all to see. Work as a group to make assignments and establish routines. This teambuilding is aimed at getting buy-in, creating ownership, and increasing relevancy.

5. Select the specific place at your school for the snow station. Site selection is crucial, as the spot needs to minimize potential for disturbance and drifting. At a good spot, the snow collects uniformly. Examine options and reach consensus on exactly where your Schoolyard Snow Station will be.

You may find your group leaping forward, past instrument selection and building to site selection. In some case, this may work. In others, the teacher may need to rein the group in and keep them moving at a better pace. Use your facilitation skills to make sure both of these tasks get accomplished, regardless of the actual order.

6. Build your station!

7. Begin the routine of daily data collection. Each school day, a designated student team takes temperature, snow depth, and precipitation readings and records these data at the inside snow survey work area. This task should become routine and, ideally, be accomplished in no more than 15 minutes.

   A daily survey team could consist of two to four students whose term lasts about two weeks. Each week half the team is replaced with new members, thereby staggering the turnover, providing training and continuity. Tell the students that NRCS tries to do this exact same thing with their snow surveyors; new workers are taught by those with experience. The job then may rotate several times around the classroom, or be passed from one class to another class, so that an entire (small, rural) school could potentially be involved.

   At your selected time interval (day, week, two weeks, or month), calculate the SWE. As with most of the steps in this activity, you have options: working individually, in small groups, as a whole.

   A sample data collection sheet is included at the end of this activity. There's a blank, for you to duplicate, and a completed example.

8. Monitor the group to make sure routines are followed. Data quality assurance and control will, except among mature students, rest mostly with the teacher(s). You'll

need to be looking over your students' shoulders checking for accuracy and reliability. Please mention to students that NRCS scientists also have their data reviewed, checked and monitored by others. Openness and peer review are two characteristics of the scientific endeavor.

9. After gathering data for at least one week, open the discussion of analysis and reporting.

   Discussion
   - Now what can we do with these data?
   - How can we produce useful information using the data?
   - What can be done with the data to make it more meaningful?
   - What kinds of reports can be generated with our data?
   - Based on the NRCS reports for your adopted SNOTEL site, how can you analyze and present your schoolyard data to allow easy comparisons to be made?

10. Work on data analysis and compilation into reports. There are many graphing possibilities, as well as other operations as noted in "A Flurry of Numbers" (p. 91). Reporting ideas we've seen include:

   - a school year-long graph of daily temperature maximum and minimums. Add in the temperatures from your adopted SNOTEL site for more interest. Add historical data from both the adopted SNOTEL site and a nearby weather station (which will require some investigation to locate), and you begin to build an basis for understanding climate and deviations over time.
   - a full-size wall-covering graph of snow depth. Through the water year, students have an ever-present visual reminder of the snowpack in the mountains near them and around their school.
   - use of the school's snow data to build predictions of spring and summer streamflow in the local river. Then, this prediction is used as the basis to recommend for or against stocking of trout that year. The recommendation was presented to the state fisheries agency.

11. No type of data from SNOTEL is more important than SWE. To find SWE manually, NRCS scientists use snow tubes, precision engineered samplers made of sectional aluminum and scales. These tubes cost about $2,500 each, way beyond classroom supply budgets! An alternate method has been devised specifically for schools.

    For figuring the SWE, here's the original procedure from the Alaska Schoolyard Climatological Data Collection Program for figuring water content from a snow core sample:

STEPS TO DETERMINE SNOW WATER-CONTENT BY MELTING A SNOW CORE

1) Preliminary Step—Prior to first snowfall, select designated snow measurement area. This must be a place where the snowpack will not be disturbed. Wind effects (snow redistribution) should be minimized. The ground surface should be smooth, level and groomed (eliminate brush, rocks, gravel, etc.). A lawn is ideal. Mark, sign or fence off, if necessary.

2) Normal Procedure

a) At survey time, dig a small pit (24 inches square, or so) to the ground surface. Disturb no more snow than necessary. You will want to save all the undisturbed area you can for future measurements (unless space is not a problem).
b) Shove cylinder, open end down, vertically through the snow profile just beyond the edge of the pit.
c) Read snow depth to nearest half-inch and record.
d) Remove snow away from wall of cylinder on pit side.
e) Carefully insert small, flat aluminum shovel piece of tin, or the like, between bottom of cylinder and ground surface to act like a cap.
f) Tilt cylinder and cap into pit, holding cap in place and being careful not to spill any of the snow core, reinvert so core slides to bottom.
g) Note length of snow core and record.
h) (Optional) If core length is less than half cylinder length, dump core into plastic garbage bag and obtain second sample. If room for three cores, get three samples. (There is enough natural variability in the snow pack that adjacent samples are rarely exactly the same. Several samples give a better average of the pack.) Dump all snow cores back into cylinder.
i) Take indoors to melt snow core.
j) Monitor time for complete melting so water depth can be recorded soon after disappearance of all ice. It take quite a while at room temperature. If it takes overnight, don't sample on Fridays.
k) Read water level and divide by number of samples to obtain snowpack water-content and record.
l) Divide average water-content by average snow depth to obtain snowpack density and record.
m) Send copy of snow survey notes (and precipitation gage readings) to NRCS (in Alaska send to nearest

field office or Anchorage state office), or to central collection point.

3) Deep, Hard, or Icy Snow Conditions
   a) If hard or crusty layers are present in pack, making insertion of cylinder difficult, or if snowpack is deeper than the length of the cylinder, remove snow core same as above, but in stages.
   b) Shove cylinder down to hard layer and stop.
   c) Insert shovel at top of hard layer and carefully remove cylinder as before and turn open end up.
   d) Cut out slab of the hard layer larger than the cylinder opening and place over the opening.
   e) Press down with bottom of shovel causing cylinder to cut through hard layer allowing piece to fall inside.
   f) Dump this much of snow profile into plastic garbage bag and save.
   g) Continue down through snow profile in like manner until ground surface is reached. Record snow depth.
   h) (Optional) Repeat steps 1-7 for several more samples, up to no more than that will all fit in cylinder at once.
   i) Dump all snow in plastic bag back into cylinder, thaw and record as before (for deep snow, pack snow back into cylinder or only thaw half at a time).
   j) Send copy of notes and precipitation gage readings to NRCS or central collection point.

4) Shallow or Highly Variable Snow Conditions
   a) Take 10 samples, dumping each snow core into the same plastic bag. Record depths of all samples.
   b) Dump snow cores of all samples back into cylinder, thaw and record as before.
   c) Divide final water-level and total depth by number of samples to determine average of each.
   d) Send copy of notes and precipitation gage readings to NRCS or central collection point.

When your class is able to work together regularly to find SWE data that's accurate, you've got a snow surveying team to be proud of!

Wrap Up

Compare your school's yearlong data with a selected SNOTEL site (or two, three or more). Use all the snow data to make predictions about the water supply for your watershed for the coming summer. Share your predictions with water users: other students in your school, parents, city/county officials, farmers and ranchers, recreational river users, etc. Check with the NRCS—via the Internet or personal contact—to see how your class predictions match up to theirs.

Assessment and Extensions

This activity does not lend itself to a set procedure. Each and every group will have their own customized Schoolyard Snow Survey. You and your learners will undoubtedly have lots of ideas about the size and shape of your project.

Because of this, we find it difficult to note concrete assessment techniques and explicit extensions. Certainly, students who have met the objectives will be able to express their competencies through data collection and manipulation. Higher-order thinking skills are demonstrated by evidence-laden reports, filled with descriptions and even predictions borne out by the measurements made. One thing to keep in mind is that water supply prediction sometimes baffles even the experts. We invite you to consult with NRCS staff at any point in your Schoolyard Snow Survey adventure.

U.S. Department of Agriculture
Natural Resources Conservation Service

SCHOOL YARD SNOW SURVEYS

School____________________________ Class __________________
Drainage Basin ________________________ State ____________
Sampler(s) __________________________ Note Taker ______________
Date ______________________ Time ______________ Temp _______________

Sample Number	Depth of Snow (inches)	Length of Core (inches)	Water Level (inches)	Density Percent	Remarks

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCHOOLYARD

SNOW SURVEYS

School: Abbott Loop Elementary Class: Mr. Smith
Drainage Basin: Cook Inlet State: Alaska
Sampler(s): B. Brown J. White Note Taker: E. Black
Date: March 1, 1989 Time: 11:00 AM Temp: 27

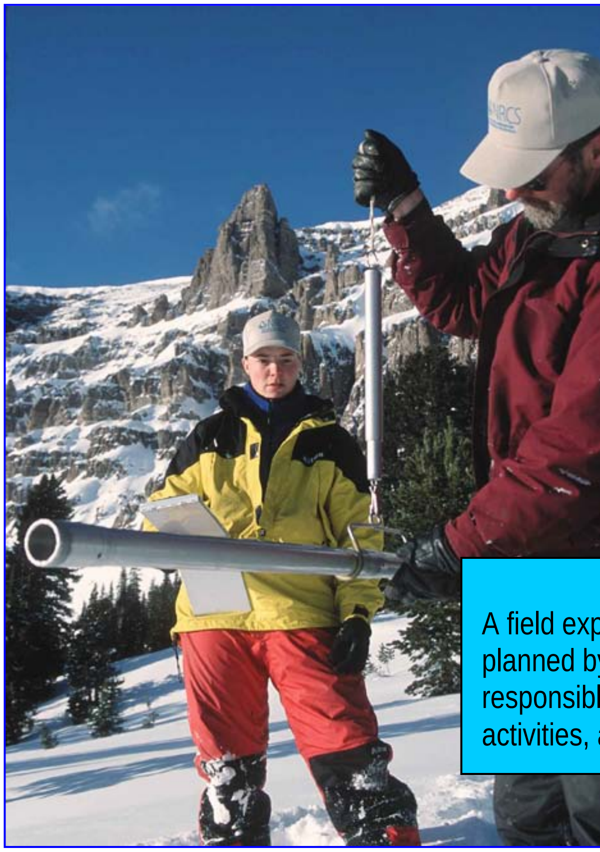
Sample Number	Depth of Snow (inches)	Length of Core (inches)	Water Level (inches)	Density Percent	Remarks
1	12	11			crust at 7"
2	12.5	12			crust at 7.5"
3	11	11	9.3		ice layer at ground surface
Total	35.5	34			(snow cores from all 3 samples melted together)
Average	11.8 (12)	11.3	3.1	26.3%	4" new snow rabbit tracks in area
					etc.
OR					no new snow
1a	26	24			wind blown snow surface
1b	27	25			crust at 38"
Total 1	53	49	16.4	30.9%	(snow core from both samples packed into cylinder for melting)
					extracted pine cone after melting

EXAMPLE

EXAMPLE

Schoolyard Snow Survey data sheet sample

Plan an Official Visit



Summary
A field experience to a SNOTEL site is planned by the students. They can be responsible for the logistics, trip-related activities, and contacting NRCS.

Warning!!!

SNOTEL sites are located in remote areas. Casual visits to a site can be hazardous to those not familiar with the area and not properly equipped. The dangers can be intensified by sudden winter storms, avalanches, and other hazards. Teachers should be careful not to inadvertently suggest or condone a site visit without supervision for the students. Visits at any time of the year should only be undertaken after coordination with your local NRCS office.

Your students will be able to…
…safely plan an educational visit to a SNOTEL site
…locate the site's exact location and map a route to it
…secure the necessary permissions and assistance from NRCS
…consider and select learning activities for field experience, including possibly a service learning component

Materials and Set Up

Maps, including road maps, topographic maps, etc (On-line services such as Mapquest might be sufficient)
Telephone and directory for contacting NRCS
Transportation to and from the SNOTEL site
Permission forms, trip journals, worksheets, guidebooks, etc., devised for the various activities selected to be part of the field experience
Writing utensil and clipboards

Procedure

Warm Up

After gaining some familiarity with your adopted SNOTEL site through the on-line information, ask the students if they would like to ask NRCS for a live and in-person visit to your site (or a similar, more accessible site in many cases). This question will likely elicit an enthusiastic affirmative response from your group. Then, let the students know, the planning and execution of the trip will be up to them (if such a field experience is possible given your school's off-campus policies).

Activity

1. Lay out the multiple tasks necessary in planning an educational field experience. Generate a to-do list with your students. We suggest five steps, each with many items, to assure a high quality trip. The first four of these steps constitute the activity and the final step, the wrap up.

2. Plan ahead (at least two months lead time).
    a. Have students contact NRCS as early in the planning as possible. Either contact your state's snow survey staff or the closest NRCS office. NRCS offices are often located within USDA Service Centers, under "Federal Government—Agriculture Dept." in the government listings of a phone directory.

       NRCS staff will be able to advise you on the timing of your trip. Some SNOTEL sites can be reached by school groups during the winter, while others can not be accessed until after the snow melts. For most, there is a muddy period during which visits would be messy and more risky.

    b. Allow students to take part in your school's administrative process to the extent feasible. For example, they might be able to invite your principal into the classroom and ask for permission for the field trip. They could also recruit parents and other adults to serve as chaperones.

c. Develop a resource file of information for the trip. Here you'll place maps, data sets and reports, important phone numbers, etc. Students should determine the most efficient route to the site and map their route. (Ask your NRCS contact for the "mileage log" for the site you'll visit. This document will help with this task.)
d. Decide on your trip's date and make transportation arrangements.

3. Preparation (four to six weeks before the trip).
   a. Ask the NRCS staff to be prepared to orient you to the equipment at the site and tell about their work.
   b. Develop learning activities to take place as part of the trip. There are many possibilities here. A few ideas:
      i. Each student carries an observation worksheet and lists the plants and animals they see and hear.
      ii. Students figure the distance they hike into the site—either estimated from a map or measured by a pedometer—and calculate the calories burned.
      iii. The group disperses for a few minutes around the site and takes time to reflect, journal or draw.
   c. If helpful, map the trip's objectives and learning activities to your curriculum.
   d. Continue to generate interest with the students, even as they work on the nitty-gritty pre-trip details.

4. Short-range preparation (two week before the trip).
   a. Verify the dates with NRCS, your school administration, and others involved. Send home permission slips.
   b. Work with students to develop a list of "do's" and "don'ts." Involve them in the process of determining expectations. This is especially important in this case, as SNOTEL sites are most often located in rugged terrain. The list of "do's" should include proper clothing, sturdy footwear, sunscreen, and insect repellent. A brown-bag lunch may also be needed, considering the travel time.
   c. Make sure you know where you're going. This may sound self-evident, but SNOTEL sites are notorious for being tough to locate.

5. Make your official visit to a SNOTEL site. Have fun and learn a lot!

Wrap Up

Have students share their products from the learning activities in the days following the trip. A whole group product may also be in order. Try:

- Putting together a trip journal, with student writing, drawings, and photos.

- Creating a bulletin board.
- Presenting your findings to other students, parents, or other water users in your community.

Assessment

Field experiences lend themselves nicely to pre-test/post-test assessments. A short form administered beforehand can ask students about what they expect to see and do. A similar follow-up form can ask what they learned, enjoyed, and how they would improve the experience. Another tried-and-true method is to ask these questions during a group discussion.

As the teacher, you should consider:

- Were our learning objectives met?
- Did the trip reinforce and enrich our in-class activities?
- Did everyone have fun?
- How could the experience be made better?

Extensions

Consider if a service-learning opportunity exists in conjunction with the trip. Picking up litter, removing noxious weeds, repairing gates or fences are all possibilities. Consult with your NRCS contact on this matter.

Section F

Related Topics & Suggested Activities

To assist your searches for additional resources, this section lists related topics and a few educational items for each. The resources included have been referred to us by educators. Each is listed under the topic to which it is most closely tied.

Our aim, with this section of *Adopt-a-SNOTEL Site Program Teacher's Guide*, is to assist you in making connections within your larger curricular framework. Sometimes you need to find a certain kind of activity, book, video, or website, to bridge a small gap in your instruction. We hope our lists might contain just such linkages from the enormous selection of educational resources about snow, snow measurement and water supply prediction.

Please note these lists are no where near conclusive and are not meant to designate any ranking within the materials presented. A listing here does not constitute an endorsement by NRCS. As you might expect, there are literally tons more water education items in existence.

1. Snow's Physical Properties

   The Snow Booklet, A guide to the science, climatology, and measurement of snow in the United States, by Nolan J. Doesken and Arthur Judson (for more information go to http://ulysses.atmos.colostate.edu/~odie/snowtxt.html)

   ISBN #0-9651056-2-8 (2nd Edition) ©1998
   $15.00 plus Shipping and Handling
   Colorado Climate Center
   Department of Atmospheric Science
   Colorado State University
   Fort Collins, CO 80523-1371

   The Kids Winter Handbook, by Jane Drake & Ann Love, illustrated by Heather Collins
   ISBN: 1550749692 Format: Paperback or Hardback, 128pp Pub. Date: October 2001 Publisher: Kids Can Press, Tonawanda, NY

http://www.snowcrystals.com/ —An extensive on-line guide snowflakes, snow crystals, and other ice phenomena

"Snow as a Field-Teaching Medium for Earth Science," Stephan Gregory Custer, *Journal of Geological Education*, 1991 (v. 39, pp. 34-43).

Alaska Lake Ice and Snow Observatory Network, educational project of University of Alaska-Fairbanks (go to http://www.gi.alaska.edu/alison/)

Snow School, an educational program of the Winter Wildlands Alliance focusing on physical pursuits outside in the winter (go to http://www.snowschool.org/teachers/)

Two classic books suitable for young readers—

Secret Language of Snow, by Terry Tempest Williams and Ted Major
ISBN 0-394-86574-X ©1984 Sierra Club/Pantheon Books, San Francisco/New York

Field Guide to Tracking Animals in Snow, by Louise R. Forrest
ISBN 0-8117-2240-6 9 ©1988 Stackpole Books, Harrisburg, PA

2. The Water Cycle

"The Incredible Journey," highly recommended educational activity about hydrologic cycling (go to http://www.montana.edu/wwwwet/journey.html), from *Project WET Curriculum and Activity Guide* (paper• 516 pages [containing 93 activities] • 8.5 x 11 • b&w photos • illustrations • appendix • glossary)
ISBN 1-888631-15-5 • ©1995

Project WET (Water Education for Teachers)
201 Culbertson Hall PO Box 170575
Montana State University Bozeman, MT 59717-0570
Phone toll free 1-866-337-5486 Fax (406) 994-1919
Email info@projectwet.org
Web site www.projectwet.org

"Thirstin's Drinking Water Games & Activities" [CD-ROM], U.S. Environmental Protection Agency Office of Water (August 2004), (for more information on safe drinking water see http://www.epa.gov/safewater/kids/index.html)

"Water Science for Schools," a large on-line collection of educational resources from the U.S. Geological Survey (go to http://ga.water.usgs.gov/edu/)

"The Water Cycle: Nature's Recycling System," USDA NRCS Program Aid Number 1588 [poster], issued 1993 and 1998.

"What is a Watershed?," USDA Soil Conservation Service Program Aid Number 420 [booklet], issued 1994.

Earth: The Water Planet, by Jack E. Gartrell, Jr., Jane Crowder, and Jeffrey C. Callister. Washington, D.C.: National Science Teachers Association, 1992.
ISBN 0-87355-083-8, collection of 18 readings with activities for grades 5-8

"Snow and Tell," educational activity from *Discover a Watershed: Watershed Manager Educators Guide* (paperback / 200 pages / 8 ½ x 11 / b&w photos / illustrations / wall map / appendix / glossary / index), contact:

Contact us at: Discoverawatershed@Montana.edu
6550 Hwy 550 • Durango, Colorado 81301 • Phone: (970)375-9047
or 1001 West Oak Street • Suite 210 • Bozeman, Montana • 59715
Toll Free: (866) 337-5486 • Fax: (406) 994-191
ISBN 1-888631-11-2

3. Soil and Soil Erosion

"All about Soil, Tools for teachers K-12" [CD-ROM], NRCS Soil Survey Division, no date (for more NRCS soil education material see http://soils.usda.gov/education/)

"Tidbits for Teachers and Students, Conservation education material for teachers K-12," main Internet entry point for NRCS educational resources (located on-line at http://www.nrcs.usda.gov/feature/education/)

"Dirt: Secrets in the Soil," a packet of lesson plans from Utah Agriculture in the Classroom (available on-line at http://extension.usu.edu/aitc/teachers/elementary/dirt.html)

"Soil Erosion by Water," USDA Agricultural Information Bulletin 513 [booklet], issued 1987 and 1990.

"Teaching Soil and Water Conservation," USDA Soil Conservation Service Program Aid Number 341 [information and educational activity booklet], issued 1957, 1986 and 1992

4. Water Quality

Project WET Curriculum and Activity Guide (paper• 516 pages [containing 93 activities] • 8.5 x 11 • b&w photos • illustrations • appendix • glossary • ISBN 1-888631-15-5 • ©1995)

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Web site www.projectwet.org

"Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions," U.S. General Accounting Office, June 2004 (available on-line at http://www.gao.gov/new.items/d04382.pdf)

"No Water Off a Duck's Back," suitable activity about water pollution and environmental degradation (from *Project WILD K-12 Curriculum and Activity Guide*) (paperback, 386 pages [122 activities], ©2003, 1992, 1985, 1983 by Council for Environmental Education, 5555 Morningside Dr., Suite 212 , Houston , TX 77005; available at professional development workshops only, see http://www.projectwild.org/)

"Your Hometown Clean Water Tour," USDA fact sheet, issued 1993.

5. Water Conservation

Conserve Water Educators Guide, provides teachers of middle school and high school students with the ins and outs of water conservation via 16 activities and 10 case studies. (307 pages • 8 1⁄2 x 11 • b&w photos •illustrations • charts • glossary • resources ISBN 1-888631-04-X)

Available from Project WET (Water Education for Teachers)
201 Culbertson Hall PO Box 170575
Montana State University Bozeman, MT 59717-0570
Phone toll free 1-866-337-5486 Fax (406) 994-1919
Email info@projectwet.org
Web site www.projectwet.org

"Every Drop Counts," recommended activity about domestic water use and reducing waste (from *Project Learning Tree PreK-8 Environmental Education Activity Guide* (paperback, 402 pages [96 activities], ©1993 by American Forest Foundation, Washington DC) available at professional development workshops only, see http://www.plt.org/)

"Snow Surveys and Water Supply Forecasting," USDA Agricultural Information Bulletin 536 [booklet], issued 1988 and 1994.

"Captain Hydro" and "Further Adventures of Captain Hydro," comic book format learning guides, also available in Spanish as Captain Tlaloc], 39 pages and 25 pages respectively.

Contact: Water Education Specialist
CA Department of Water Resources
Public Affairs Office
Telephone: (916) 653-9892
FAX: (916) 653-4684
E-Mail: carolyn@water.ca.gov
or go to: http://www.publicaffairs.water.ca.gov/education/catalog.cfm

"WaterLearn," on-line storybook and lesson plans for teachers by the U.S. Bureau of Reclamation (go to http://www.usbr.gov/mp/watershare/resources/waterlearn.html)

6. Drought

"Creating a Drought Early Warning System for the 21st Century: The National Integrated Drought Information System," Western Governors' Association, June 2004 (available on-line at http://www.westgov.org/wga/publicat/nidis.pdf)

U.S. Drought Monitor, major national partnership producing weekly maps of drought condition (go to http://www.drought.unl.edu/dm/index.html)

Drought for Kids, produced by the National Drought Mitigation Center (go to http://www.drought.unl.edu/kids/)

"Thirsty for Drought Relief: Evaluating Different Strategies for Managing Drought Conditions," educational activity from the New York Times Learning Network Daily Lesson Plans collection (available at http://www.nytimes.com/learning/teachers/lessons/20030128tuesday.html?searchpv=learning_lessons)

"Long-Term Aridity Changes in the Western United States," E.R. Cook, C. Woodhouse, C.M. Eakin, D.M. Meko, and D.W. Stahle, Science, Oct. 8, 2004 (v. 306) (published via www.scienceexpress.org)

7. Winter Safety

"Snow Survey Safety Guide," USDA Agricultural Handbook Number 137 [booklet], issued 1974.

"Avalanche!" Nova, Adventures in Science video, ©1997 (60 minutes)

"Avalanche: The White Death," National Geographic Video, ©1999 (60 minutes)

"Extreme Cold: A Prevention Guide to Promote Your Personal Health and Safety," booklet from Center for Disease Control's National Center for Environmental Health, also available in Spanish (On the web at http://www.bt.cdc.gov/disasters/winter/guide.asp or call the NCEH Health Line, 888-232-6789)

http://www.avalanche.org/~education/ offers links to many government and non-profit entities offering education in avalanche safety

U.S. Forest Service National Avalanche Center (on-line at http://www.fsavalanche.org/), especially the "Avalanche Basics" and "Interactive Backcountry Tour."

Section G

Correlations to Educational Standards

To document alignment with educational standards, we provide correlation lists for “Do You Know Snow?” and “A Flurry of Numbers.” The correlations offered are to the Idaho Achievement Standards.

The other two activities, “Schoolyard Snow Surveying” and “Plan an Official Visit,” lend themselves to student-driven, long-term projects, taking customized paths depending on your particular setting and group. So, these two activities potentially cover many, many standards. Any iteration of “Schoolyard Snow Surveying” and/or “Plan an Official Visit” will cover lots of academic territory, but are not likely to match those standards emphasized by another group following the same lesson plans.

In the lists, a standard noted in **bold red** is a power standard, as defined by the Idaho Department of Education.

Do You Know Snow?

Aligned with these Idaho Achievement Standards:

Language Arts:

Major Emphasis

Grd K	671.01, 671.02, 671.03, 672.01, 672.02, 673.01, 673.04
Grd 1	680.01, 680.02, 680.03, 681.01, 681.02, 682.01, 682.04
Grd 2	689.01, 689.02, 689.03, 690.00, 690.01, 691.01, 691.04
Grd 3	698.01, 698.03, 699.01, 699.02, 700.01, 701.03
Grd 4	707.01, 707.03, 708.01, 708.02, 709.01, 710.03

	Grd 5	716.01, 716.03, 716.04, 717.01, 717.02, 718.01, 719.03
	Grd 6	725.01, 725.03, 726.01, 726.02, 728.03
	Grd 7	734.01, 734.03, 735.01, 735.02, 737.03
	Grd 8	743.01, 743.03, 744.01, 744.02, 746.03
	Grd 9-12	752.01, 753.01, 753.02
Minor Emphasis	Grd K	674.01
	Grd 1	683.01
	Grd 2	692.01
	Grd 3	698.02, 698.05, 701.01, 701.02
	Grd 4	707.02, 707.05, 710.01, 710.02
	Grd 5	716.02, 716.05, 719.01, 719.02
	Grd 6	725.05, 726.04, 728.01
	Grd 7	734.05, 735.04, 737.01
	Grd 8	743.05, 744.04, 746.01
	Grd 9-12	753.04, 755.01, 755.03, 752.03

Science:

Major Emphasis

Grd K	529.01, 533.01, 536.01
Grd 1	544.01, 548.01, 551.01
Grd 2	559.01, 563.01, 566.01
Grd 3	573.01, 574.01, 581.01, 581.03
Grd 4	588.01, 589.01, 596.01, 596.03
Grd 5	603.01, 604.01, 611.01, 611.03
Grd 6	618.01, 619.01, 626.01, 626.03
Grd 7	633.01, 641.01, 641.03, 634.01
Grd 8	633.01, 641.01, 641.03, 634.01
Grd 9-12	648.01, 649.01, 656.01, 656.03

A Flurry of Numbers

Aligned with these Idaho Achievement Standards:

Language Arts:

Minor Emphasis

Grd 4	709.01, 710.01, 710.03
Grd 5	718.01, 719.01, 719.03
Grd 6	727.01, 728.01, 728.03
Grd 7	736.01, 737.01, 737.03
Grd 8	745.01, 746.01, 746.03
Grd 9-12	754.01, 755.01, 755.03

Math:

Major Emphasis

Grd 4	297.01, 297.02, 297.03, 298.01, 298.02, 298.03, 299.01, 302.01, 302.02
Grd 5	307.01, 307.02, 307.03, 308.01, 308.02, 308.03, 309.01, 312.01, 312.02
Grd 6	317.01, 317.02, 317.03, 318.01, 319.01, 318.02, 319.03, 322.01, 322.02
Grd 7	327.01, 327.02, 327.03, 328.01, 328.02, 329.01, 329.02
Grd 8	337.01, 337.02, 337.03, 338.01, 338.02, 339.01, 339.02
Grd 9-12	347.01, 347.03, 348.01, 348.02, 348.03, 349.01, 350.01, 350.02, 350.03, 352.01, 352.02

Science:

Major Emphasis

Grd 4	588.02, 588.03, 589.01
Grd 5	603.02, 603.03, 604.01
Grd 6	618.02, 618.03, 619.01
Grd 7 & 8	633.02, 633.03, 634.01
Grd 9-12	648.02, 648.03, 656.01, 656.02

Section H

Glossary for Adopt-a-SNOTEL Site: Snow Survey Dictionary

Produced originally by NRCS Idaho, November 2002

A

Accumulation season: That portion of the year when snow water content is building towards its maximum value for the year

Acre-Feet or AF: Unit of volume measure for stream and reservoir storage. One acre covered with one foot of water, 43,560 cubic feet. Acre-feet are often given in units of 1,000 acre feet (denoted as "KAF") due to the large volume.

Aerial Marker: A vertical marker with equally spaced crossbars. The depth of snow at these remote sites is determined by observation from low-flying aircraft. Snow water equivalent is calculated by using snowpack density measurements from nearby snow sties.

Average: The mean value for a 30-year base period. The current base period is 1971-2000 and is updated every 10 years. A 30-year period is used as opposed to the period of record because it represents the most current climatological record.

B

Basin: Major drainage area in which a measuring site is located.

C

Cubic Feet per Second or CFS: Measurement of volume of water, one cubic foot, passing a given point in one second.

1 CFS = 7.48 gallons per second
1 CFS = 448 Gallons per minute
1 CFS for 24 hours = 1.983 acre-feet

Changes in storage: Changes in the amount of water stored in regulated lakes and reservoirs over a period of time, usually a day or month.

D

Data: Refers to snow water equivalent or precipitation amounts.

Date collection site: Manual or automated station permanently marked or installed where climatic data is regularly collected. Primary SNOTEL data collected includes snow water equivalent, snow depth on ground, precipitation and air temperature. Data sites are usually located in small forested openings or high mountain meadows where the trees protect snow at the site from wind scour and deposition in snow drifts. Snow measuring stations are typically located in areas well protected from the wind where the natural snowfall can be measures.

Diversion: A point at which water is removed from a stream for conveyance to another point within the basin or into another basin.

Drought: Prolonged period of dryness. The governor declares a drought in a state or portion of a state, not NRCS.

E

Elevation: Vertical reference of a site location about mean sea level. Measured in feet.

El Nino: El Nino is a warming of the Pacific Ocean between South America and the International Date Line. Warming is expressed as a departure from long-term average ocean temperatures. During a typical El Nino, the ocean warms a degree or two (C) above its climatological average. A strong El Nino can warm by 3 to 4 degrees C overlarge areas, and even 5 degrees C in smaller regions. El Nino events usually result in drier than normal conditions in the Pacific Northwest and favor wetter winters in southwest United States. The correlation is not as strong across southern Idaho and northern Nevada and Utah.

El Nino/Southern Oscillation or ENSO: Frequent use of this acronym has arisen in the climate research community, and reflects a focus on the warm phase of the entire cycle. El Nino is just one phase of an irregular fluctuation between warmer than usual and colder than usual ocean temperatures in the Pacific region. The cold phase is known as "La Nina".

F

Forecast period: That part of the year for which streamflows are predicted which are primarily derived from snowmelt in the West. Normally the period that produces most of the spring/summer runoff that is used or stored for irrigation and other purposes.

G

Graupel: Granular ice pellets; also called soft hail.

L

La Nina: Opposite of El Nino. La Nina exists when cooler than usual ocean temperatures occur on the equator between South America and the International Date Line. The name La Nina ("the girl child") was coined to deliberately represent the opposite of El Nino ("the boy child"). La Nina occurs almost as often as El Nino. They are two faces of the same larger phenomenon. Stronger than usual trade winds accompany La Nina. These winds, from the east, push the ocean water away from the equator in each hemisphere. This is caused by the earth's rotation. Cold water from below rises to replace warm surface water which has moved away from the equator. La Nina usually favors the odds of receiving wetter than normal winter precipitation in the Pacific Northwest and below normal in the desert Southwest. As in 2001, this does not always occur. That year saw near record low snow and stream flows in the Pacific Northwest, especially northern Idaho.

M

Meteor burst technology: Method of bouncing radio signals at a steep angle off the ever present band of particle trails left by meteors entering Earth's atmosphere and disintegrating. This residue of meteorites exists from about 50 to 75 miles above the ground. Meteor burst technology can establish reliable communication with remote sites—such as SNOTEL—located behind mountains and deep in canyons.

Most probable forecast: Best estimate of streamflow volume given current conditions and based on outcome of similar past situations. "Most Probable

Forecast" may not be the best term to use since it is often associated with the 50% exceeding forecast. Following are the statistical exceeding forecasts that water users and managers should use to base their decision-making on the chance of each volume occurring. For example, in a dry winter or years following a dry summer/fall, users may want to lean more toward a lesser volume of the 70% or 90% exceedance forecasts to reduce their risk and improve the chance of that volume of water materializing. In wet years, users may want to use the 30% or 10% forecasts to reduce the chance of having too much water.

> **90% chance of exceeding:** 90% chance that actual streamflow volume will exceed forecast value; 10% chance streamflow volume will be less than forecast value
>
> **70% chance of exceeding:** 70% chance that actual streamflow volume will exceed forecast value; 30% chance streamflow volume will be less than forecast value
>
> **50% chance of exceeding:** 50% chance that actual streamflow volume will exceed forecast value; 50% chance streamflow volume will be less than forecast value
>
> **30% chance of exceeding:** 30% chance that streamflow volume will exceed forecast value; 70% chance streamflow volume will be less than the forecast value
>
> **10% chance of exceeding:** 10% chance that streamflow volume will exceed forecast value; 90% chance streamflow volume will be less than forecast value

N

Natural (adjusted) flows: Best estimate of flows that would have occurred without human influence. Calculated by adjusting observed flows for changes in storage and gauged diversions that affect streamflow volumes. Streamflow forecasts are issued for natural flows where there are no major reservoirs or diversions, such as on the Salmon River, and for the natural flow that would occur below a reservoir if the reservoir were not there.

O

Observed flows: Measured flow at a given point on a stream, regardless of the effect of upstream water management on streamflows.

P

Palmer Drought Index: A widely used measure of drought severity. Where the predominant moisture falls as snow and irrigation occurs, it may not produce the best measure of droughts. Also see Surface Water Supply Index.

Percent of Average: Value determined by dividing the current measured parameter (snow water equivalent, precipitation, streamflow) by the long-term 30-year average for that day or period. This means 100% is average and a value greater than 100% is above average, and less than 100% is below average.

Percent of Peak: Value determined by dividing the current snow water equivalent by the average seasonal peak amount that occurs around April1. This is a useful indicator for gauging the snow water equivalent on the ground for today and comparing it to its seasonal maximum.

Precipitation: Includes rain, snow, sleet and hail, measured in tenths of an inch by NRCS. Accumulated precipitation is the total amount of precipitation that has fallen since the start of the water year—running from October 1 through September 30.

R

Reservoir: A pond, lake, basin, or other space, created in whole or in part by the building of engineered structures, so that it can be used for storage, regulation, and control of water.

Reservoir storage: Volume of water held by a reservoir. NRCS reports reservoir information in terms of useable volumes that may include active, inactive and dead storage in the facility.

Reservoir Operation Guide: Decision support tool used to help reservoir operators manage their facilities by using streamflow forecasts.

Residual streamflow forecasts: Volume of water that is still to come during the remaining forecast season.

S

SNOTEL (SNOw TELemetry) sites: Unstaffed permanent automated weather stations designed to operate in severe, remote mountainous environments. Most sites collect daily, or even hourly, snow water content, snow depth, precipitation, and air temperature data. Enhanced sites also collect relative humidity, wind speed and direction, solar radiation, soil moisture and soil temperature.

Snow course: An area marked for measuring the snow periodically during each winter to develop the long-term historic record of snow at that site. Usually 3 to 8 samples are taken and averaged to determine the snow depth and snow water equivalent for that location.

Snow depth: Depth of snow on the ground or snow pillow, measured in inches. Snow is measured from the top of the snowpack to ground level.

Snowmelt runoff: Streamflow water originating from melting of the seasonal snowpack. In the West, over 75% of the annual streamflow come from melting snow.

Snowpack: Snowpack is a general term used in to denote large snow-covered areas. Areas may include the low- and mid-elevation valleys that may have an intermittent snowpack in the winter, as well as the high mountainous areas that store the seasonal water supply in the West. The amount of water produced by a snowpack of a given depth varies, depending on the density of the snow.

Snow pillow: Standard measuring device used to measure snow water equivalent. It us usually constructed flush with the ground level and made from synthetic rubber or steel filled with water and antifreeze. The snow pillow hydrostatically weighs the snowpack on top of it.

Snow tube: Hollow aluminum tube that is pushed down through the snow to the ground below. The snow-filled tube is then brought to the surface and weighed to determine how much water the snow contains.

Snow water content: Amount of water in between snow grains in snowpack. Note the subtle difference with “snow water equivalent,” which is often used interchangeably with “snow water content.”

Snow water equivalent or SWE: Amount of water in the snow if it were melted. Measured in inches. Represents the potential amount of water in the snowpack.

Southern Oscillation Index or SOI: Atmospheric barometric pressure difference between Darwin, Australia, and the island of Tahiti; SOI is tightly correlated with El Nino/La Nina. The difference, Tahiti minus Darwin, is frequently used as a convenient, simple and reasonably accurate tool to monitor the status of El Nino/La Nina. NRCS uses SOI in calculations for forecasting next year's runoff. The July-November period is when the SOI correlates closest with next spring/summer's streamflow in northern and central Idaho. The strength of the SOI signal is at a maximum in the North Fork Clearwater River basin (Dworshak Reservoir) and decreases to the south.

Streamflow forecast: As snowpack accumulates and precipitation falls, streamflow forecasts reflect current conditions and projected amount of streamflow for spring and summer period. Streamflow forecasts are for natural (unregulated) flows and usually improve in accuracy as you near the snowmelt peak in April.

Surface Water Supply Index or SWSI: Predictive indicator of surface water available in a basin. It combines current reservoir storage and streamflow forecasts for the spring and summer water use season. In Idaho, SWSI is used in conjunction with the threshold where agricultural irrigation shortages start to assist irrigators in their decision-making process and water management.

T

Telemetry: Transmission of data captured by measuring devices from a remote station to another location where it is recorded and analyzed.

W

Watershed: An area of land drained by a stream and its tributaries.

Water year: Twelve month period beginning October 1 in one calendar year and ending September 30 of the following calendar year. The water year is designated by the calendar year in which it ends. October 1 starts the water year because it is typically when streams and reservoirs are at their minimum levels for the year, the growing season has come to a close, and Mother Nature starts her annual cycle of bring moisture across North America to replenish the water supply.

Water supply forecasting: Projections of streamflow volume in smaller basins and upstream reaches of larger streams.